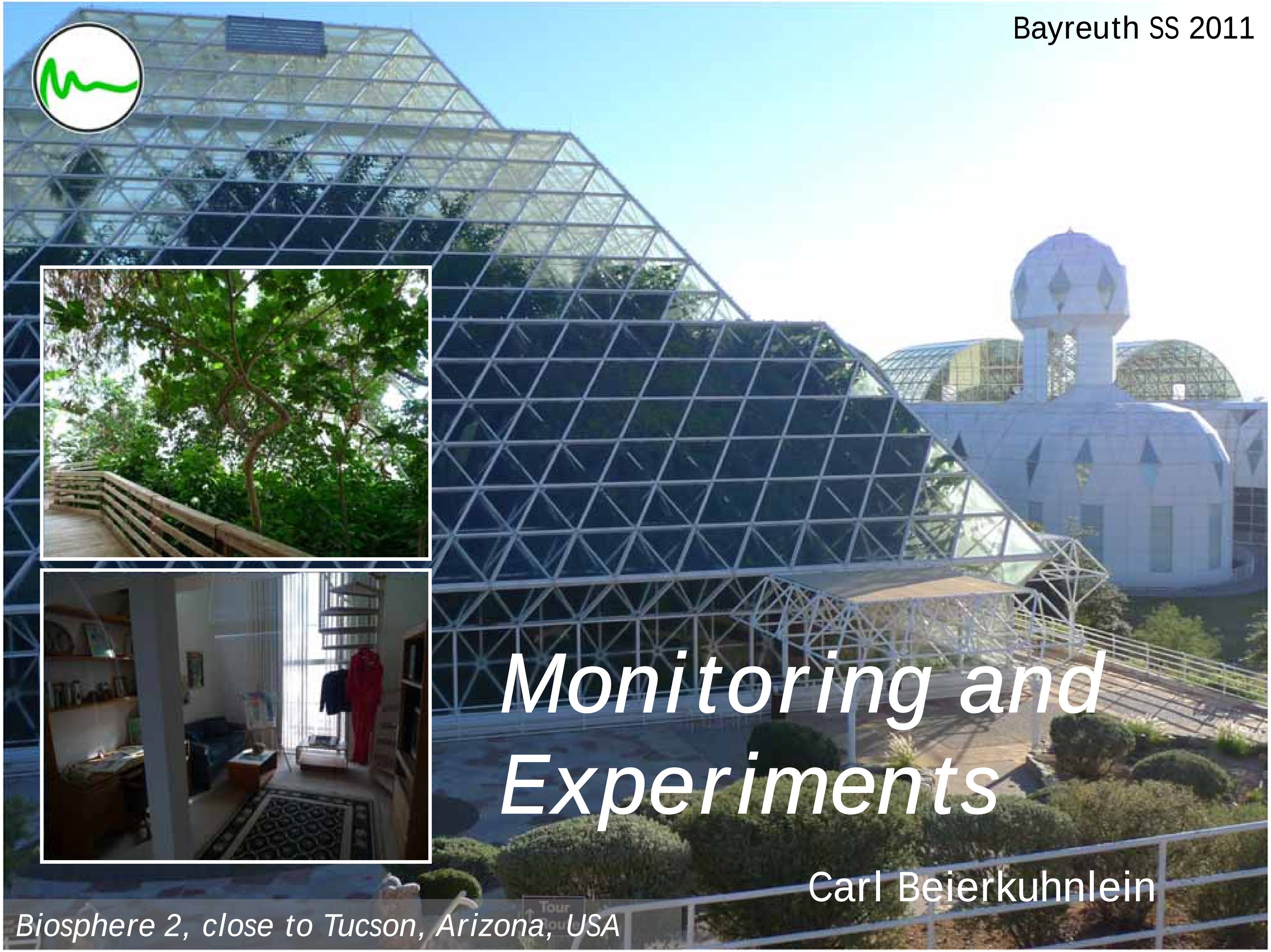
Bayreuth SS 2011



Monitoring and Experiments

Carl Beierkuhnlein

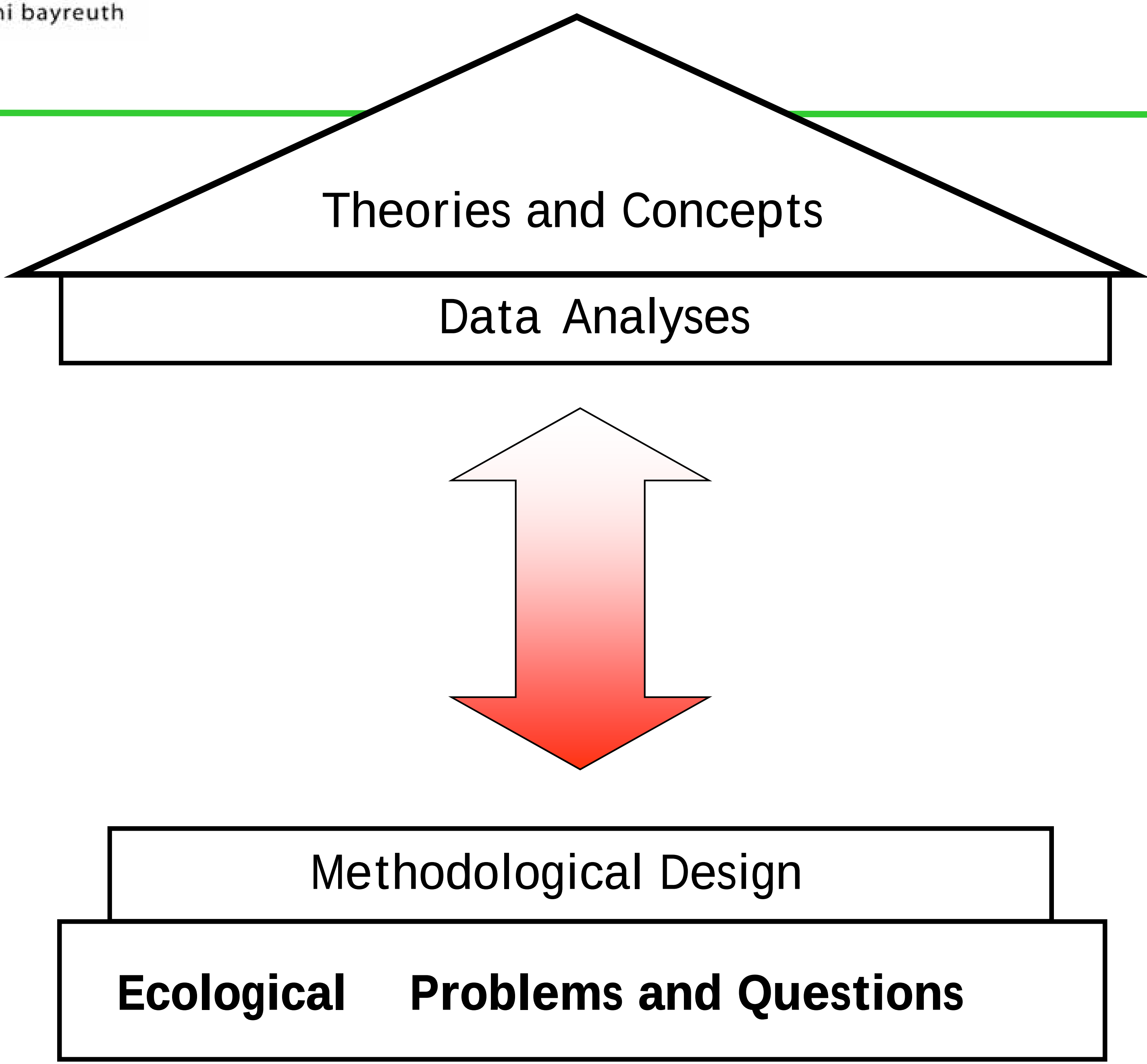
Biosphere 2, close to Tucson, Arizona, USA

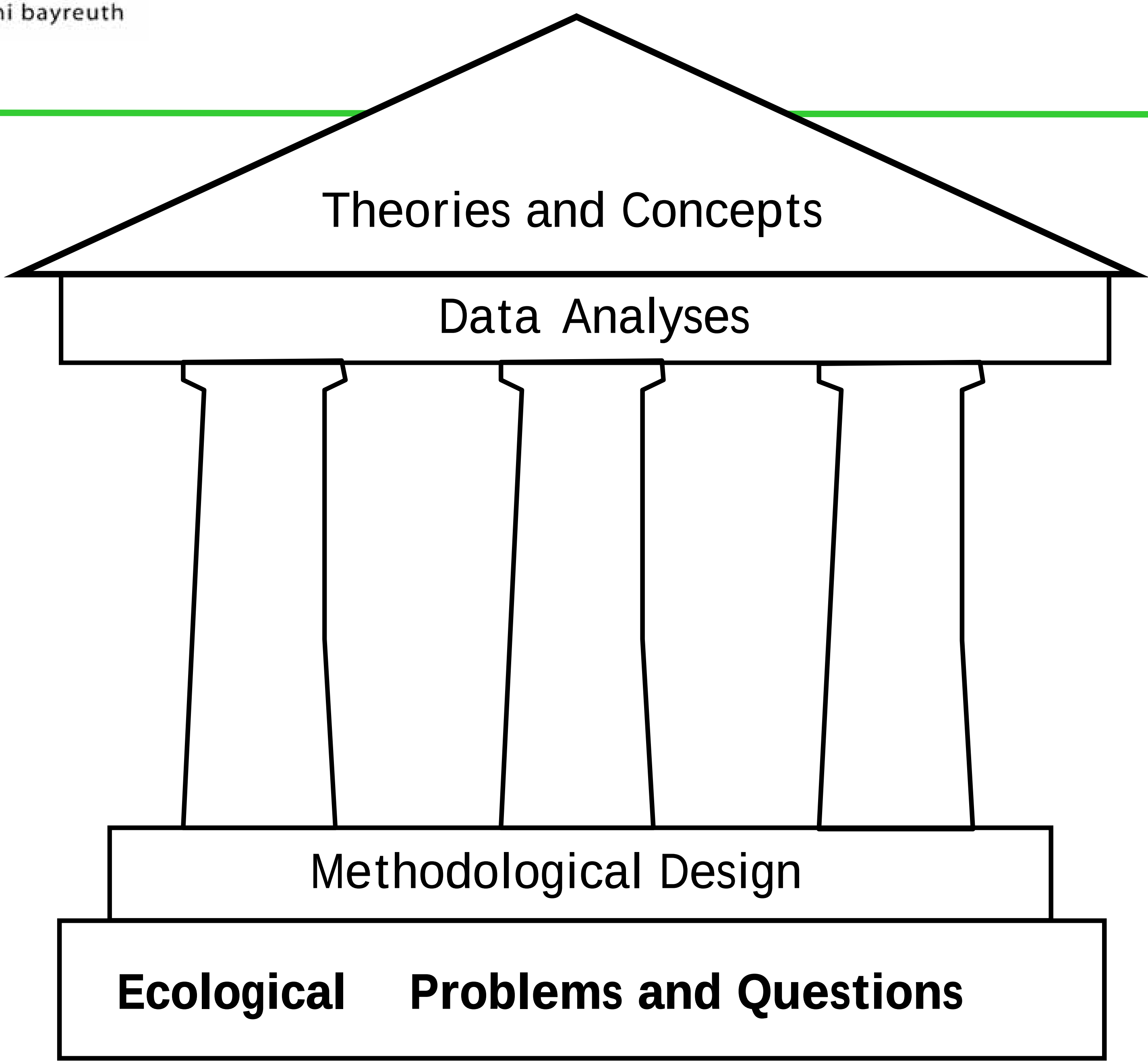
Theories and Concepts

Without a sound theoretical and conceptual background, the solution of problems will fail!

Ecological Problems and Questions

biogeografie
uni bayreuth




Theories and Concepts
Data Analyses
Methodological Design
Ecological Problems and Questions

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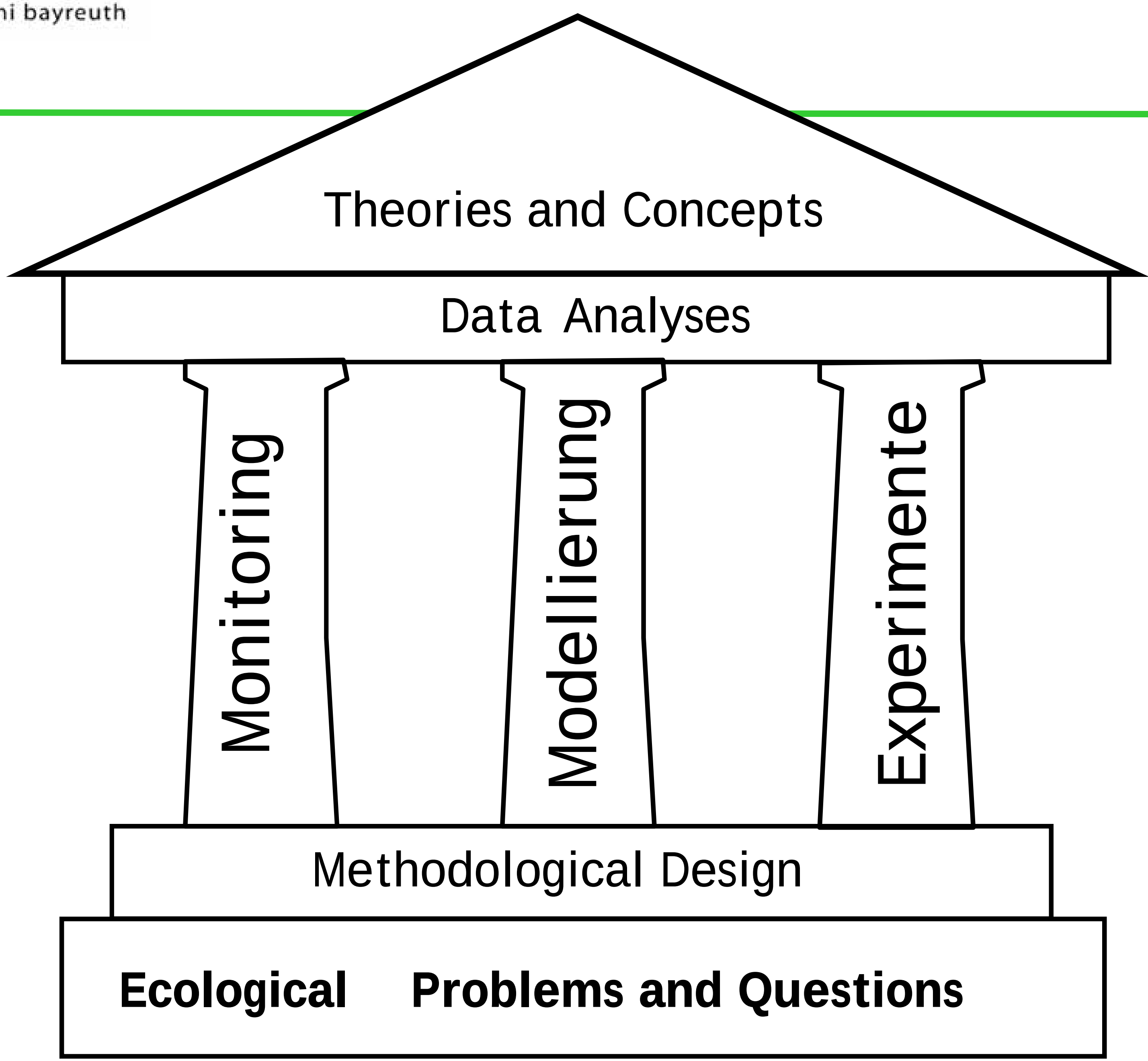


Research Strategies
- Ecological Consequences of Climate Change

Analysis and Prognosis of Climatic Processes

Monitoring

Remote Sensing

Long-Term Ecological Research Sites

Observation of sensitive Communities (e.g. Springs)

Monitoring of critical species

Biodiversity Research

Modelling

Spatially explicit Dispersal Models

Modelling the future role of vectors

Simulation of biodiversity loss

Prognosis of changes in competition and mutualisms

Experiments

Simulation of future extremes

Effects of novel species composition of communitites

Functional consequen-ces of biodiversity loss

Manipulating nutrient & energy fluxes

Manipulating biotic interactions

Research Strategies
- Ecological Consequences of Climate Change

Analysis and Prognosis of Climatic Processes

Monitoring — Modelling — Experiments

Common / Transdisciplinary Research Questions
(e.g. Effects of novel extremes on permanent communities)

and **Model Ecolsystems**
(e.g. Forests, Grasslands, Rivers)!

- Necessity of a concerted **Research Program, Research Coordination** and **Research Action**

Research Strategies
- Ecological Consequences of Climate Change

The necessity of a concerted **Research Program,**
Research Coordination and **Research Action** leads to the
development of a transdisciplinary

Research Design

Monitoring

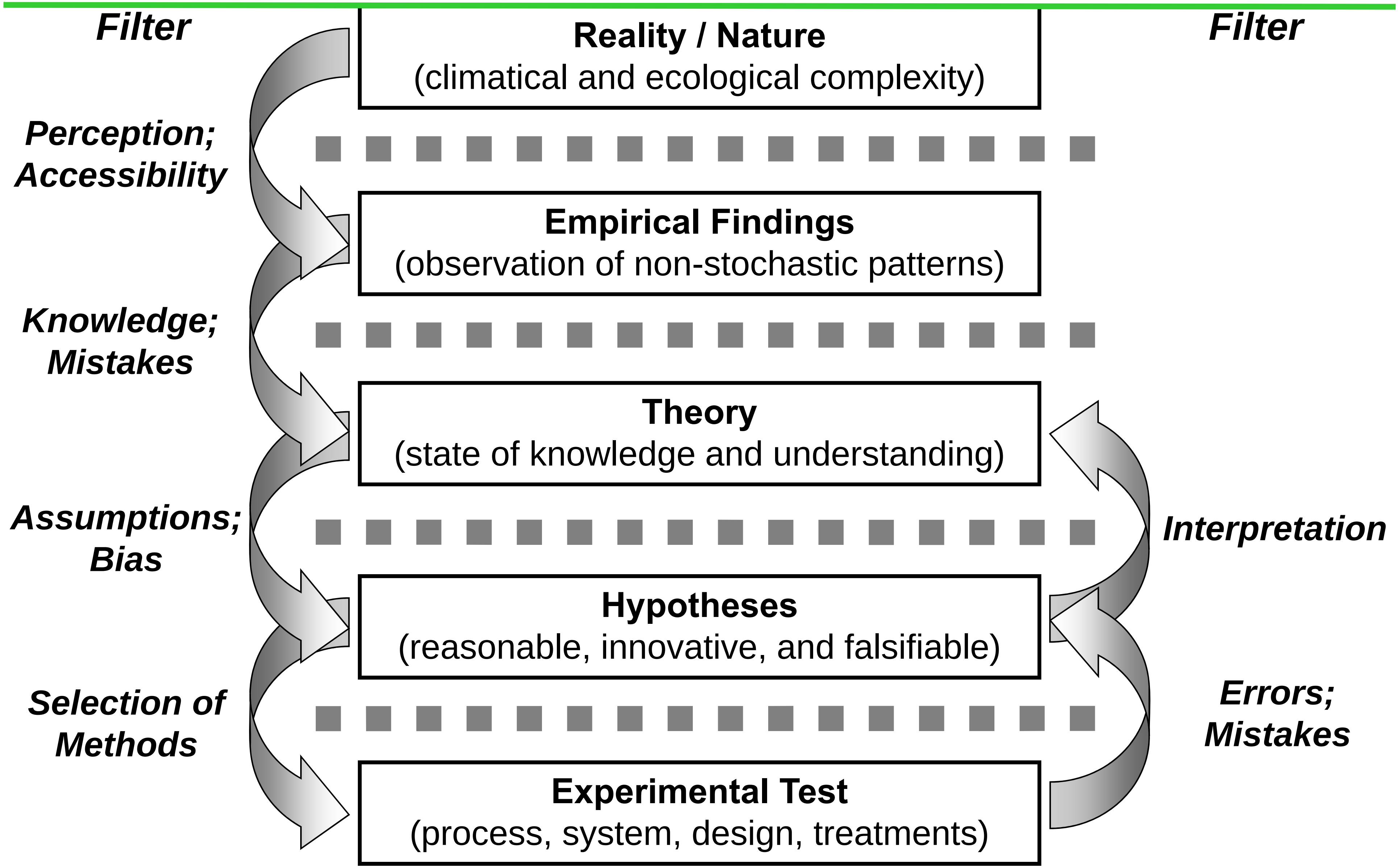
Modelling

Experiments

will allow finding

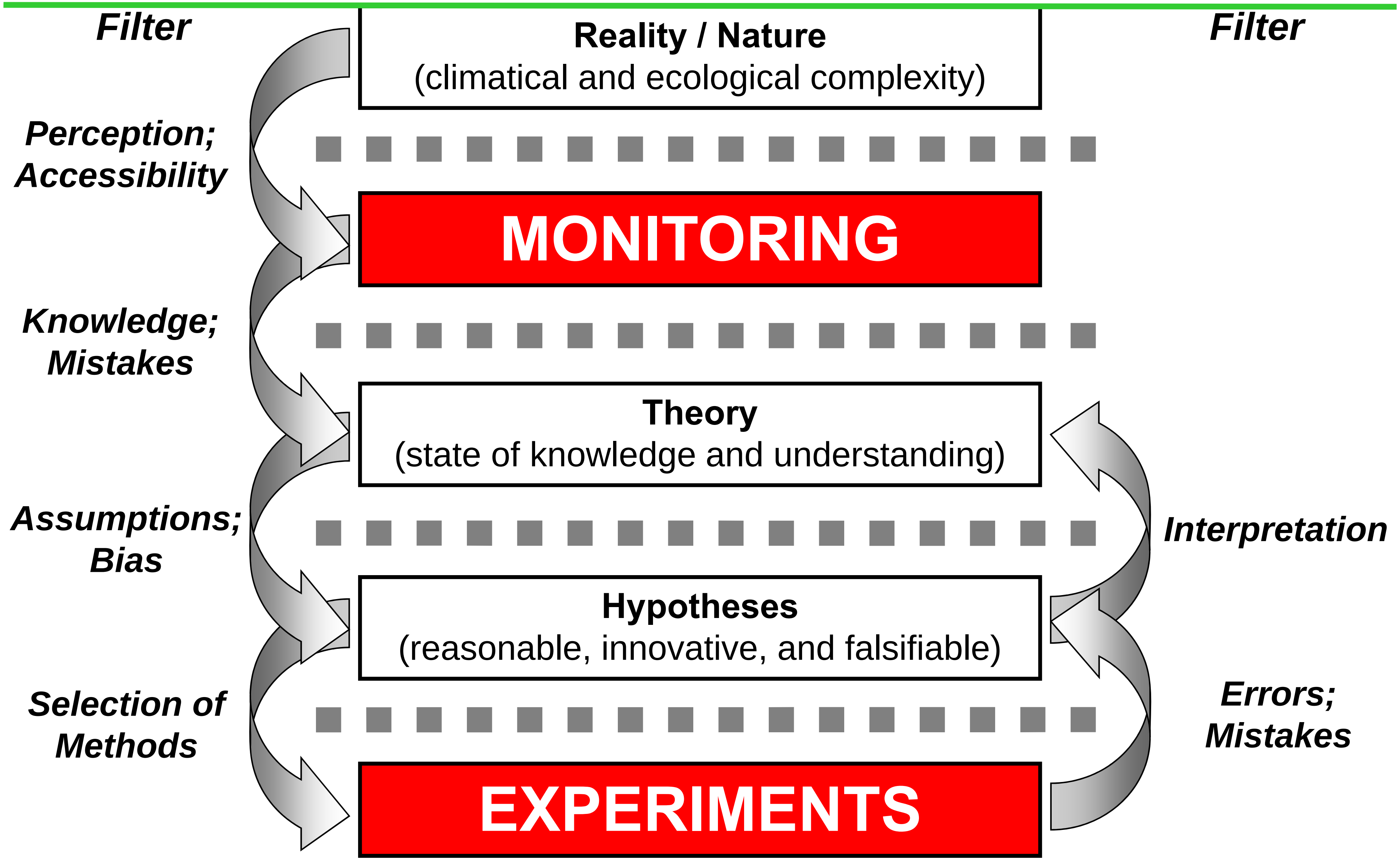
Answers to specific **Research Questions**

Advancing Knowledge



Jentsch, A., Beierkuhnlein C (2010). Simulating the Future. Nova Acta Leopoldina NF 112 (384): 89-98

Advancing Knowledge



Jentsch, A., Beierkuhnlein C (2010). Simulating the Future. Nova Acta Leopoldina NF 112 (384): 89-98

Advancing Knowledge

Reality / Nature
(climatical and ecological complexity)

MONITORING

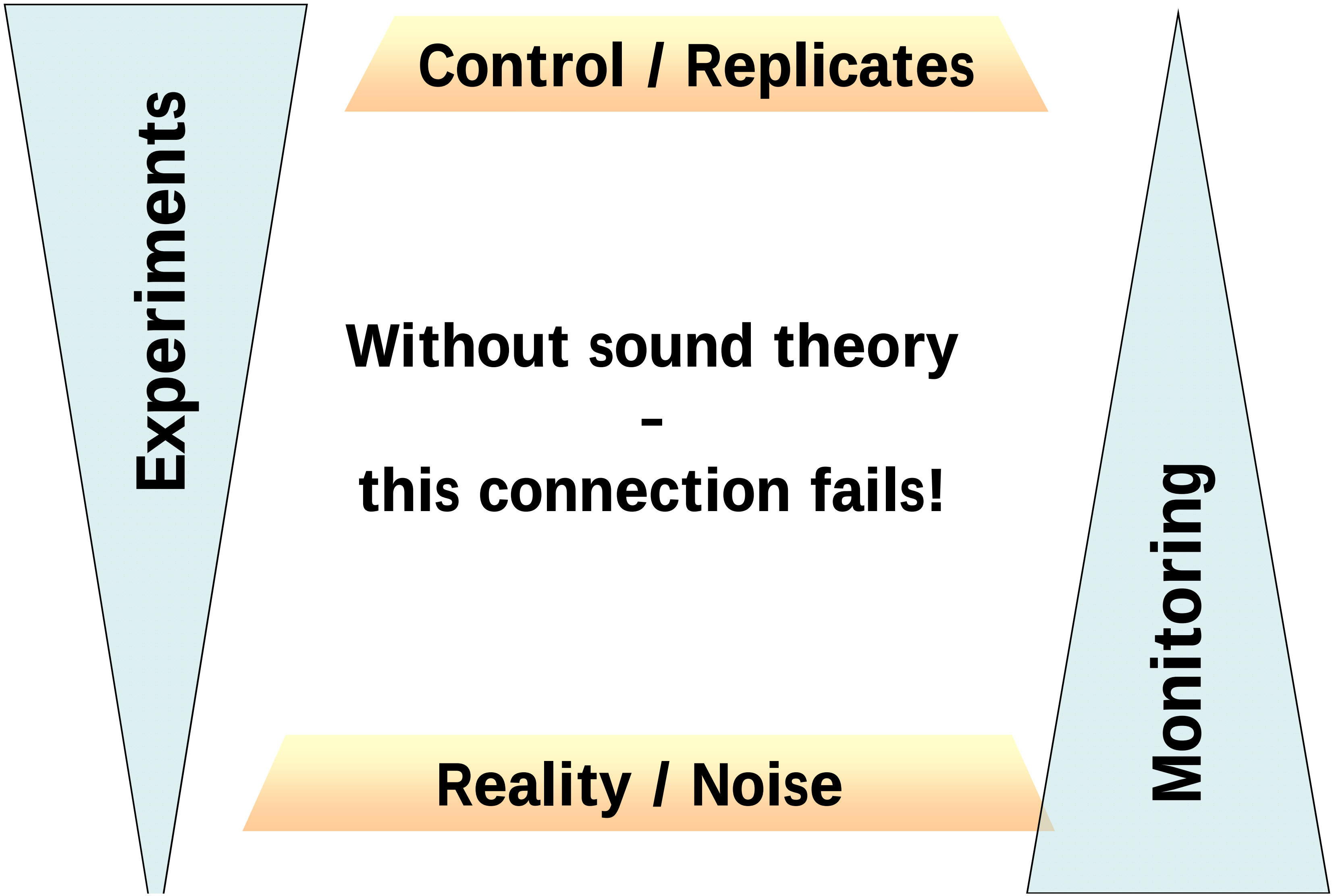
THEORY ☺ → **MODELLING**

Hypotheses
(reasonable, innovative, and falsifiable)

EXPERIMENTS

Jentsch, A., Beierkuhnlein C (2010). Simulating the Future. Nova Acta Leopoldina NF 112 (384): 89-98

Scaling


Experiments
Control / Replicates
Without sound theory
-
this connection fails!
Reality / Noise
Monitoring

Challenges

In the face of global changes especially the ecological responses to these changes must be understood.

- Climate change and modified temperatures and water availability
- Land use and cover change
- Changes in biogeochemical cycles
- Invasive species and disequilibria
- Species extinctions and loss of biodiversity

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Challenges

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend [b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely* [c]	*Likely* [d]	*Virtually certain* [d]
Warmer and more frequent hot days and nights over most land areas	*Very likely* [e]	*Likely (nights)* [d]	*Virtually certain* [d]
Warm spells / heat waves. Frequency increases over most land areas	*Likely*	*More likely than not* [f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not* [f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not* [f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis) [g]	*Likely*	*More likely than not* [f, h]	*Likely* [i]

IPCC 2007: The Physical Science Basis

Challenges

What is extreme?

Climate is a moving target - How can we define a reference for extremes?

How can we define controls for „normal“ conditions?

How can we guarantee replicates?

Challenges

nature geoscience

CLIMATE SCIENCE

Elusive extremes

Extreme climate events can cause widespread damage and have been projected to become more frequent as the world warms. Yet as discussed at an interdisciplinary workshop, it is often not clear which extremes matter the most, and how and why they are changing.

Gabriele C. Hegerl, Helen Hanlon and Carl Beierkuhnlein

Changes in the frequency, intensity and timing of climate extremes matter to ecosystems and society. Characterizing such changes and their impacts is a challenge, not only for climate scientists but also for statisticians, ecologists and medical scientists. The impacts of rare climate events can be difficult to detect, for example when they arrive with significant delay. To complicate matters further, combinations of extreme climate events — such as heatwaves coinciding with droughts or air quality problems — could cause more severe consequences for humans and ecosystems. At a conference in Cambridge on 'Extreme Environmental Events' in December 2010[1] that brought together climate scientists, statisticians and ecologists, the conclusion evolved that useful prediction of climate change impacts hinges on understanding the right types of extremes, and then producing reliable projections for their changes.

Weather and climate extremes are usually defined as rare events in the context of historical climate data. Alternatively, weather events can be classified as extreme according to the amplitude of their impacts on society or ecosystems. The Russian heatwave of 2010 and the European heatwave of 2003 fulfilled both criteria: they were climatically highly unusual[2], and at the same time had substantial consequences for human health and ecosystems.

Extreme events can span a wide range of spatial and temporal scales. For example, storms are usually short-lived and occur over only a few hours, whereas a drought can extend over months. In the spatial domain, they can range from an anomalously warm summer or cold winter diagnosed on a continental scale, to events such as a hail storm that affect only a small region. When defining extremes, it is therefore easy to drown in choices. It is not obvious whether it is the frequency, intensity or duration of an extreme event that matters — or a combination of all three. Impact researchers may be able to guide the choice of characteristics that matter for society and ecosystems.

Challenges

An *extreme weather event* is an event that is rare at a particular place and time of year. […] an extreme weather event would normally be as rare as or rarer than the 10th or 90th *percentile* of the observed *probability density function*. By definition, the characteristics of what is called *extreme weather* may vary from place to place in an absolute sense. […]

When a pattern of extreme weather persists for some time, such as a season, it may be classed as an *extreme climate event*, especially if it yields an average or total that is itself extreme (e.g., *drought* or heavy rainfall over a season).

IPCC 2007: Climate Change 2007: The Physical Science Basis Annex I, Glossary.

Challenges

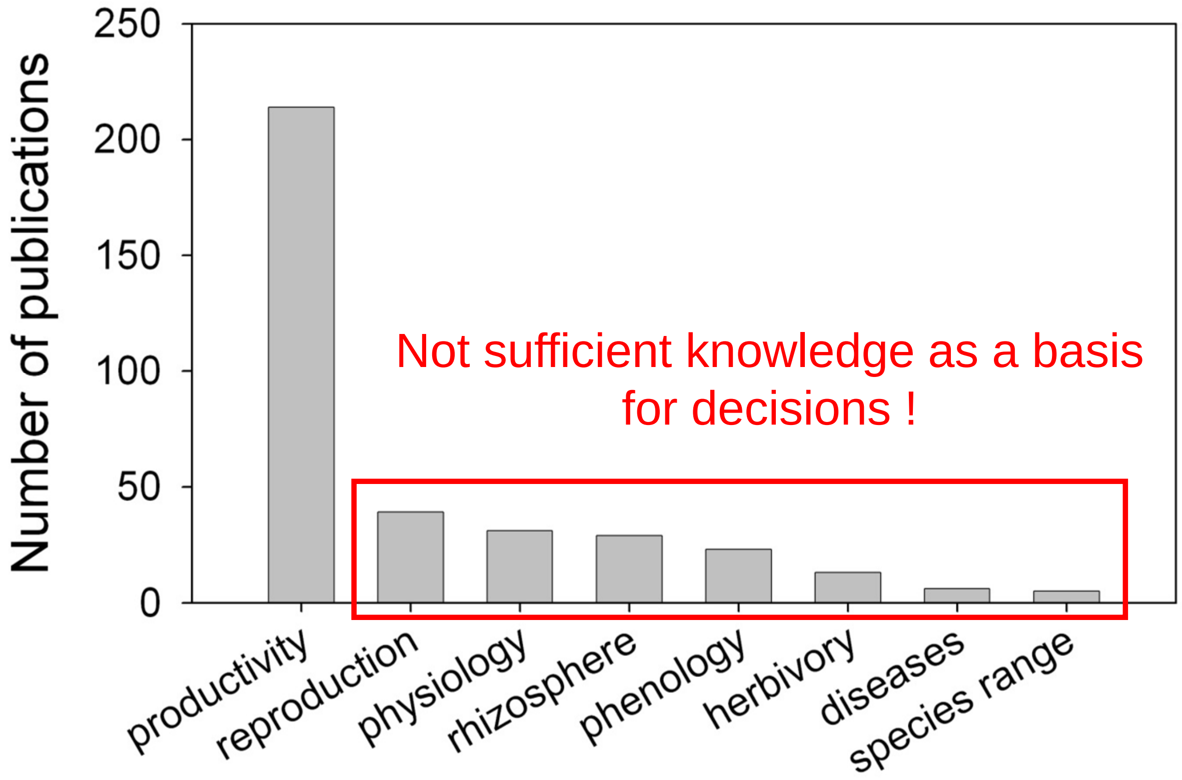
Ecosystem Effects of Extreme Weather Conditions

Observed effect	Manipulation	Sources
Reduced aboveground productivity	drought	Borghetti *et al.* 1998; Gordon *et al.* 1999; Sternberg *et al.* 1999; Grime *et al.* 2000; Koc 2001; Llorens *et al.* 2002; Filella *et al.* 2004; Gorissen *et al.* 2004; Llorens *et al.* 2004; Penuelas *et al.* 2004b; Wessel *et al.* 2004; Kahmen *et al.* 2005; Le Roux *et al.* 2005
	rain & drought*	Fay *et al.* 2000; Fay *et al.* 2002; Knapp *et al.* 2002; Fay *et al.* 2003
	frost	Weih and Karlsson 2002
	heat	Marc[illegible] *et al.* [illegible]
	drought & heat	Roden and Ball 1996; Ferris *et al.* 1998; Hamerlynck *et al.* 2000; Shah and Paulsen 2003; Xu and Zhou 2005
Reduced belowground productivity	drought	Bassirirad and Caldwell 1992; Beier *et al.* 1999; Asseng *et al.* 1998
Altered species composition	drought	Grime *et al.* 2000; Buckland *et al.* 2001; Koc 2001; Lloret *et al.* 2004; Schwinning *et al.* 2005
	heavy rain	Sternberg *et al.* 1999; Gillespie and Loik 2004
	rain & drought	Knapp *et al.* 2002; Bates *et al.* 2005; English *et al.* 2005
	heat	White *et al.* 2000, 2001
Reduced reproductive success	drought	Fox *et al.* 1999; Gordon *et al.* 1999; Lloret *et al.* 2004; Morecroft *et al.* 2004; Penuelas *et al.* 2004b; Llorens and Penuelas 2005; Lloret *et al.* 2005; Schwinning *et al.* 2005
	heavy rain	Germaine and McPherson 1998
	drought & heat	Shah and Paulsen 2003
Altered phenology	drought	Llorens and Penuelas 2005
	rain & drought	Fay *et al.* 2000; Penuelas *et al.* 2004a

We have some knowledge, but most findings are very specific and can hardly be generalised.

Jentsch, Kreyling, Beierkuhnlein 2007: A new generation of climate change experiments: Events, not trends Frontiers in Ecology and the Environment, 5, 315-324

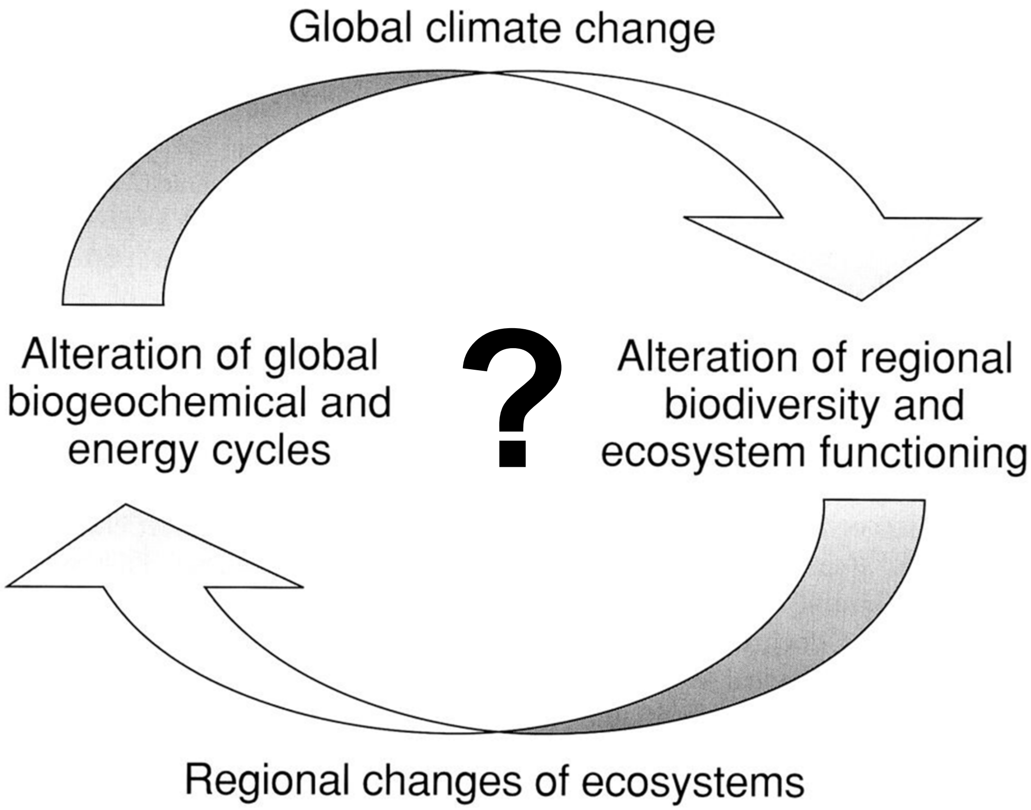
Challenges



Publications to *experimentally* proven effects of climate change (trends and extremes).
All Journals in ISI Web-of-Science. 1990 bis 2005.
295 Papers.

Jentsch, Kreyling, Beierkuhnlein 2007: A new generation of climate change experiments: Events, not trends
Frontiers in Ecology and the Environment, 5, 315-324

Challenges



Feed Back Loops

Jentsch & Beierkuhnlein 2003. Global climate change and local disturbance regimes as interacting drivers for shifting altitudinal vegetation patterns, Erdkunde, 57, 218-233

Monitoring and Experimental Methods and Approaches in Ecosystems Research

Problems:

Ecosystems can not be captured completely!
(Many units – e.g. species, life forms, molecules, compounds)

Ecosystems are very complex units!
(Many processes, functions, interactions among biotic and abiotic compartments)

Ecosystems are influenced by recent and historic processes!
(some ecosystem traits are related to actually proceeding mechanisms, others reflect processes that have occured in the past)

Monitoring and Experimental Methods and Approaches in Ecosystems Research

Requirement:

Ecosystems are the units that have to be understood, when environmental problems are discussed or have to be solved !

- It is simply the scale of human interest. Impacts and benefits occur at this level!
- Problems and restrictions have to be identified, but there is no way to avoid this complex level of organisation!
- Findings at other levels (e.g. organisms, organs, cells) can not be transferred to ecosystem scale!

Monitoring and Experimental Methods and Approaches in Ecosystems Research

Consequence:

Ecosystem research is needed to give advice about system responce to global change

- Selection of parameters has to be made
- Selection of methods has to be made
- Selection of temporal design has to be made
- Selection of spatial design has to be made

Scale matters

„*The problem of pattern and scale is the central problem in ecology*“

Simon A. Levin, 1992

Questions

1. Which abiotic parameters should be recorded ?
2. Which biotic parameters should be recorded ?
3. Where should measurements be located ?
4. How large an area of investigation has to be ?
5. How large should a single plots / records be ?
6. What is the minimum / maximum spatial distance between records?
7. How many plots / measurements are required ?
8. What is the optimum period / season for investigation ?
9. Is one record per year sufficient ?
10. How can we disentangle current and historic effects ?
11. How can we reduce subjectivity / bias ?

Heterogeneity

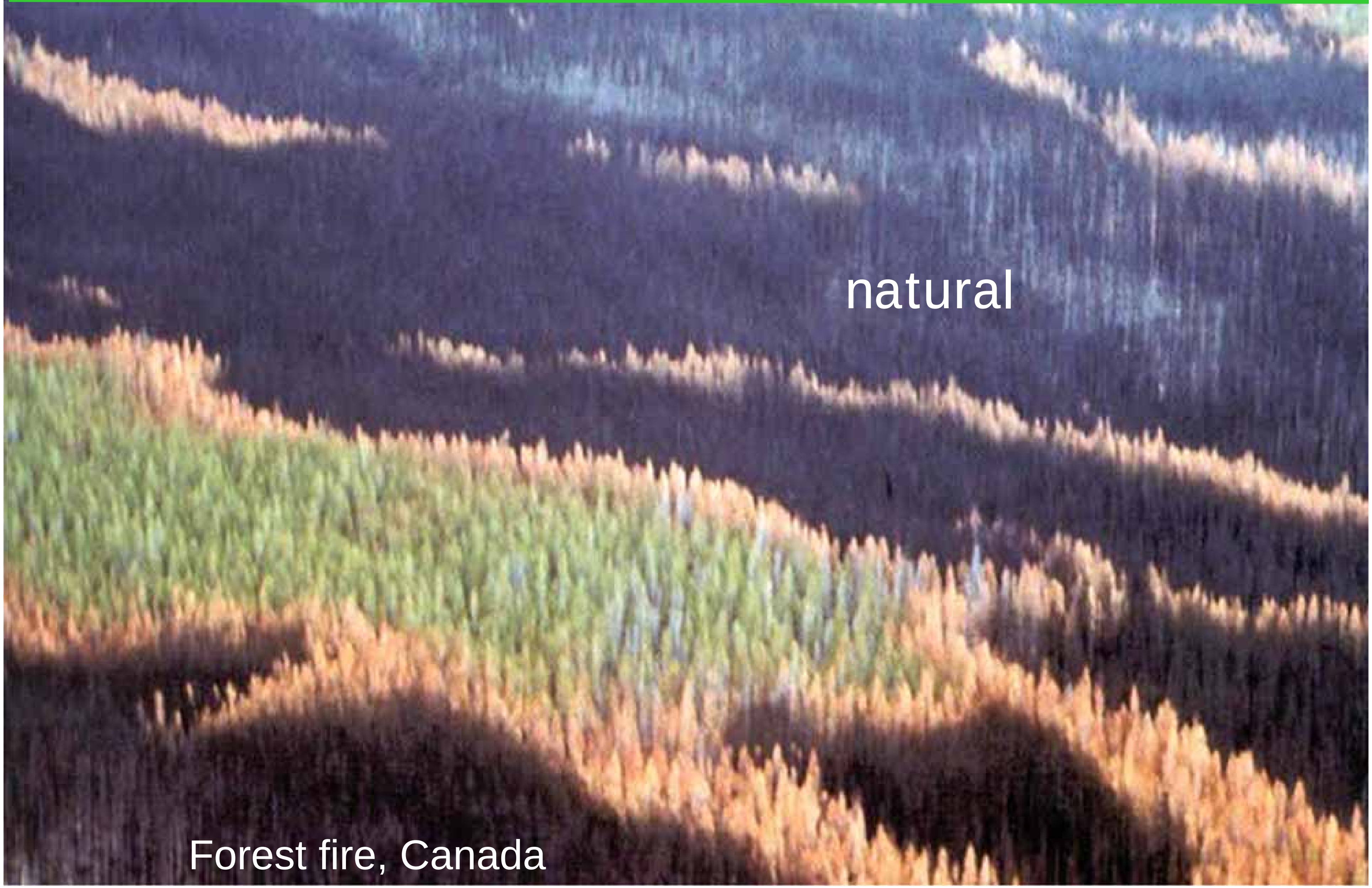
Spatial arrangements reflect the complexity of ecosystem interactions.

Homogeneity / Heterogeneity of biotic patterns must be considered (but is widely ignored!).

Heterogeneity

Gravelbed, New Zealand, South Island, Feb. 2007

Heterogeneity



Heterogeneity

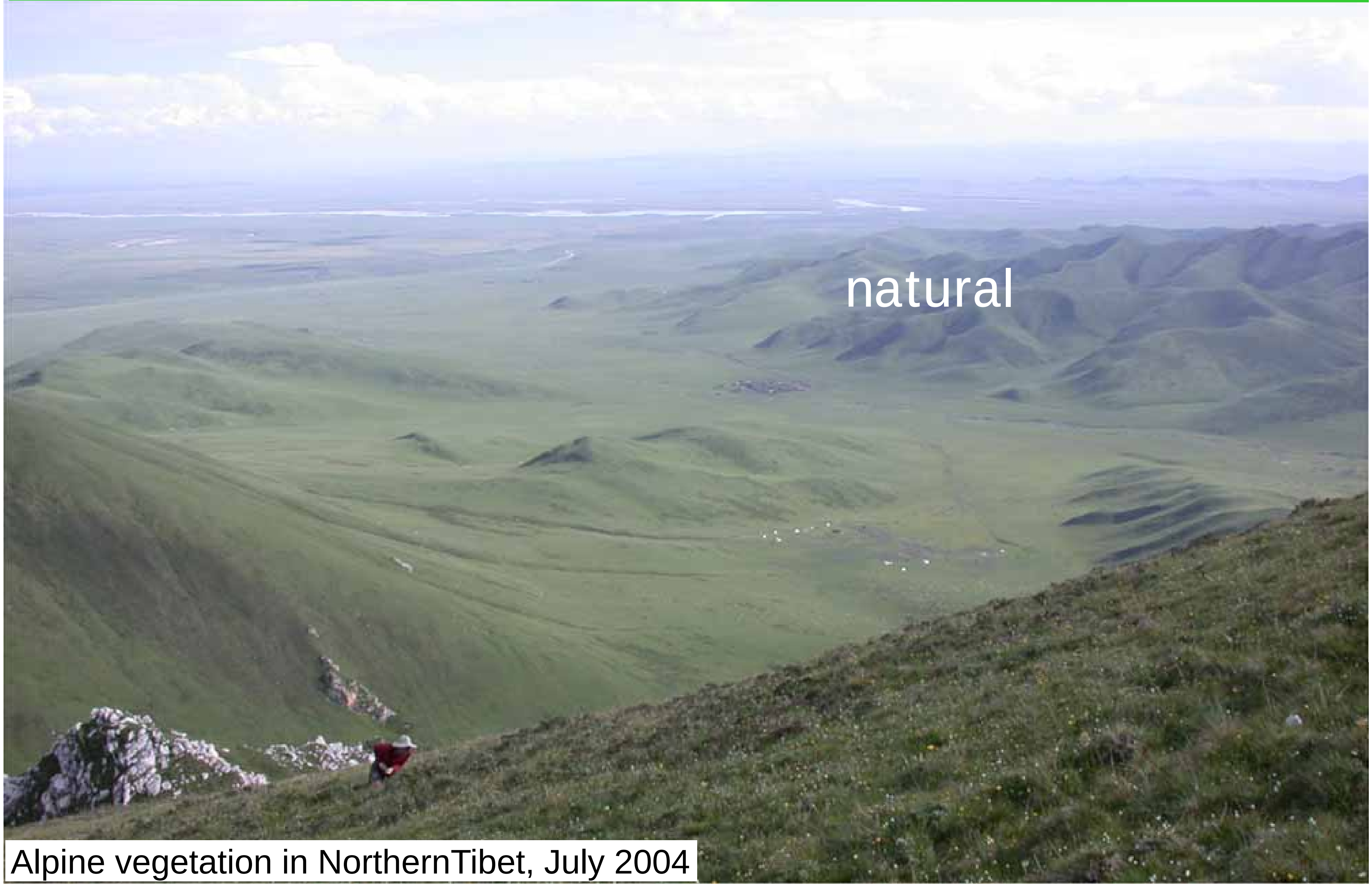
Heterogeneity

Clearcuts, Monashee Mountains, Canada, Feb. 2000

Heterogeneity

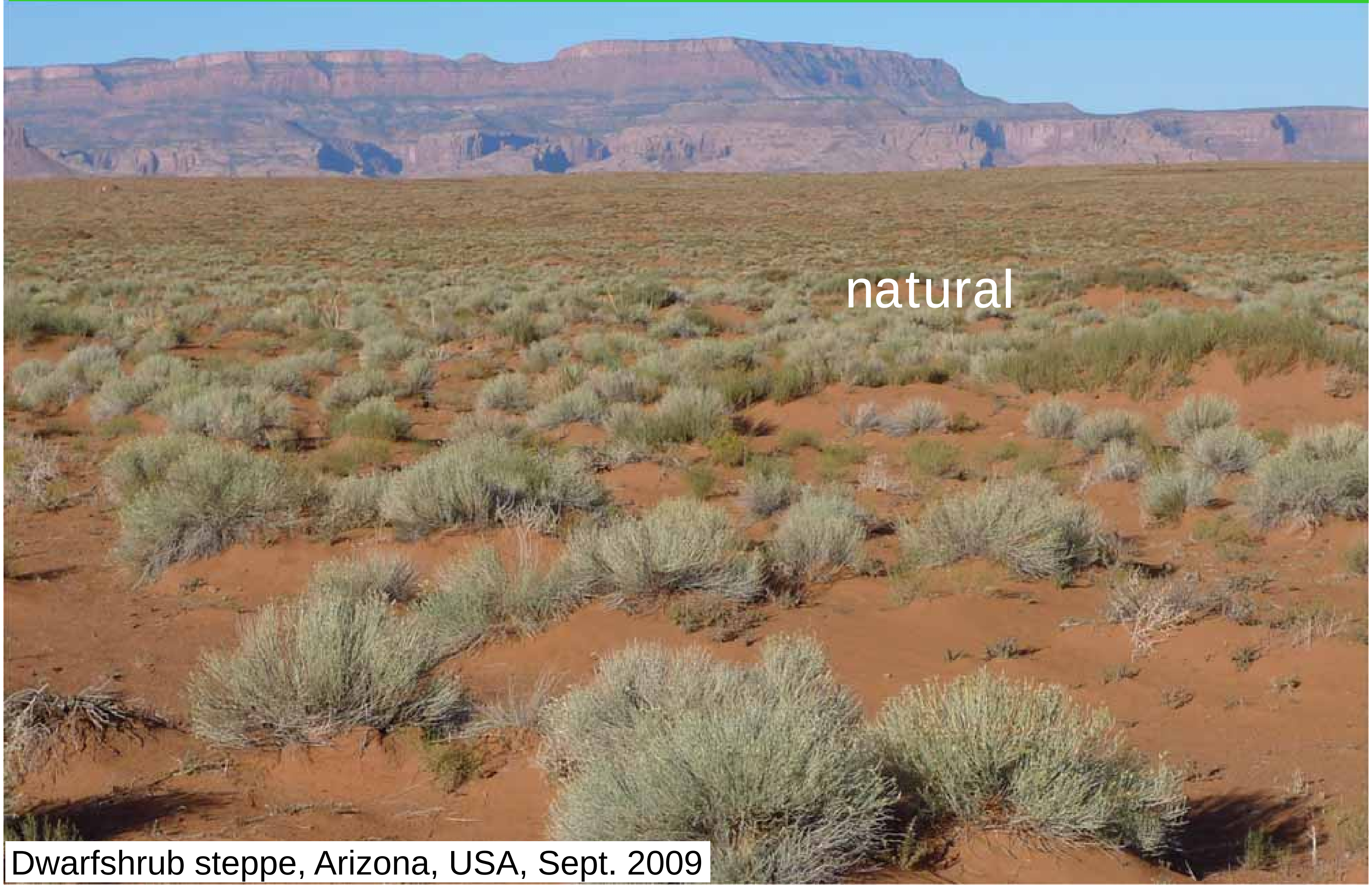
Cultural landscape, Wohnsgehaig near Bayreuth, April. 2006

Homogeneity



Alpine vegetation in NorthernTibet, July 2004

Homogeneity



Dwarfshrub steppe, Arizona, USA, Sept. 2009

Homogeneity

Cultural steppe landscape in Central Mongolia, September 2005

Homogeneity

Pinus elliotii plantation in Southern Brazil, March 2002

Homogeneity

Olive orchard, Northern Morocco, March 2001