Landscape Ecology & Climate Change Research:
Beyond the Ecosystem Approach

景观生态学和气候变化研究:超越生态系统途径

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OUTLINE

1. Climate change research: Emphasis to date and priorities in future
2. Why a landscape approach for climate change research?
3. Key elements of a landscape approach
4. Concluding remarks




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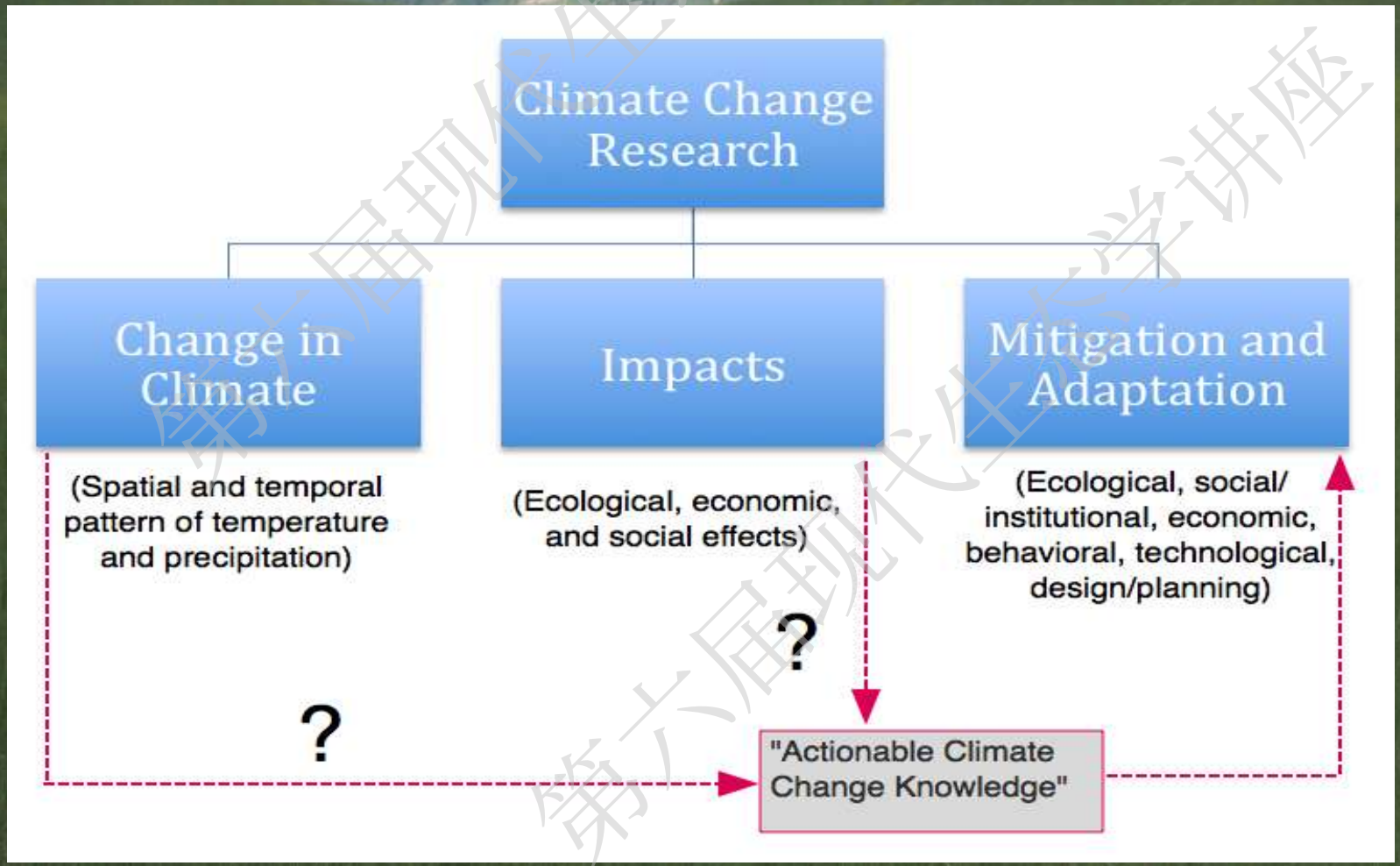
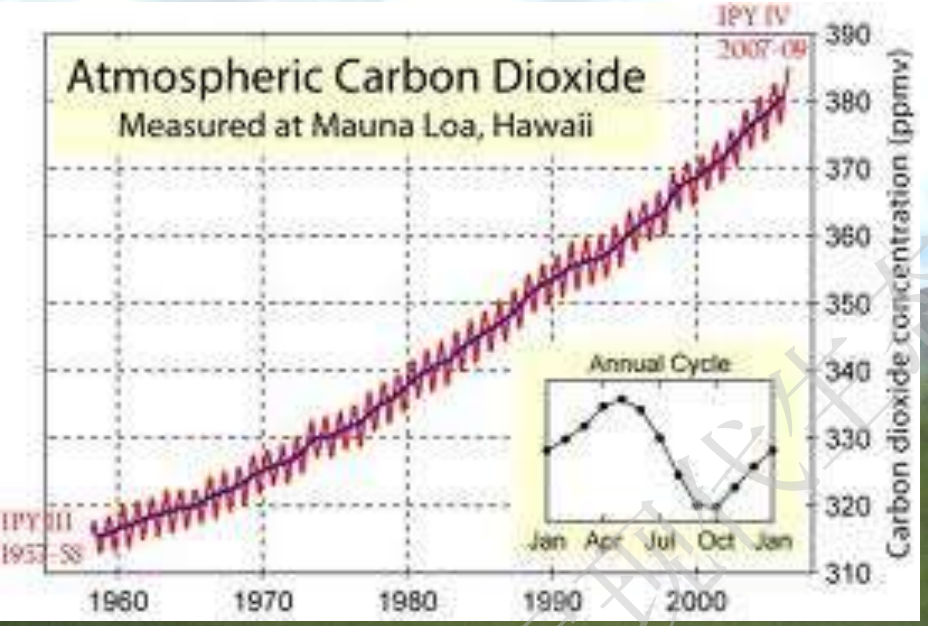
Climate Change Research

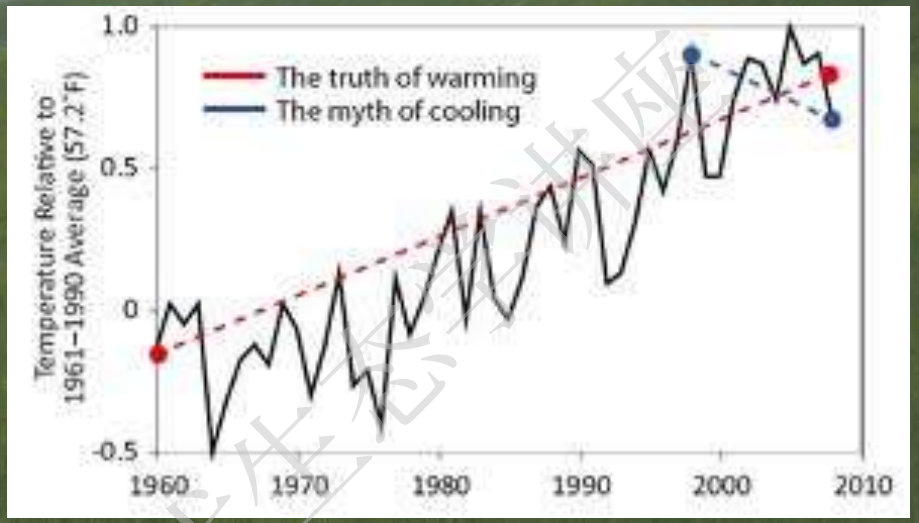
- **Focused on change detection and impacts, but "actionable knowledge" is needed for actions!**

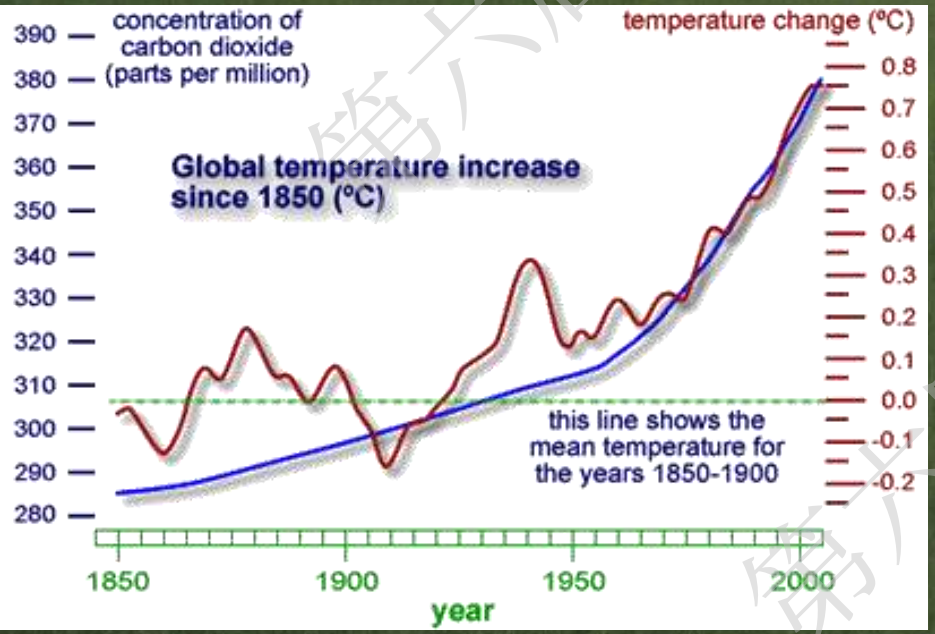


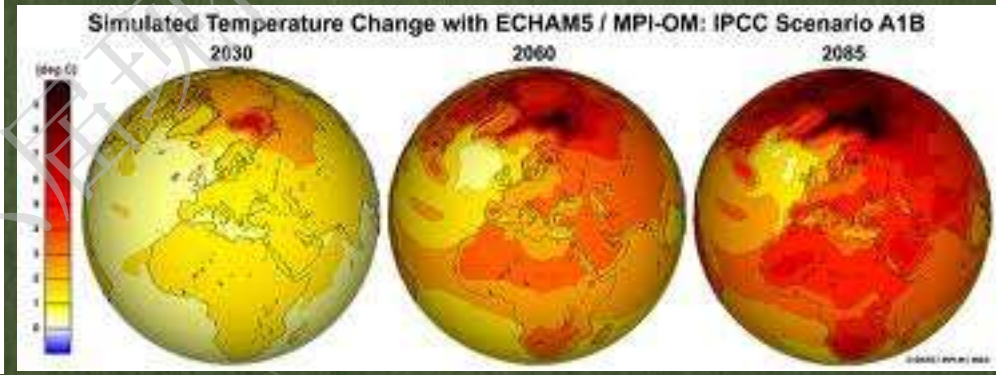
Patterns of Climate Change:

Trends, Means, High/Low (or Max/Min), Extreme events, and Scale









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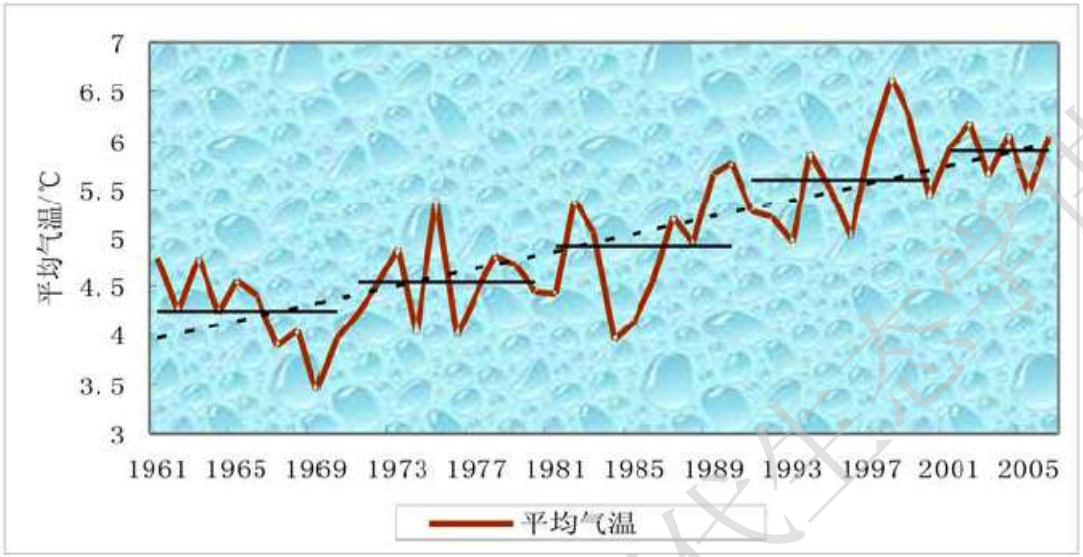


图 2　内蒙古全区平均气温年际及年代变化

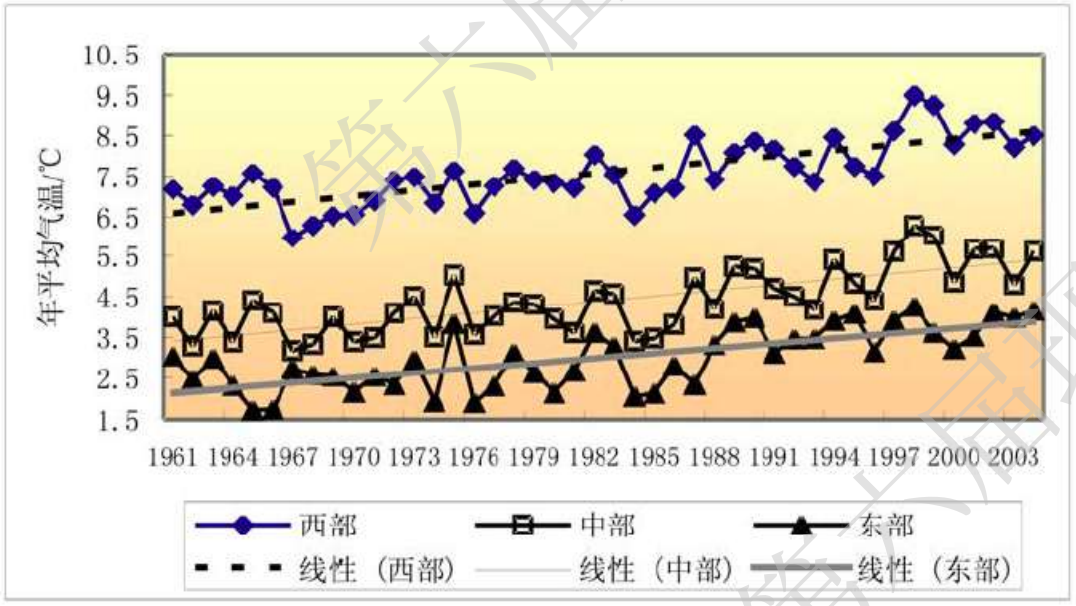


图 3　内蒙古地区年平均气温变化

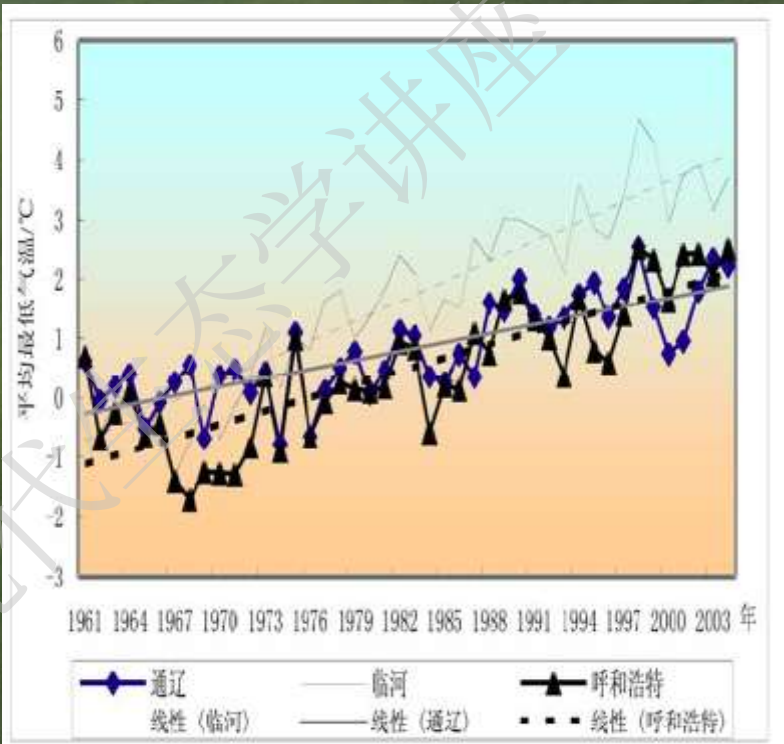
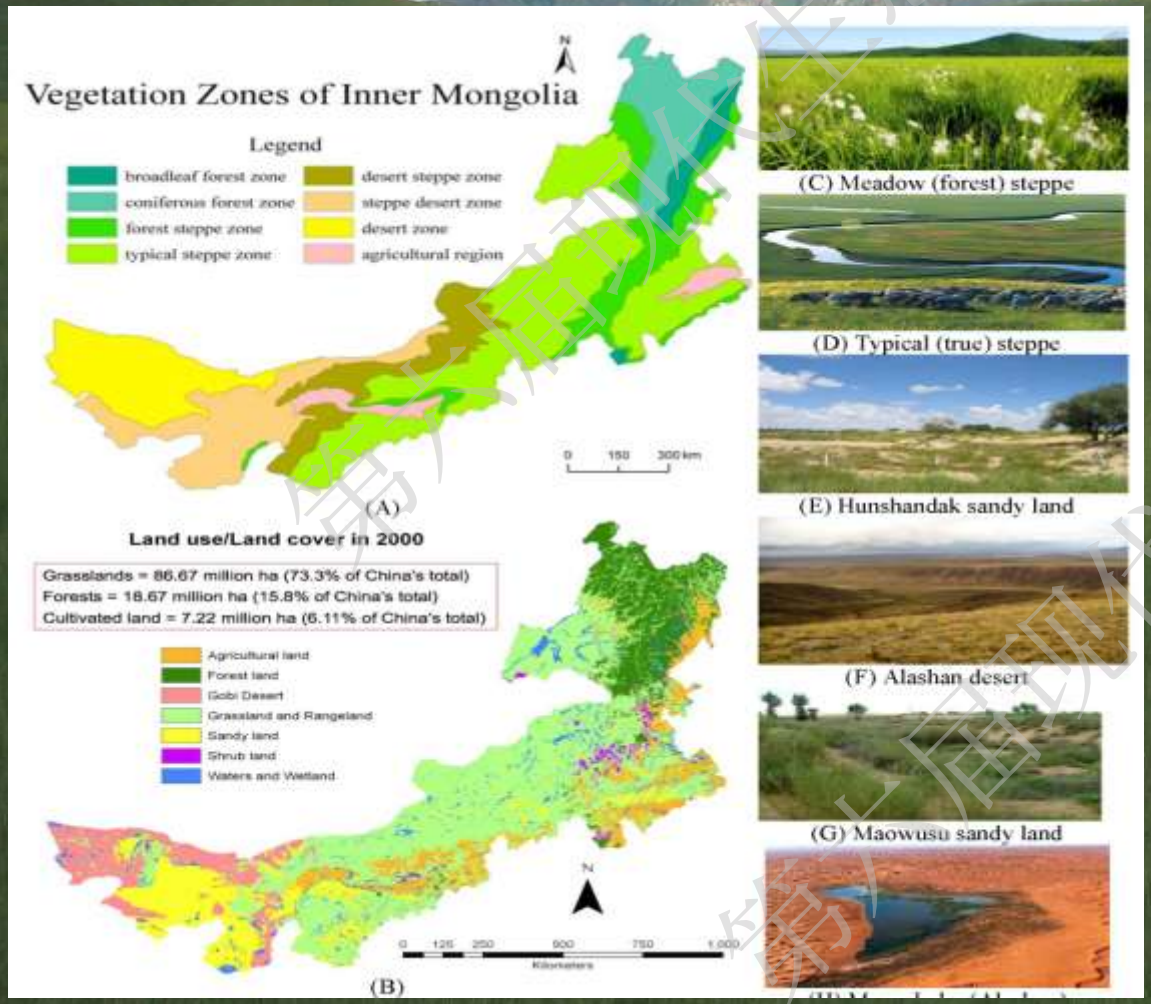


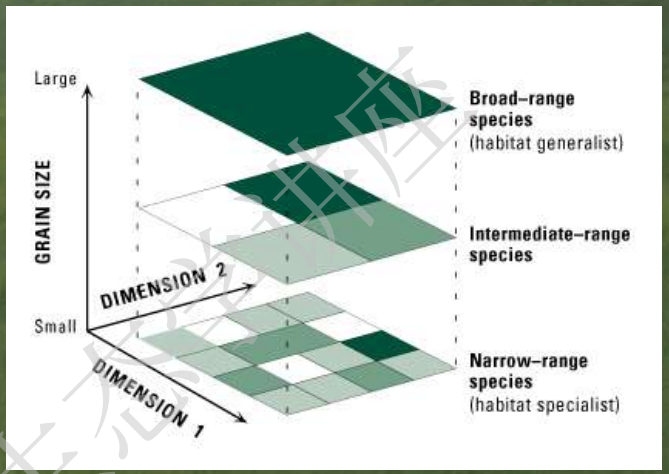
图 16　内蒙古地区平均最低气温

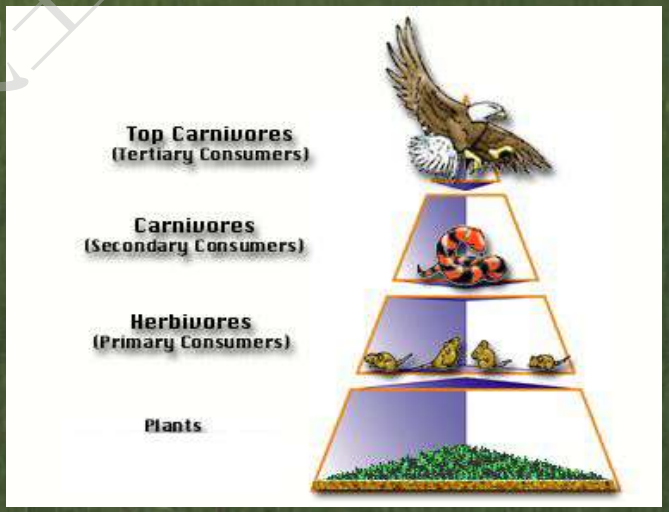
Lan (2007)

Spatial heterogeneity of climate change and idiosyncratic responses at different levels of ecological organization:

individuals – Populations/Species– Communities/Ecosystems – Landscapes – Regions – Continents – the Globe



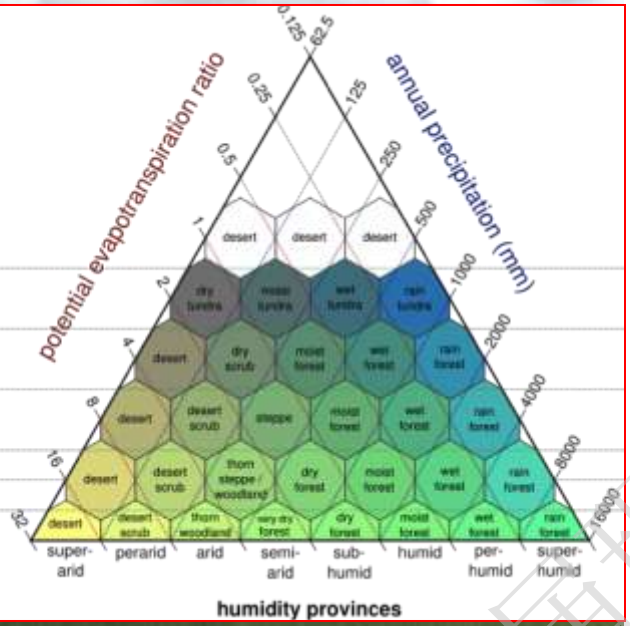




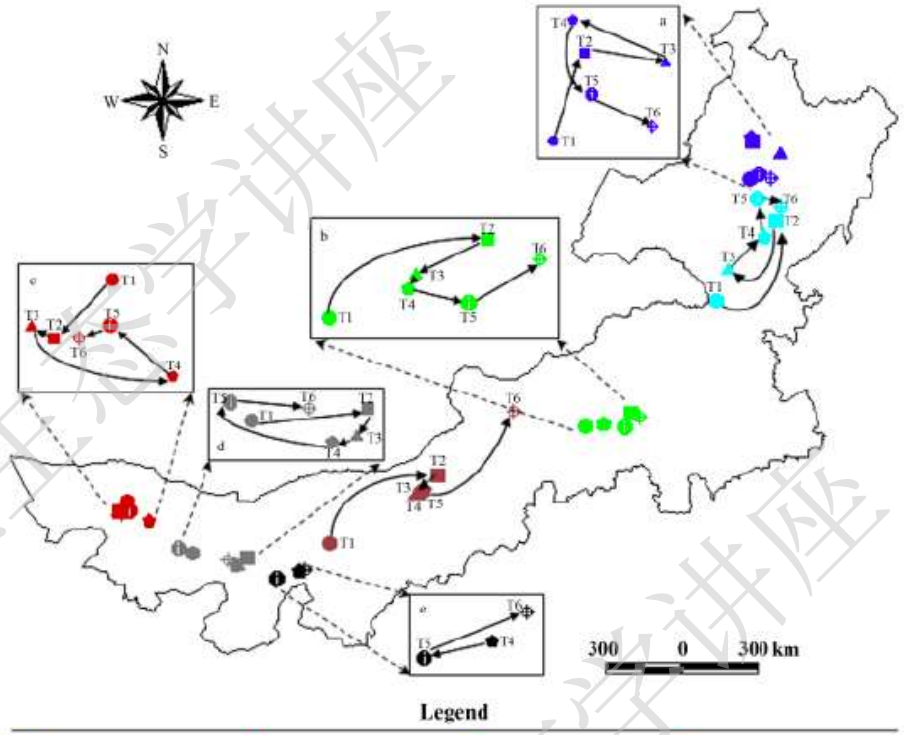
Climate Change Research

- **Ecological studies of climate change have focused mainly on the responses of individuals, species, and ecosystems …???… regions and the globe.**

Climate envelop approach



- Range shifts most likely involve individual species or populations, instead of the entire ecosystems
- These range shifts of species are determined primarily by species traits (colonization abilities) and landscape pattern.



From Barbour et al. 1987

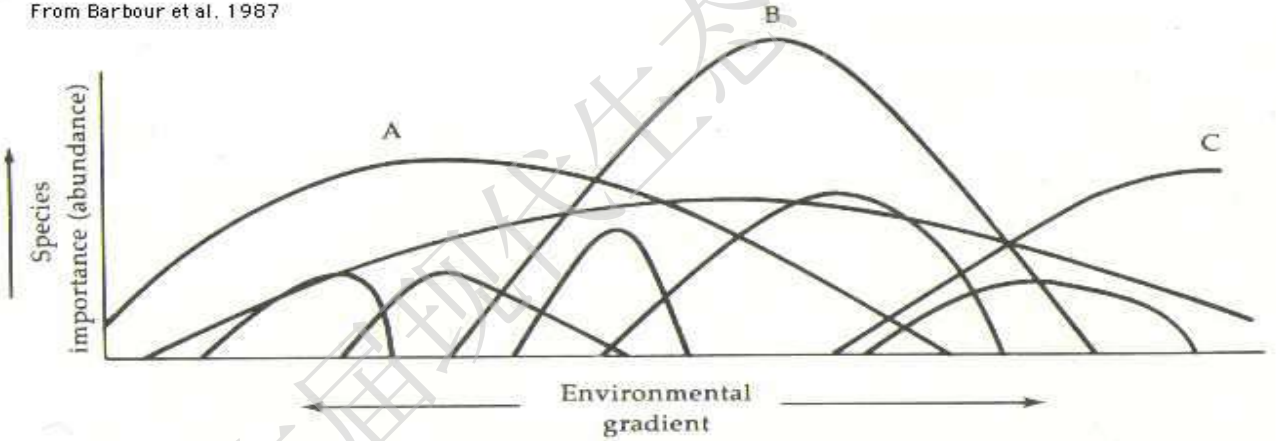


Figure 8-2 Patterns of species importance (abundance) along an environmental gradient as predicted by the continuum view of associations. Noda do not exist. If associations are recognized, based on peaks in abundance of dominant species such as A, B, or C, it can be seen that these associations are merely arbitrary segments along the continuum.

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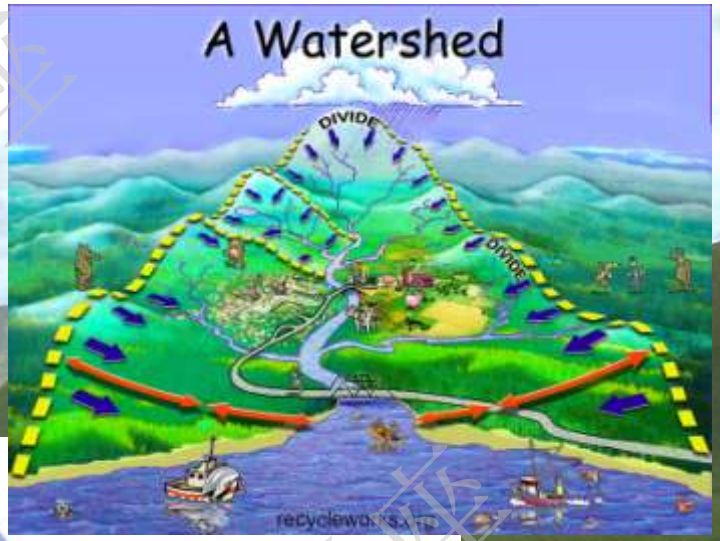
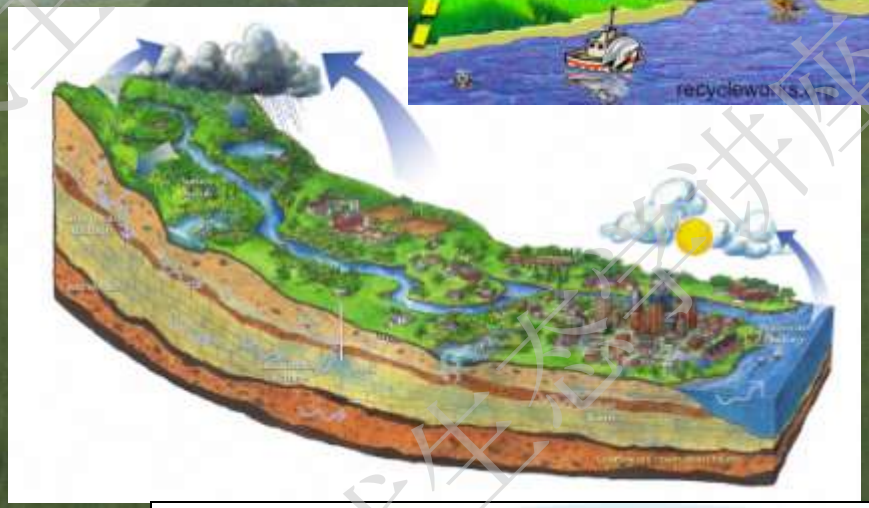
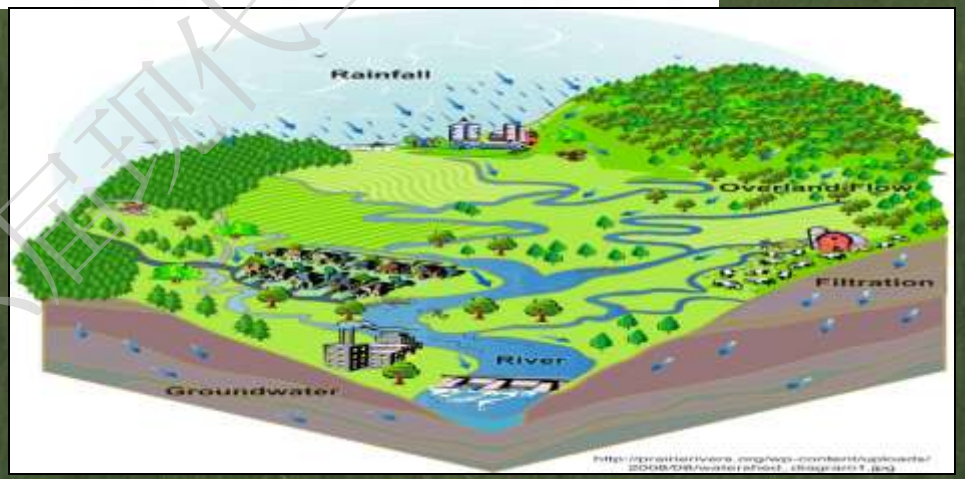
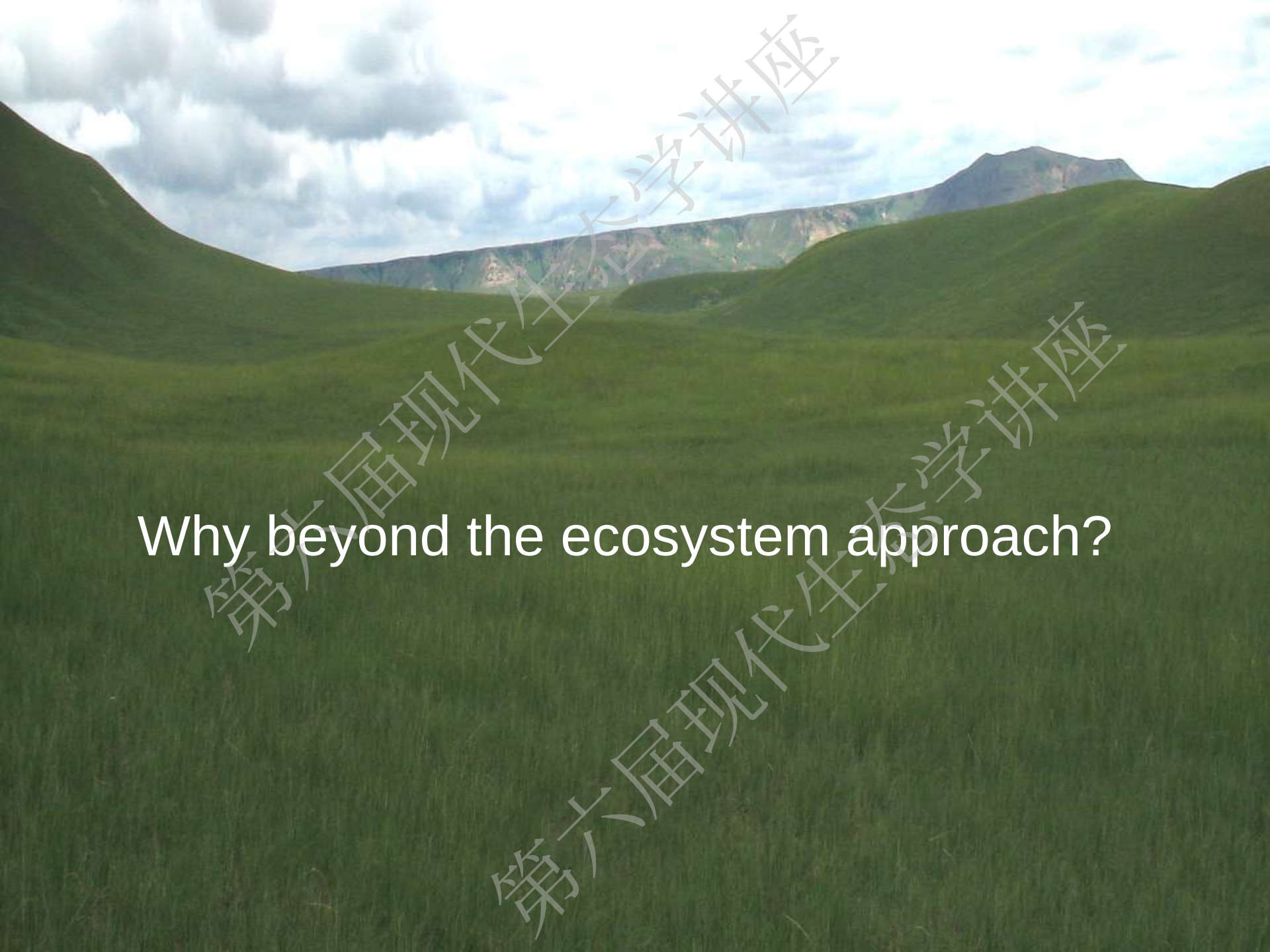
- Climate change take place in landscapes.
- **Both ecosystems and landscapes are spatially heterogeneous.**
- Species live and interact with each other in landscapes.
- **Ecosystems reside and interact with each other in landscapes.**
- Humans live and do their things in landscapes.









Ecology, 82(12), 2001, pp. 3275–3284

IS IT TIME TO BURY THE ECOSYSTEM CONCEPT? (WITH FULL MILITARY HONORS, OF COURSE!)[1]

ROBERT V. O'NEILL

Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6036 USA

ROBERT V. O'NEILL, MacArthur Award Recipient, 1999

CONCLUSIONS

Is it time to bury the ecosystem concept? Probably not. But there is certainly need for improvement before ecology loses any more credibility. This paper suggests some of the key problems. Spatial pattern, extent, and heterogeneity are critical to stability. You cannot get a predictive theory if you assume them away. Temporal variability and scale are critical to stability. You cannot get a predictive theory if you assume them away either. It is the interplay of natural selection and internal feedback mechanisms that determines dynamics. Again, you cannot get a predictive theory if you assume either away. Basically, all the processes and constraints needed to explain stability are not encompassed within the boundaries of the local ecological system.

VOLUME 70, NO. 4 *THE QUARTERLY REVIEW OF BIOLOGY* DECEMBER 1995

FROM BALANCE OF NATURE TO HIERARCHICAL PATCH DYNAMICS: A PARADIGM SHIFT IN ECOLOGY

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Elements of Hierarchical Patch Dynamics Paradigm

Wu, J. and O. L. Loucks. 1995. From balance-of-nature to hierarchical patch dynamics: A paradigm shift in ecology. *Quarterly Review of Biology* 70:439-466.

1. Ecological systems usually are spatially nested hierarchies.
2. Dynamics of a given ecological system can be derived from the dynamics of patches at adjacent hierarchical levels.
3. Pattern and process are related and scale dependent.
4. Nonequilibrium and stochastic processes are common and important in ecological systems (not to be "smoothed out"!).
5. (Meta)stability of ecological systems is often achieved through hierarchical/scale linkages (spatial and temporal incorporation).

(Wu & Loucks 1995; Wu & Levin 1994, 1997; Wu 1999, Wu and David 2002)

Landscape Ecol (2009) 24:715–721
DOI 10.1007/s10980-009-9377-1

Opdam et al. (2009) – 3 major methodological problems" with ecological studies of climate change:

1. Majority of ecological studies focus on IMPACTS of climate change on biodiversity, ecosystems, and land use rather than ADAPTATION AND MITIGATION.

2. Most "impact studies" lack of explicit consideration of spatial patterns, pattern-process interactions, and scale dependencies.

3. Most "impact studies" are narrow in scope – lacking social and planning perspectives.




Biodiversity management in the face of climate change: A review of 22 years of recommendations

Nicole E. Heller, Erika S. Zavaleta*

Environmental Studies Department, University of California, Santa Cruz, Santa Cruz, CA 95606, United States

BIOLOGICAL CONSERVATION 142 (2009) 14–32

Heller and Zavaleta (2009):

- Ecological studies usually provide general recommendations that are difficult to operationalize.
- Most ecological studies neglect social and economic processes.
- A holistic landscape ecological approach is gaining impetus.




A holistic landscape ecological approach is gaining impetus.

Landscape Ecol (2009) 24:715–721

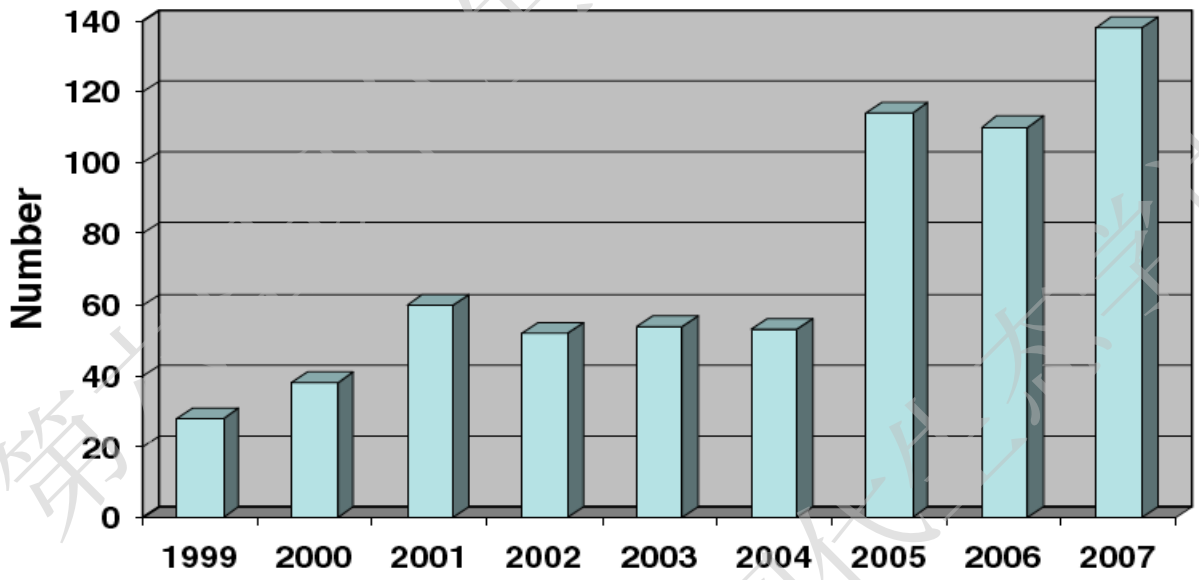


Fig. 1 Number of publications on adaptation to climate change with reference to land use or landscape (Google scholar search 23-08-2008; $N = 771$)

Opdam et al. (2009)




But not enough …

Landscape Ecol (2009) 24:715–721
DOI 10.1007/s10980-009-9377-1

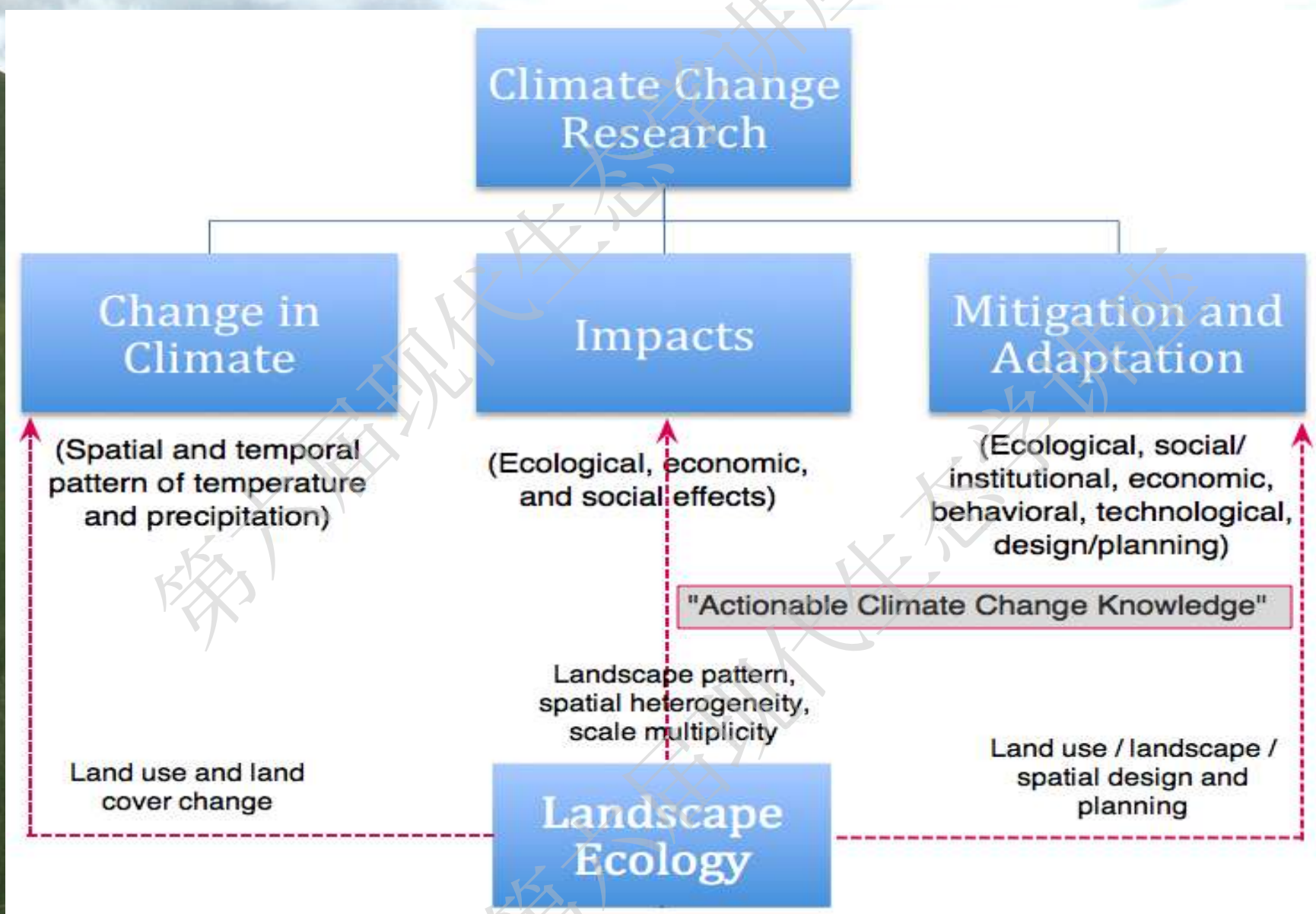
EDITORIAL

Changing landscapes to accommodate for climate change impacts: a call for landscape ecology

Paul Opdam · Sandra Luque · K. Bruce Jones

To make produce “actionable climate change knowledge” (Meinke et al. 2006), ecological studies of climate change must explicitly consider landscape pattern because actions of climate mitigation and adaptation frequently involve changing landscape composition and configuration (Opdam et al. 2009).





Climate Change Research
Change in Climate
Impacts
Mitigation and Adaptation
(Spatial and temporal pattern of temperature and precipitation)
(Ecological, economic, and social effects)
(Ecological, social/ institutional, economic, behavioral, technological, design/planning)
"Actionable Climate Change Knowledge"
Landscape pattern, spatial heterogeneity, scale multiplicity
Land use and land cover change
Land use / landscape / spatial design and planning
Landscape Ecology

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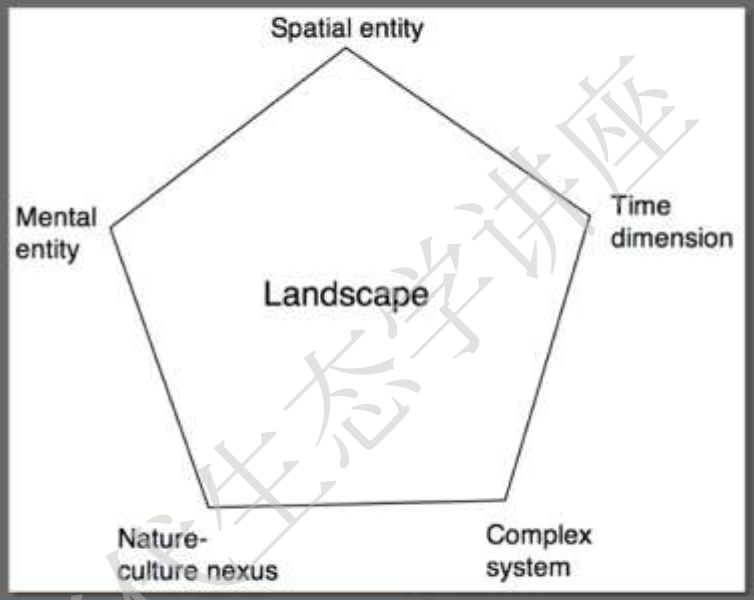
What Is a Landscape?

A word with too many meanings…

- a natural landscape
- a cultural landscape
- a political landscape
- an economic landscape
- an mental landscape
- an adaptive landscape
- a landscape view
- landscaping
- landscape painting
- etc.

Transdisciplinary Concept of Landscape



Tress and Tress (2001)




Wu (2011)

Evolving Concepts of Landscape Ecology

Risser, P. J. Karr, and R. Forman (1984):

- **“Landscape ecology is not a distinct discipline or simply a branch of ecology, but rather is the synthetic intersection of many related disciplines that focus on the spatial-temporal pattern of the landscape”.**

Risser P.G., Karr J.R. and Forman R.T.T. 1984. Landscape Ecology: Directions and Approaches. Illinois Natural History Survey Special Publ. 2, Champaign.

LANDSCAPE ECOLOGY AS AN INTERDISCIPLINARY AND TRANSDISCIPLINARY SCIENCE

Wu and Hobbs (2007):

- **The integration of *science* and *art* of *studying* and *influencing* the relationship between spatial *pattern* and ecological as well socioeconomic *processes* on multiple *scales*.**

Wu J. and Hobbs R. 2007. Landscape ecology: The-state-of-the-science. *In* Wu J. and Hobbs R. (eds.), Key Topics in Landscape Ecology, pp. 271-287. Cambridge University Press, Cambridge, UK.

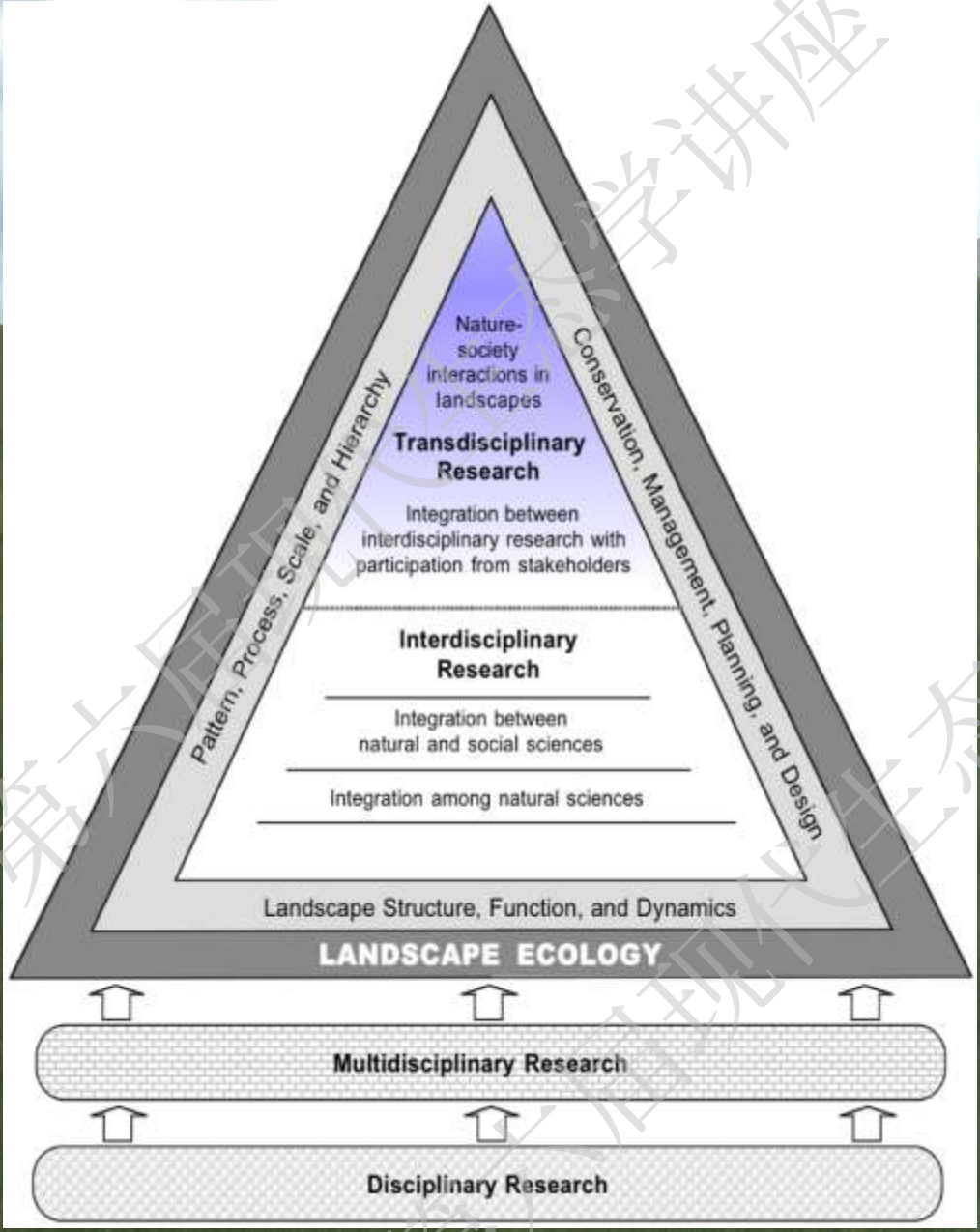
Sustainability of Landscapes

|

Ecology of Landscapes

|

Ecology in Landscapes



Example research topics

Landscape sustainability

- Sustainability science
- Holistic landsc ecology
- Sustainable land architecture
- Land change science (LCS)

Pattern-process relationships

- Landsc pattern and conserv
- Landsc pattern & ecosystems
- Landsc pattern & pop/species
- Behavioral landsc ecology
- Landscape genetics
- Landscape epidemiology
- Soundscape ecology

Pattern/process in landscapes

- Non-spatial ecological studies at the landscape scale
- Landscape-scale characterization of ecological patterns and processes

A Hierarchical Pluralistic Framework for Landscape Ecology and Sustainability Science (Wu 2006)

Top 10 Research Topics

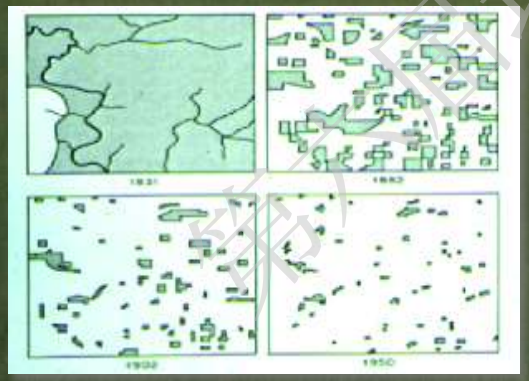
1. Ecological flows in landscape mosaics
2. Causes, processes, and consequences of land use and land cover change
3. Nonlinear dynamics and landscape complexity
4. Scaling
5. Methodological development
6. Relating landscape metrics to ecological processes
7. Integrating humans and their activities into landscape ecology
8. Optimization of landscape pattern
9. Landscape conservation and sustainability
10. Data acquisition and accuracy assessment

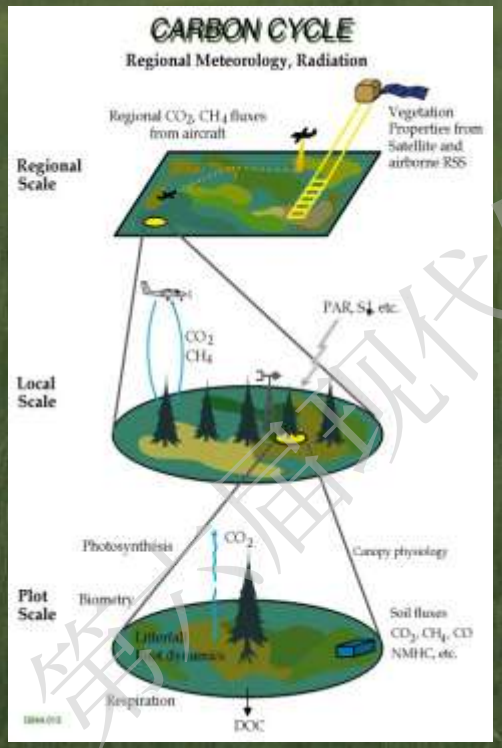
Key Differences Between Landscape Ecology and Other "Ecologies"

- Place/picture friendly – locations and spatial pattern
- Human friendly – humanistic
- "Disturbance" friendly – "disturbances are major determinants of landscape pattern and key drivers of landscape change
- Interdisciplinarity friendly – pluralism in origin, methodology, and objectives
- Designer/planner/decision maker friendly – the landscape scale is where ecological, environmental, and social processes meet.

The Essence of a Landscape Ecological Approach

- Explicitly consider spatial heterogeneity
- Land use and land cover change
- Scale multiplicity





“Actionable” climate change research needs to consider land use and land cover change.

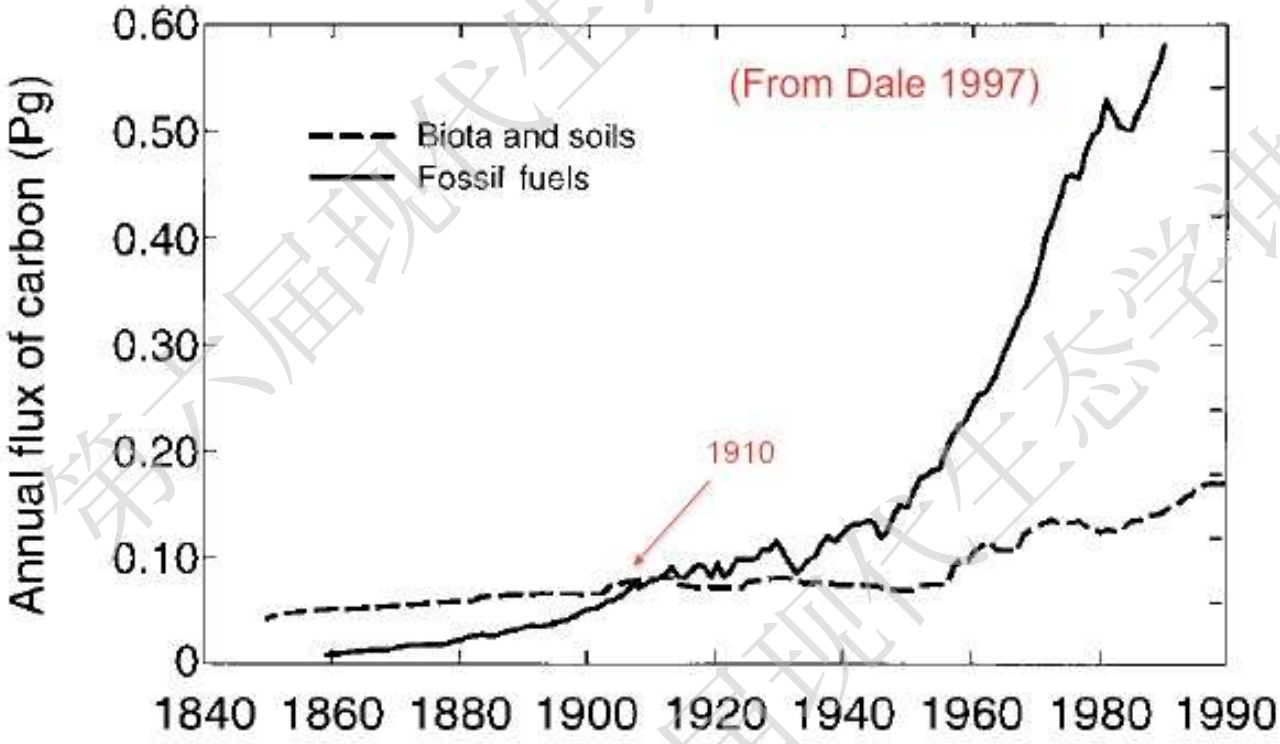


FIG. 2. Historical contributions to atmospheric CO_2 concentrations from greenhouse gases (Marland et al. 1989) and land-use change (Houghton 1994). (Note: 1 Pg = 10^{15} g = 10^9 metric tons.)

TABLE 5. Human causes and consequences of land-cover change.

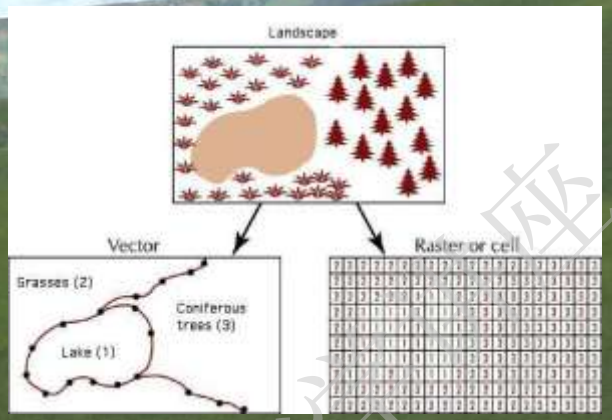
	Consequences		
Causes†	Typical land-cover changes	Typical activities that modify land cover	Ecological characteristics affected
Population growth	Forest harvesting	Irrigation	Biodiversity
Affluence	Agricultural expansion	Fertilization	Habitat
Technology	Urbanization	Forest degradation (thinning, coppicing, gathering wood)	Soil quality
			Productivity
Political economy	Second home development	Introduction of exotics	Extractable resources
Political structure	Flooding	Landscape fragmentation	Water quality
Attitudes and values			Regional and global climate

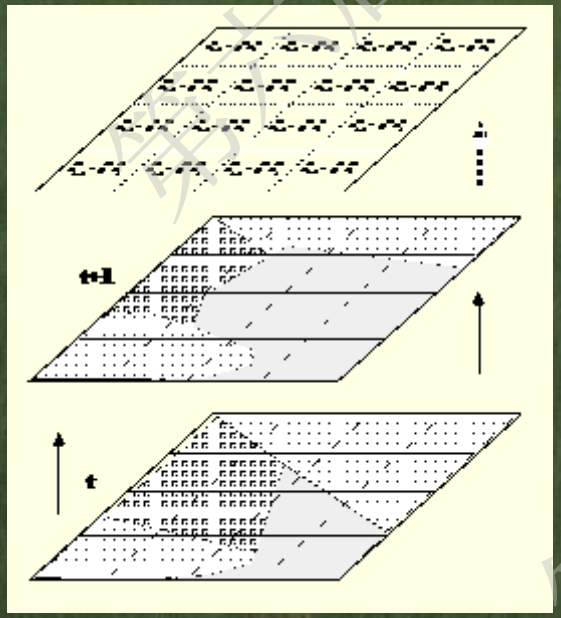
† From Turner et al. (1993).

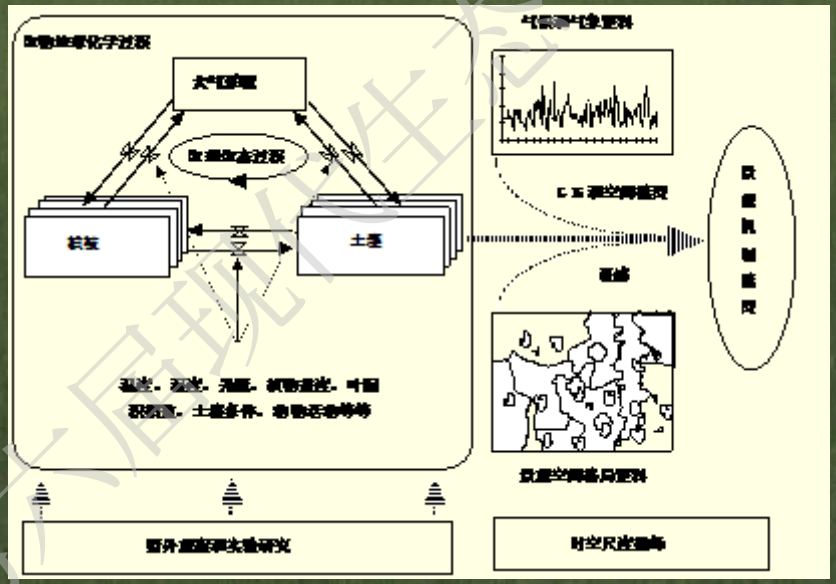
Landscape heterogeneity / pattern-process interactions / hierarchical linkages between scales

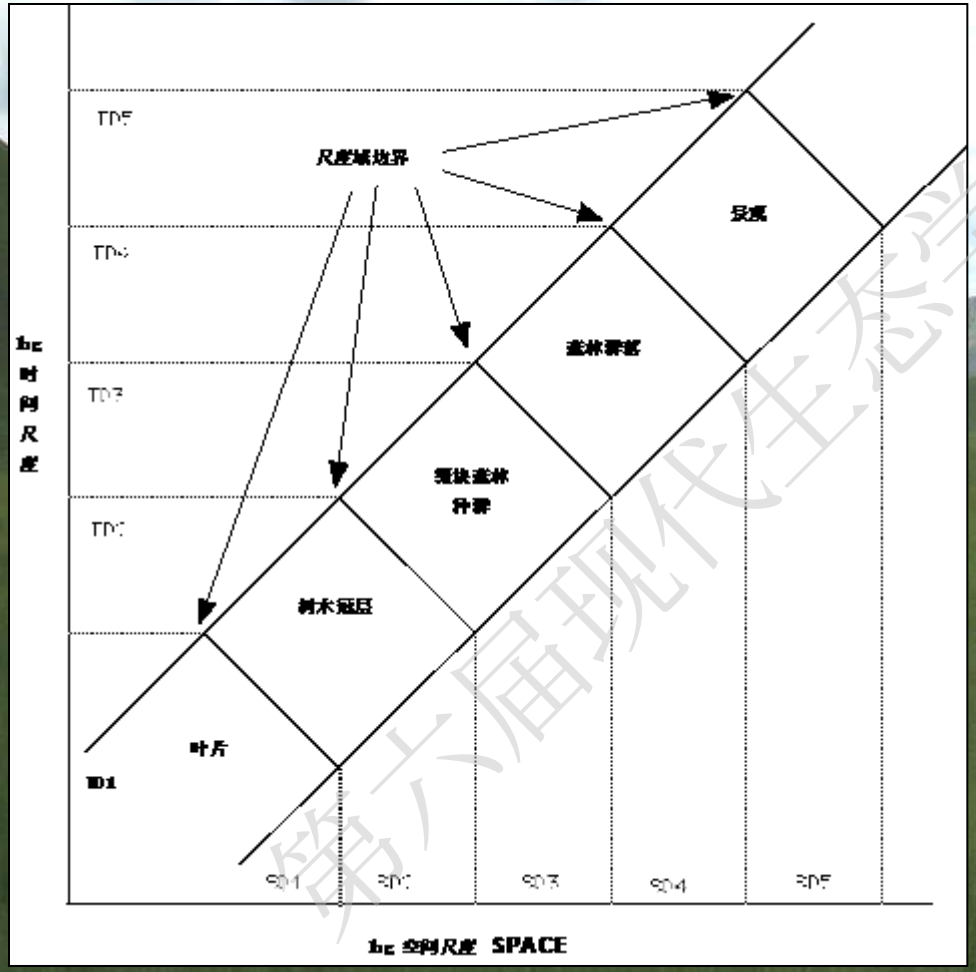
Landscape ecological methods

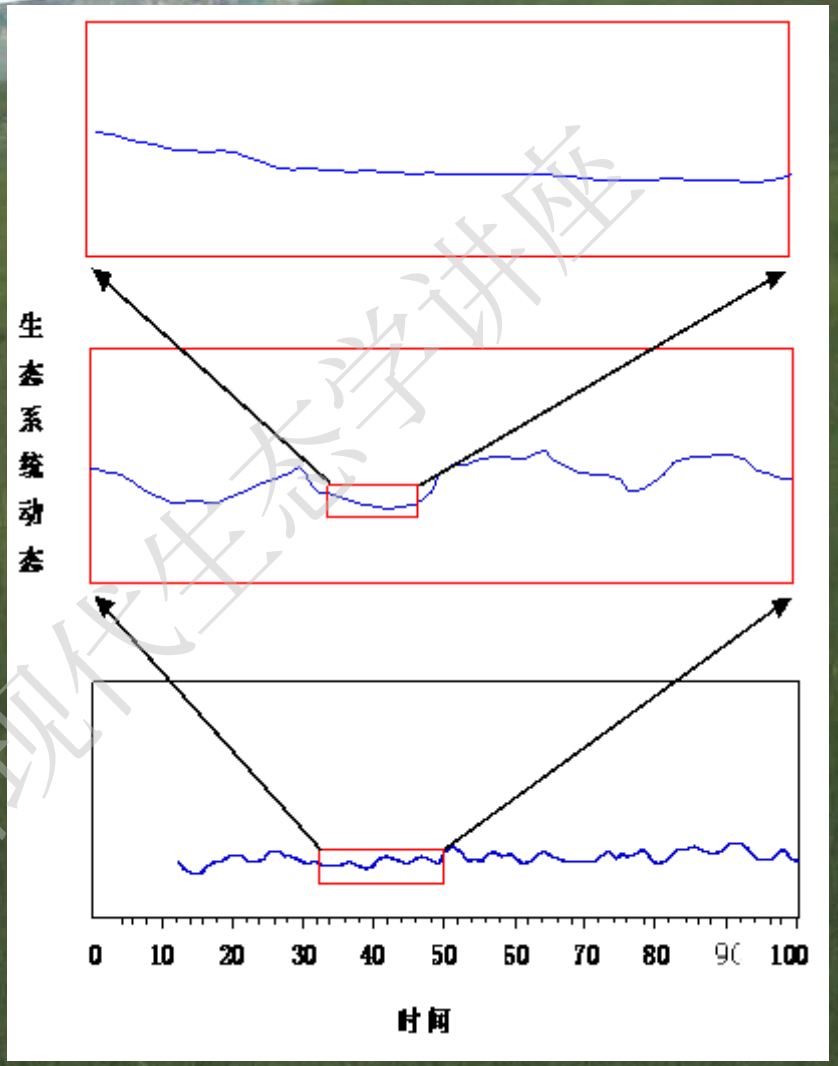
- Landscape-scale observations
- GIS/Remote sensing
- Spatial pattern analysis
- Spatial modeling





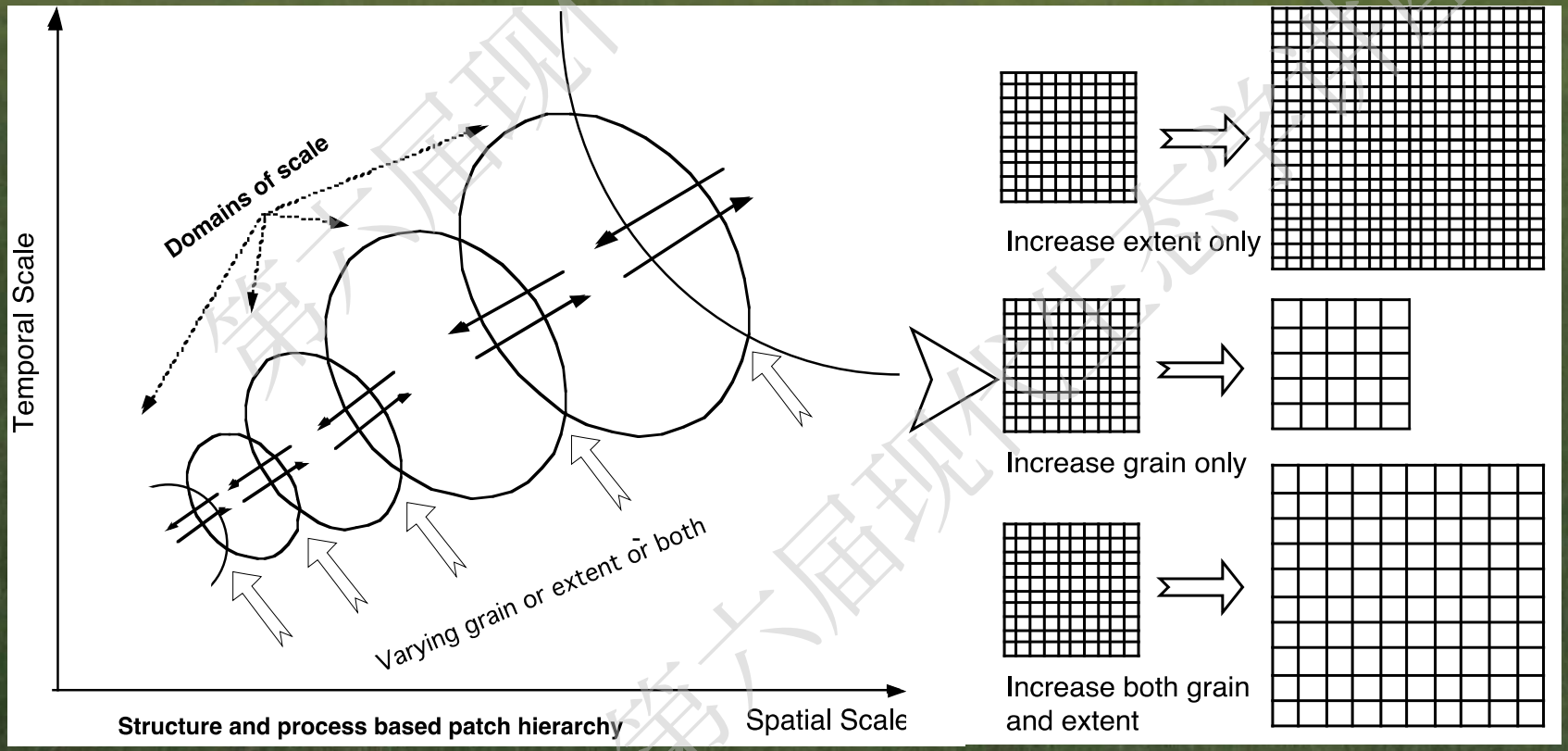






Scaling ladder

Hierarchy and Scaling (Wu 1999)



Some landscape ecological topics in relation to climate change

- Land use and land cover change and climate change
- Interactions between habitat fragmentation and climate change
  - E.g., How to ameliorate climate change impacts on biodiversity in fragmented landscapes?
- Landscape genetics
- Increased invasions of exotic species that are adapted to warmer climate conditions
- “Spatial resilience” to climate change
- Landscape mitigation and adaptation to climate change
- Scaling (climate change and impacts) across landscapes




Some Frameworks for Landscape-Scale Climate Change Research



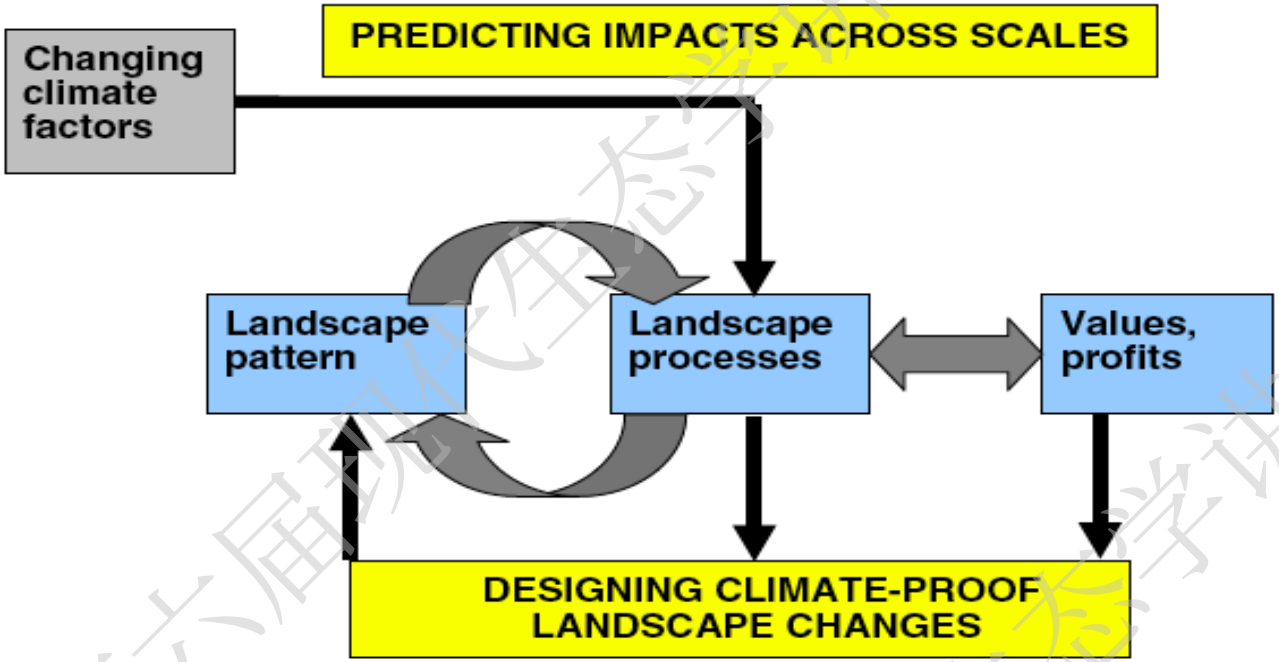
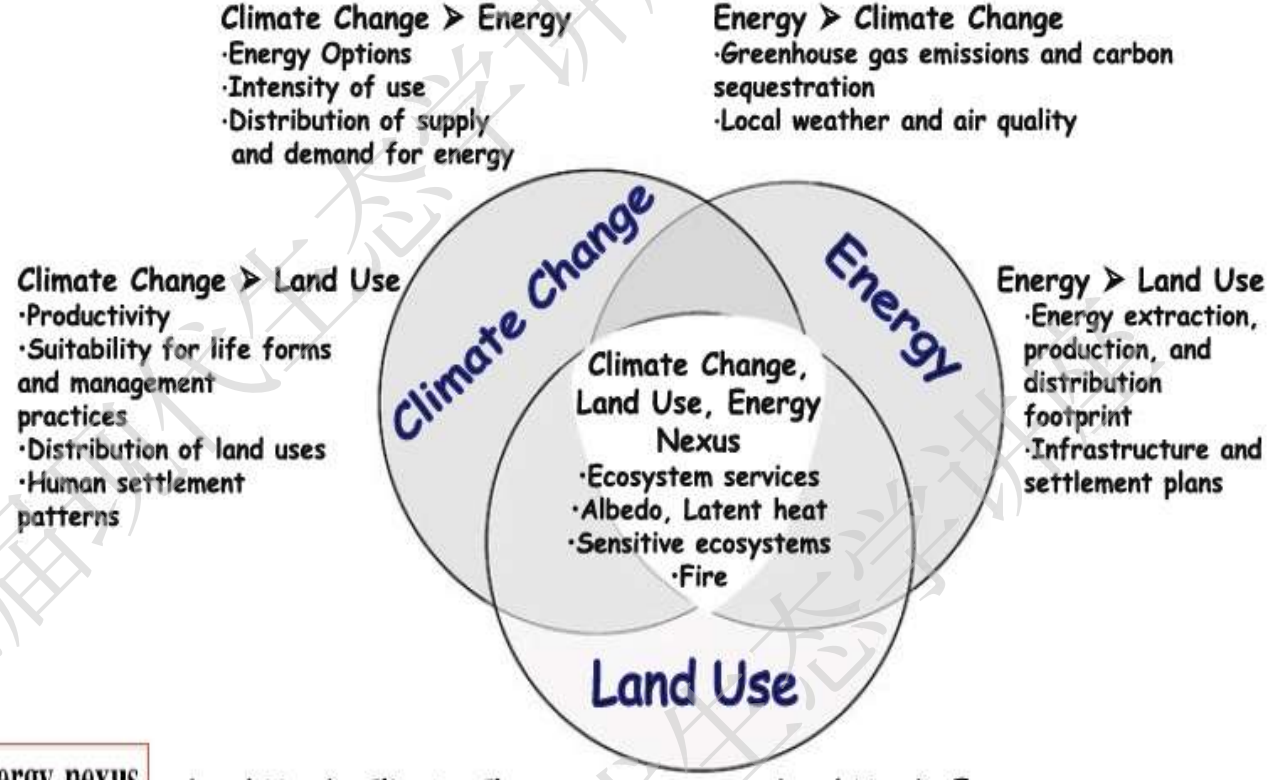



Fig. 2 Conceptual framework showing the relationship between climate change impact assessment on landscapes and design based research generating plans for adapting landscapes. While impact assessment provides insight into impacts on landscape functioning, to get relevant to adaptation change of function need to be translated into change of value.

Opdam et al. (2009)




Fig. 1 Relationships among energy, land use, and climate change. Arrows indicate influence of one factor on another



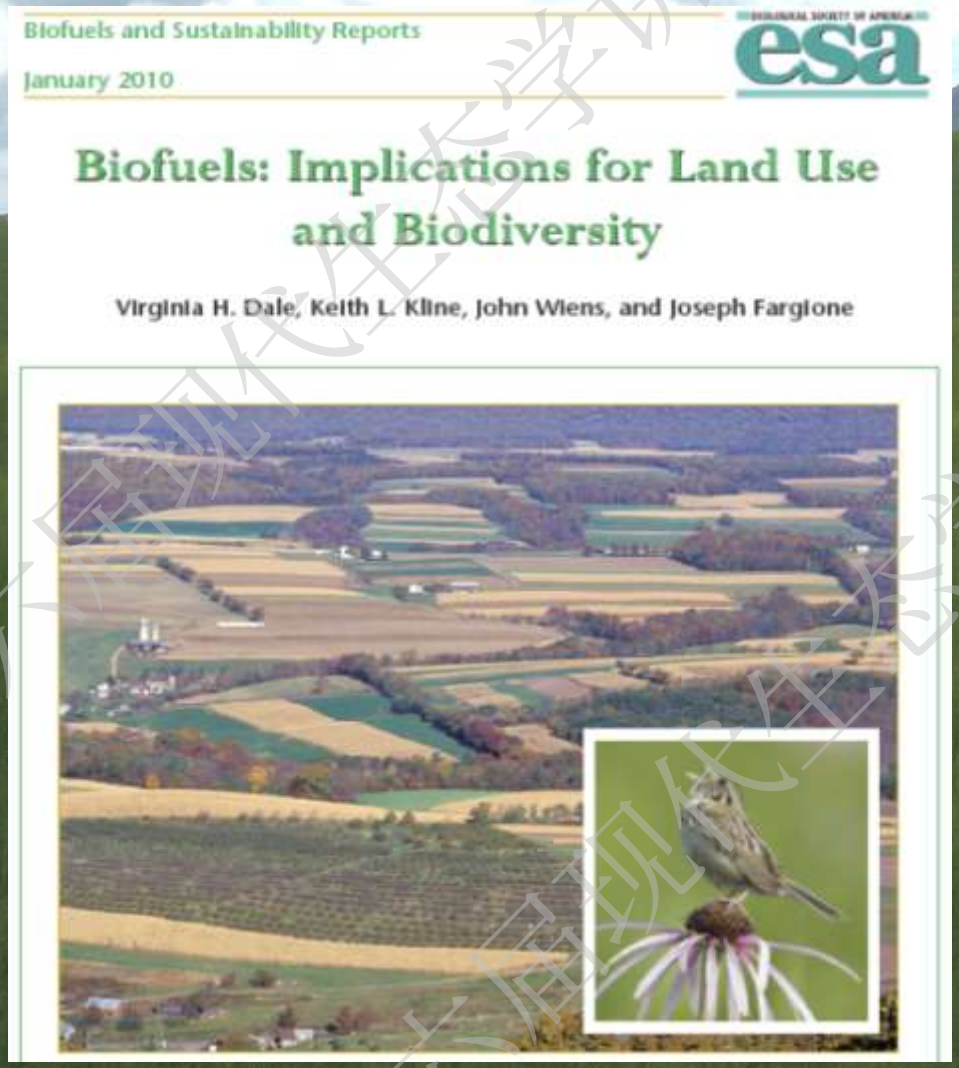
The land use–climate change–energy nexus

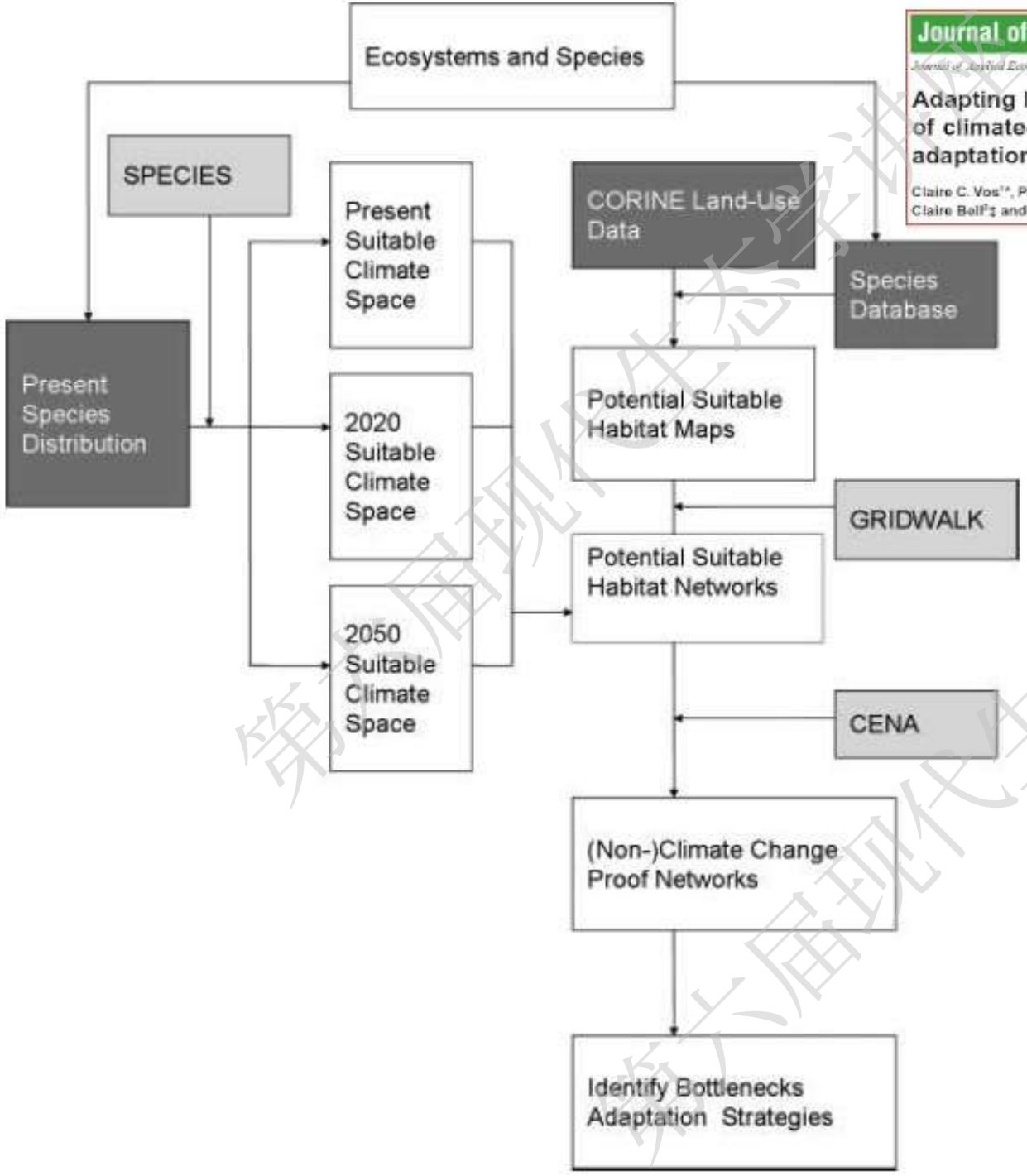
Virginia H. Dale · Rebecca A. Efroymson · Keith L. Kline

Dale et al. (2011)




Climate change + LUCC + Energy





Journal of Applied Ecology
Journal of Applied Ecology 2008, 45, 1722–1731 doi: 10.1111/j.1365-2664.2008.01569.x

Adapting landscapes to climate change: examples of climate-proof ecosystem networks and priority adaptation zones

Claire C. Vos[1]*, Pam Berry[2], Paul Opdam[1,3], Hans Baveco[1], Bianca Nijhof[1], Jesse O'Hanley[2]†, Claire Bell[2]‡ and H. Kuipers[1]

Fig. 1. Schematic overview of the analysis steps. The simulation models are indicated in grey boxes, input data in dark grey boxes.

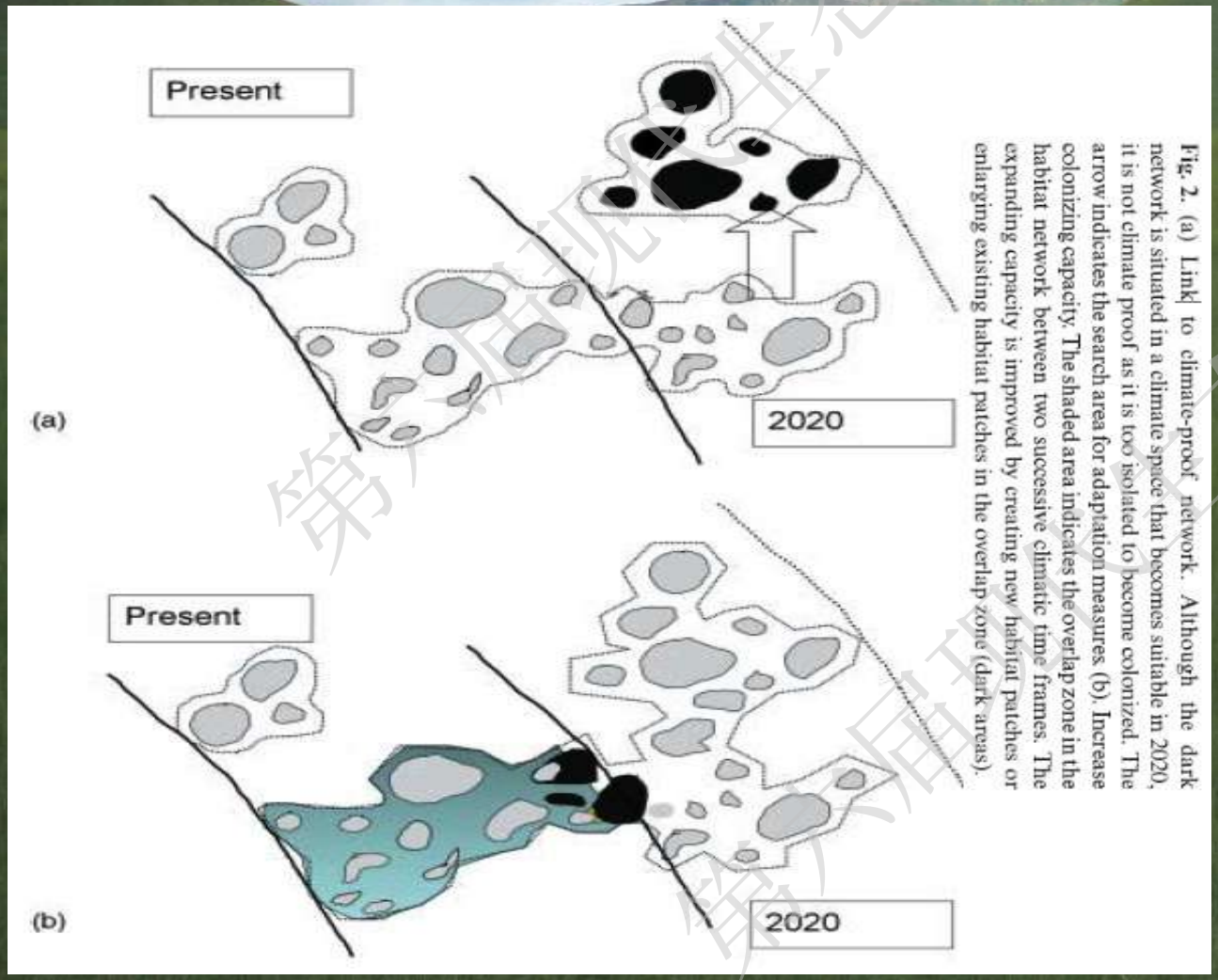


Fig. 2. (a) Link to climate-proof network. Although the dark network is situated in a climate space that becomes suitable in 2020, it is not climate proof as it is too isolated to become colonized. The arrow indicates the search area for adaptation measures (b). Increase colonizing capacity. The shaded area indicates the overlap zone in the habitat network between two successive climatic time frames. The expanding capacity is improved by creating new habitat patches or enlarging existing habitat patches in the overlap zone (dark areas).

Vos et al (2008) suggested two spatial adaptation strategies:
(1) to increase the connectivity between ecosystem networks on a large spatial scale, and
(2) to increase the area and density of ecosystem networks in regions where dispersal sources are small and widely dispersed.

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LANDSCAPE ECOLOGY IN PRACTICE

Spatial planning of a climate adaptation zone for wetland ecosystems

Claire C. Vos · Dirk C. J. van der Hoek · Marijke Vonk

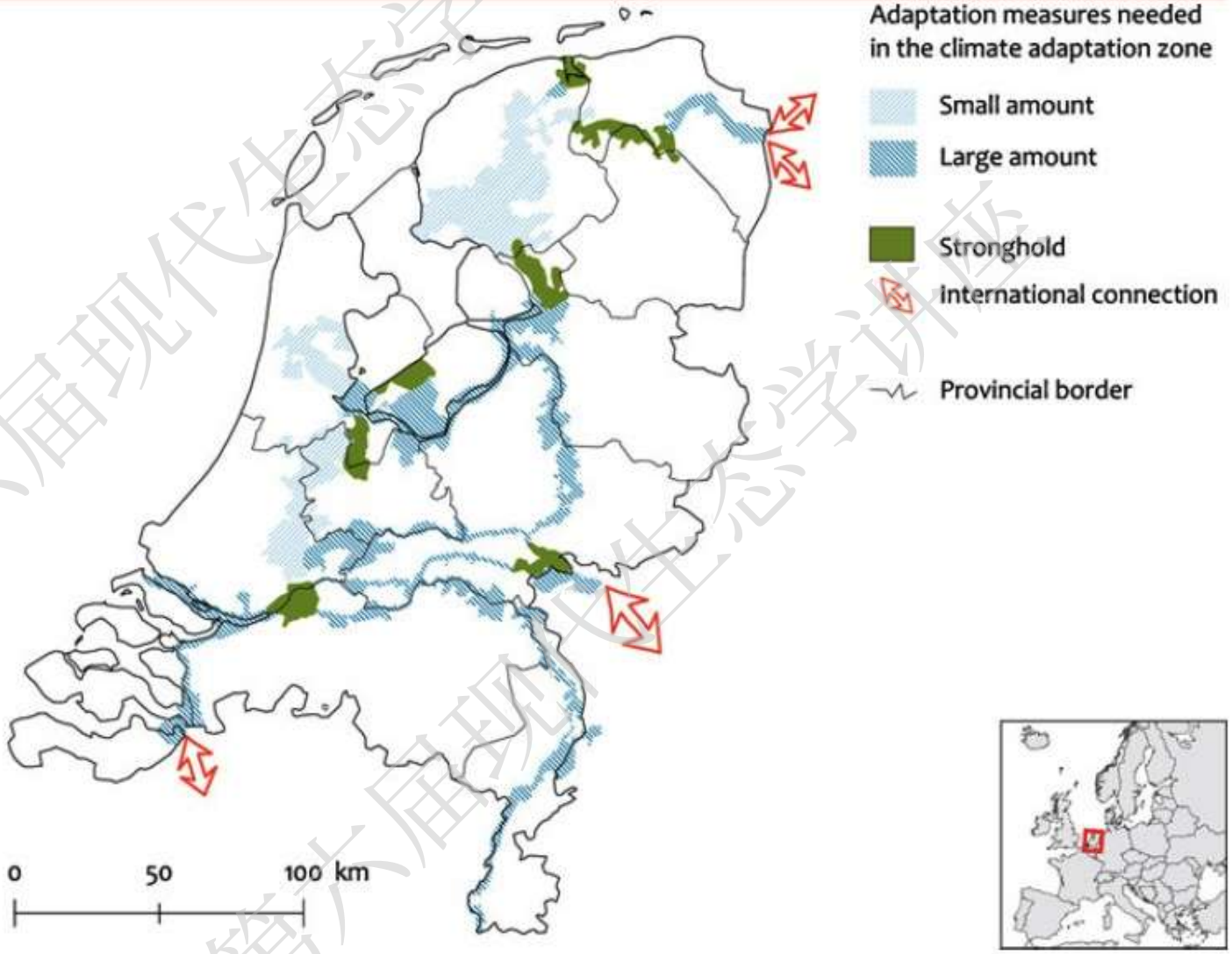


Fig. 4 The proposed climate adaptation zone for wetland ecosystems. The climate adaptation zone is a focus zone for adaptation measures. The optimal location for the climate adaptation zone is determined by the large existing wetlands (strongholds), a high spatial cohesion of the wetland network, a low number of dispersal bottlenecks, high suitable conditions for wetland restoration and potential international connectivity

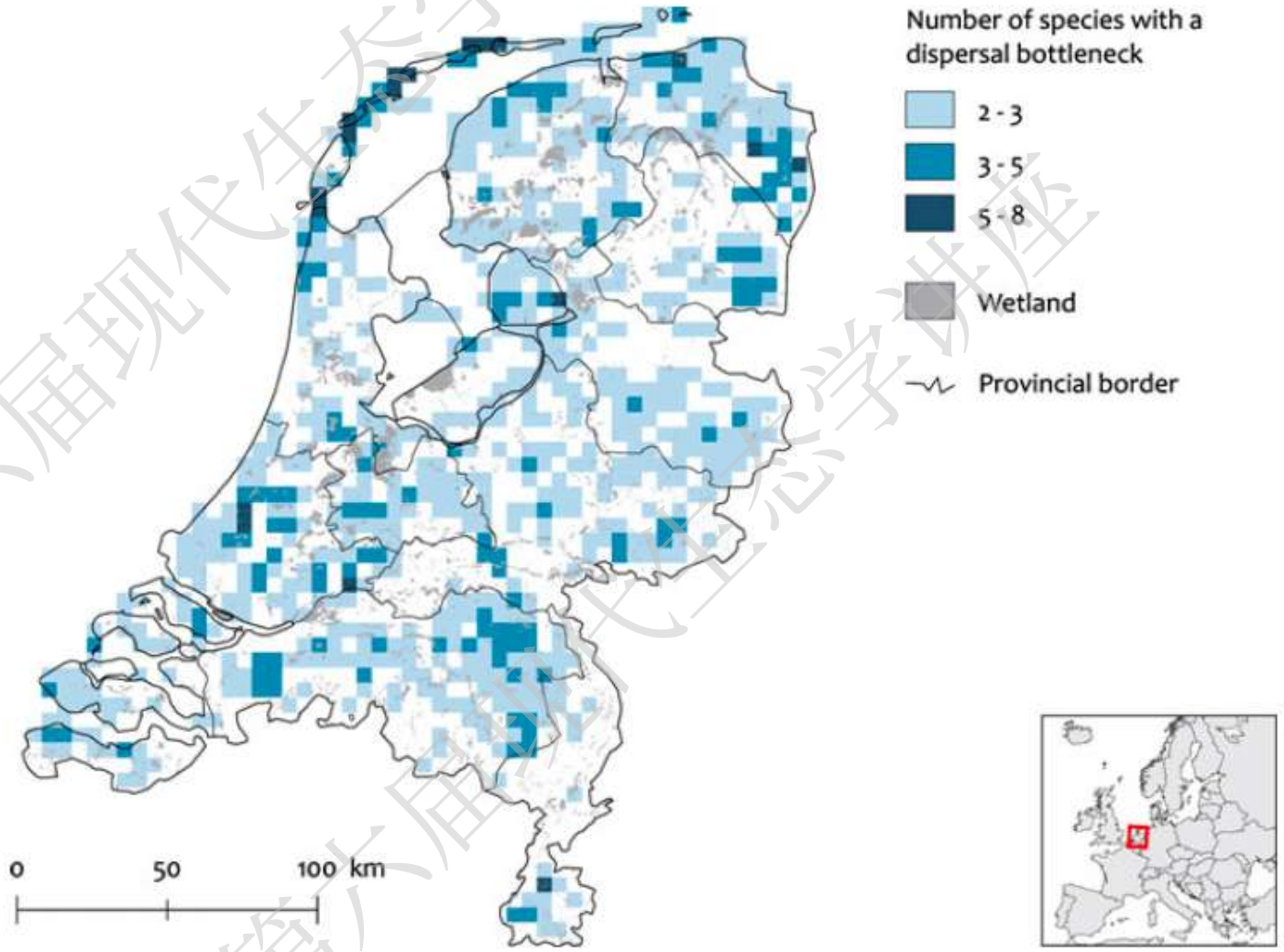


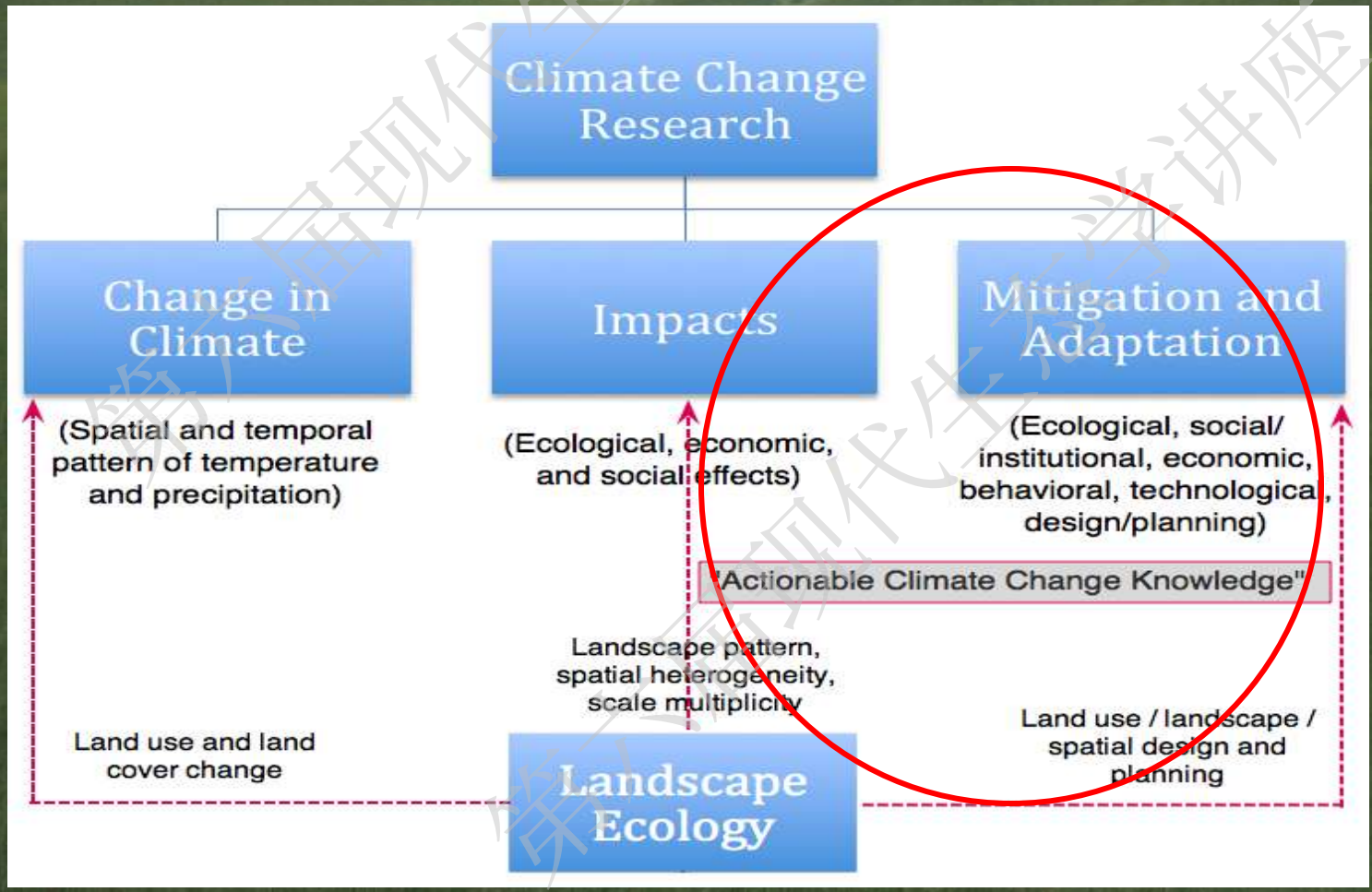
Fig. 1 The distribution of dispersal bottlenecks in the wetland habitat network for a sample of 42 target wetland species. The number of species that encounter a bottleneck is summarised in 5 × 5 km grid cells. A dispersal bottleneck occurs where the distance between suitable habitats exceeds the dispersal distance of the species

OUTLINE

1. Climate change research: Emphasis to date and priorities in future
2. Why a landscape approach for climate change research?
3. Key elements of a landscape approach
4. Concluding remarks




CONCLUDING REMARKS



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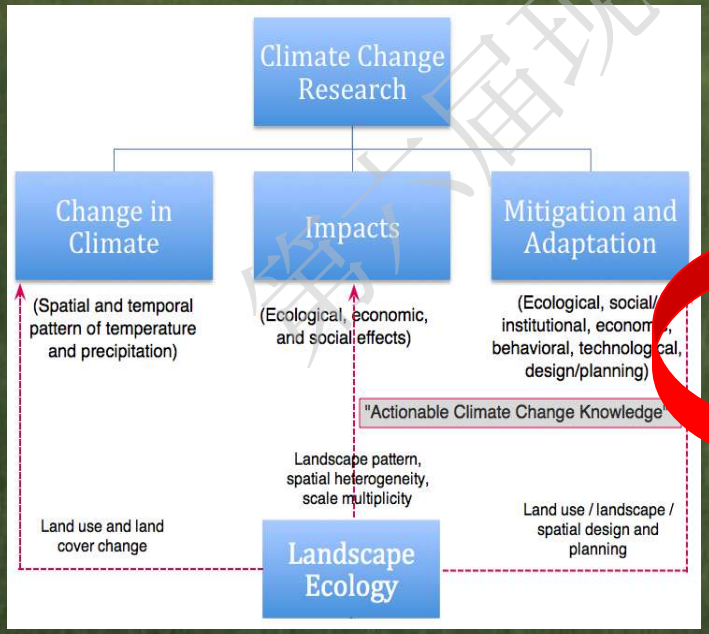

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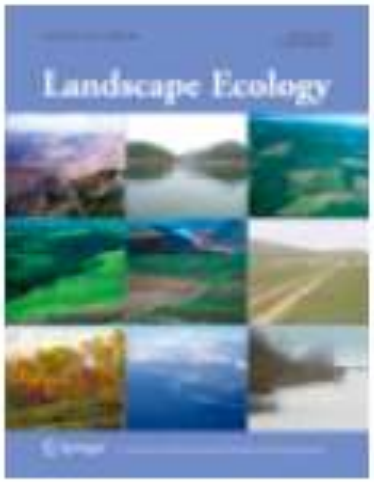

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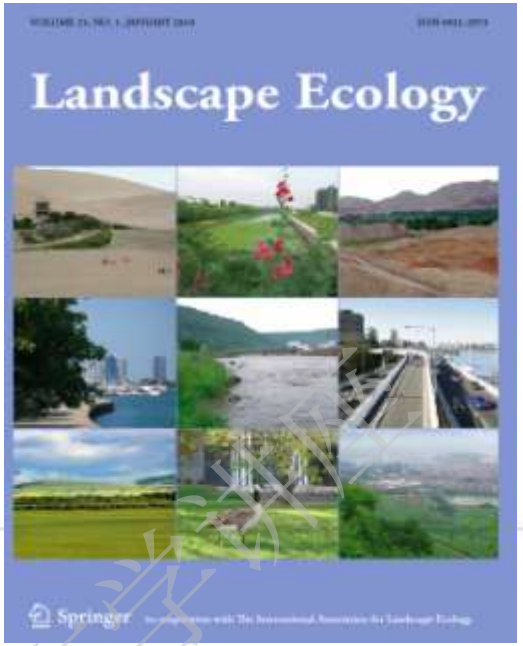
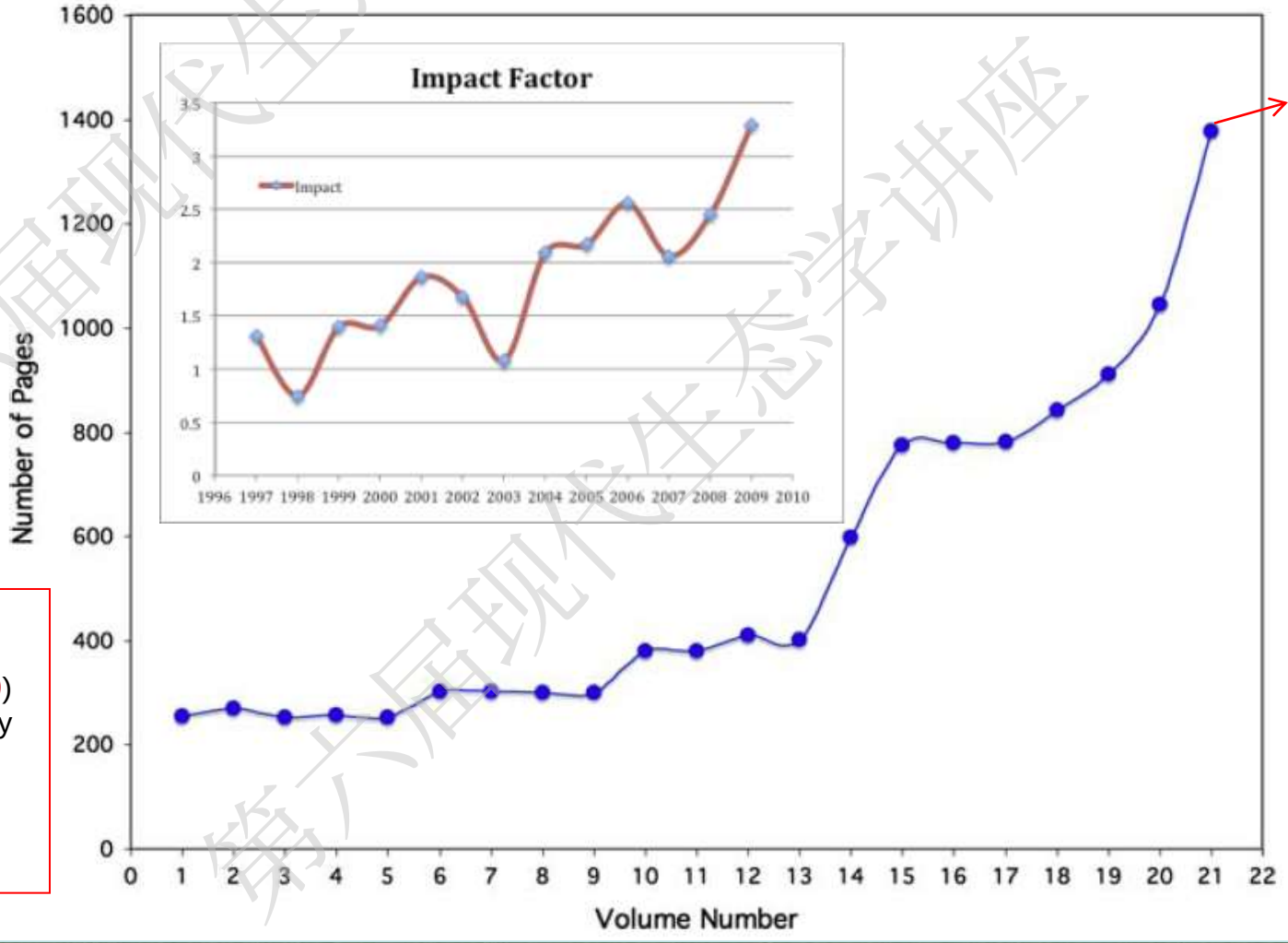


Aims and scope

Landscape Ecology is the flagship journal of landscape ecology which is a rapidly developing discipline as well as a new ecological paradigm. Focusing on highly inter- and transdisciplinary studies, *Landscape Ecology* draws together expertise from biological, geophysical, and social sciences to explore the formation, dynamics and consequences of spatial heterogeneity in natural and human-dominated landscapes. In particular the journal publishes new and innovative papers which seek to improve our understanding of the relationships between spatial patterns and ecological processes, and which provide guidance and solutions to help develop and maintain sustainable landscapes. A valuable resource for both researchers and practitioners in broad-scale ecology, biodiversity conservation, ecosystem management, and landscape planning and design, *Landscape Ecology* is currently one of the leading journals across these fields.

The number of published pages per year and impact factor of *Landscape Ecology*

Fig. 1 The number of published pages per year and impact factor of the journal, *Landscape Ecology*. The data on impact factor have become available since 1998 through Thomson Institute for Scientific Information (ISI; http://www.portal.isiknowledge.com/)



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