7 土地利用/土地覆盖变化

Box 7. Ecosystem Goods and Services

Earth System processes provide environmental goods and services that sustain life and are essential for human well-being. These "ecosystem goods and services" include potable water, fertile soil, clean air and flood mitigation. Throughout history these have largely been taken for granted, because they were not significantly affected by human activities. As a result, most economic institutions have inadequate ways of valuing ecosystem goods and services, most of which are not traded in the market place. The magnitude of the human impacts on the environment – including direct effects on biogeochemical cycles, now threatens the quality and long-term delivery of ecosystem goods and services.

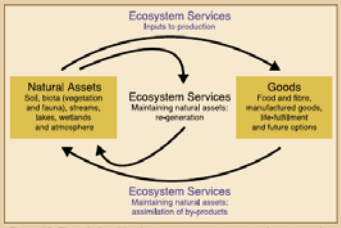


Figure 10. The relationships between ecosystem natural assets and ecosystem goods and services. From ASEC (2001).

陆地过程对物理气候的影响

– Just a decade ago, land systems were considered passive recipients of climate changes, the dynamics of which were largely driven by the ocean-atmosphere system. It is now understood that land systems are active players, not passive spectators, in climate dynamics (Steffen et al., 2004).

- Vegetation affects the physical characteristics of the land surface, which affect water evaporation and transpiration, the reflection or absorption of solar radiation, and the transfer of momentum with atmospheric flows. These processes determine water and energy exchanges with the atmosphere at its lower boundary, and can exert a major influence on climate at all scales.

- Land systems also affect the cycling of chemical elements, the most prominent and well-known being the carbon cycle, in particular the role of land systems in modulating atmospheric concentrations of the greenhouse gases carbon dioxide and methane. Land systems are a significant net sink for atmospheric carbon, but the longevity of this sink is a matter of intense debate and research. Land systems also influence climate through the production of the greenhouse gas nitrous oxide and through the emission of volatile organic compounds, which influence cloud physics and precipitation processes.

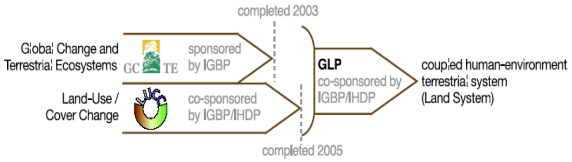
- The spatial patterns of land systems can have surprising feedbacks to climate. Various patterns of "wet" and "dry" surfaces (e.g. vegetation and dry soil) can have dramatic effects on regional precipitation patterns. The same overall ratio of wet to dry surfaces can produce significantly different rainfall patterns, depending on the spatial arrangement of the different surfaces. Vegetation rooting patterns and soil characteristics and activity are also very important for soil moisture and soil moisture uptake by plants, which influence the partitioning of water between evaporation and runoff, and hence influence the amount of energy transferred between land and the atmosphere.

– Finally, land systems can affect the climate through changes in biodiversity, because of indirect impacts on the biogeophysical and biogeochemical effects described above. For example, manipulative experiments of land system biodiversity suggest relationships between diversity and primary productivity, and diversity and nutrient cycling, both of which influence the exchange of greenhouse gases between land and the atmosphere. Biodiversity can also act as a buffer against rapid change in the structure of land systems, which could in turn could influence climate.

- As land systems are likely to change significantly in both structure and function in the coming century, feedbacks from land systems to climate are becoming increasingly important in Earth System science.
- 土地利用/覆盖变化是另一类全球变化

7.1 从LUCC到GLP

Figure 1. The genesis of GLP, emerging from previous global change projects.



土地利用／土地覆盖变化（LUCC）研究计划

- 1995年IGBP与IHDP合作实施的土地利用／土地覆盖变化（LUCC）研究计划。它以四个中心问题为导向：
  - 第一，近300年来人类利用(human use)导致的土地覆盖的变化；
  - 第二，人类土地利用发生变化的主要原因；
  - 第三，土地利用的变化在今后50年如何改变土地覆盖；
  - 第四，全球变化对土地利用与土地覆盖的影响。

- 支撑LUCC的重大科学问题包括：
  - 改进对引起人与环境关系发生正向或逆向变化（即一方面荒漠化、营养失调、缓慢的食物危机，另一方面植树造林与恢复环境）的土地利用/土地覆盖变化轨迹的认识；
  - 揭示土地利用/土地覆盖变化作为元素生物地球化学循环的源和汇的重要作用，辨识决定脆弱景观（易损的或弹性的）状态的驱动者（Coleen Vogel，1999）。

Table 1. Changes in our understanding of land-cover/land-use changes

Before	Today
land-cover conversions,	land cover modifications generally more prevalent over the recent past;
mostly of tropical forests,	of all cover types, including rangelands, open forests, peri-urban areas, wetlands;
assumed to be pristine before,	landscapes altered by humans for millennia;
permanent changes,	complex and reversible trajectories of change; land covers in a constant state of flux;
spatially homogenous,	high spatial heterogeneity ; landscape fragmentation is important ;
due to population growth,	also due to people's responses to changes in economic opportunities and policies, with biophysical and socio-economic trigger events,
mostly local,	with influences from remote urban centers, amplified or attenuated by globalization, with strong local-global interplay;
mostly expansion of agriculture,	land use intensification and diversification are common responses to pressures and opportunities ,
with impact on C cycle,	with impacts on human health, biodiversity, albedo, H_2O cycle, emissions of C, methane, NOx, etc.;
impact depending on magnitude of biophysical change,	impact depending mostly on vulnerability of people and places ;
everywhere,	spatial concentration in « hot spots » of change,

全球变化与陆地生态系统

（Global Change and Terrestrial Ecosystem，GCTE)

科学目标

- 预测气候、大气组成、土地利用变化对陆地生态系统的影响，包括农业，森林，土壤，生物多样性，等。
- 确定这些变化如何反作用于大气及物理气候系统。

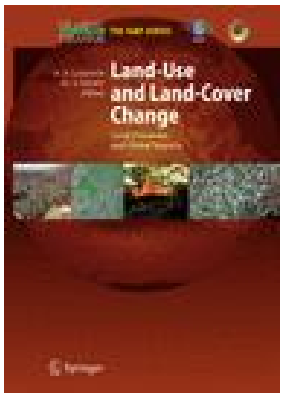
研究焦点

- 焦点 1: 生态系统生理学
- 焦点 2: 生态系统结构变化
- 焦点 3: 农业生态学和生产力系统
- 焦点 4: 生物多样性和生态系统功能

- 国际上以陆地生态系统为研究核心的全球变化研究主要集中在3个方面：
  - (1)生物地球化学循环：研究生态系统生命元素(C、N、S和P等)的全球与区域循环，特别是陆地生态系统的净第一性生产力、碳及养分循环特征，以揭示陆地生态系统的源／汇对于全球变化的贡献及其反馈作用，探讨适应与减缓全球变化的对策；
  - (2)生物地球物理动力学：研究不同植被类型的土壤－植被－大气系统的能量、水分和动量平衡，以及不同气候条件下的植被结构特征，如叶面积指数等，探讨不同植被类型对于气候变化的反应及其反馈作用；
  - (3)生物地球社会驱动力：研究区域性的土地利用格局、产业结构转变、经济生活水平及自然资源开发决策机制等对于生态系统的生物、物理、化学过程的影响机制，以加深人类活动对于全球变化贡献及其反馈作用的理解。

“BIOME300”

- PAGES与LUCC和GAIM等合作开展的综合研究项目“BIOME300”，国际上过去土地利用/土地覆盖变化研究的主要目标是改进对CE1700～1950期间全球和区域尺度上土地覆盖重建结果的认识，并且在对300年土地覆盖历史进行复原的同时研究与此相联系的全球C循环等生物地球化学循环过程（Jill J ger，1999）。



Land-Use and Land-Cover Change

Local Processes and Global Impacts
Series: Global Change - The IGBP Series
Lambin, Eric F.; Geist, Helmut J. (Eds.)
2006, XVIII, 222 p., 44 illus., 19 in colour, Hardcover
ISBN: 3-540-32201-9

PAGES: 生态系统/人的相互作用
（Ecosystem/Human Interactions）

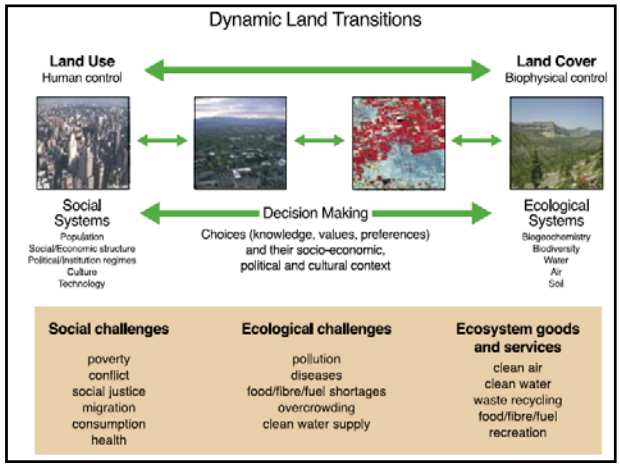
目标：
将过去人-环境相互作用和当前生态系统和流域研究成果和模型一体化。

三个子计划：
- 人类影响和陆地系统（Hite: Human Impacts on Terrestrial Ecosystems）
- 土地利用变化及其对河流生态系统的冲击（LUCIFS: Land Use Changes and Impacts on Fluvial Ecosystems）
- 人类对湖泊生态系统的影响（LIMPACS: Human Impacts on Lake Ecosystems）

全球陆地计划（Global LAND Project）

目标

判断人类-环境系统的变化，以及局部、区域和全球尺度上该系统的承受限度



The GLP goal is

- ***to measure, model and understand the coupled socio-environmental terrestrial system.***
  - This coupled socio-environmental terrestrial system is henceforth referred to as the 'land system'.
  - The GLP research goal is part of the broader efforts to understand changes in the interaction between people and their environments, and the ways these have affected, and may yet affect, the sustainability of the Earth System.
  - These broader efforts must also deliver proposals for substantive and practicable changes in socio-environmental interaction.

Major Scientific Issues

- (i) the need to move toward to a more **integrative** approach from the current disciplinary fragmentation of the land system science community;
- (ii) the need for true integration of scientific efforts to deal with the **large-scale changes** taking place in the land system;
- (iii) **methods for scaling** across physical and scientific dimensions of observational systems and methods, case studies, experiments, and model analyses; and
- (iv) **methods to incorporate the historical aspects and timescales** of social and environmental changes.

- GLP will focus on human **decision making and actions** regarding the terrestrial environment (especially Theme 1) and on **ecosystem services** (Theme 2). These topics are at the interface of the societal and the environmental domains that co-evolve through time to shape the land and landscapes.

- **Remote sensing and geographic information systems** now allow simultaneous investigations at many scales, and with respect to many variables. These help in modelling different perspectives on human activities, and thus help to elaborate models of spatial decision making. However, **these are only tools**, **the rapid development of which is not yet matched by the theory needed to determine which scales and interactions are most important.**

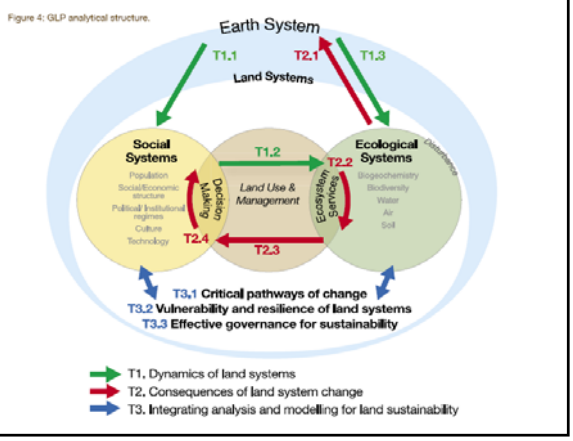
方法

- **Case Study Comparisons**
- **Using the Past to Inform the Future**：The availability of various palaeo-records provides the opportunity to investigate how choices made in the past have influenced present-day landscapes, and thus help to introduce a longer time perspective into policy-relevant land system projections.
- **Synthesising Insights in Dynamic Models**

Research Framework

- GLP will focus
  - firstly, on a clear set of questions addressing the **interface** between people, biota and natural resources of terrestrial systems,
  - and secondly, on **combining** detailed **regional** studies with a **global**, comparative perspective.

- GLP has three objectives that determine the research framework:
- (i) to **identify** the agents, structures and nature of change in coupled socio-environmental systems on land and **quantify** their effects on the coupled system;
- (ii) to **assess** how the provision of ecosystem services is affected by the changes in (i) above; and
- (iii) to **identify** the character and dynamics of vulnerable and sustainable coupled socio-environmental land systems



Theme 1: Dynamics of Land Systems

- 1.1: How do **globalisation and population change** affect regional and local land use decisions and practices?
- 1.2: How do changes in **land management decisions and practices** affect biogeochemistry,biodiversity, biophysical properties and disturbance regimes of terrestrial and freshwater ecosystems?
- 1.3: How do the atmospheric, biogeochemical and biophysical dimensions of **global change** affect ecosystem structure and function?

Theme 2: Consequences of Land System Change

- 2.1: What are the **critical feedbacks** to the coupled Earth System from ecosystem changes?
- 2.2: How do changes in ecosystem structure and functioning **affect the delivery** of ecosystem services?
- 2.3: How are ecosystem **services linked to** human well-being?
- 2.4: How do people **respond** at various scales and in different contexts to changes in ecosystem service provision?

Theme 3: Integrating Analysis and Modelling For Land Sustainability

- 3.1: What are the **critical pathways** of change in land systems?
- 3.2: How do the **vulnerability and resilience of** land systems to hazards and disturbances vary in response to changes in human-environment
- interactions?
- 3.3: Which institutions enhance **decision making and governance** for the sustainability of land systems?

- This implies a shift of emphasis from **question-driven** research to **solution-driven** policy support and testing. Research is still required to answer questions, but the choice of questions to answer is strategic, giving priority to questions that need to be answered to make scientific results policy-relevant.

7.2土地利用/土地覆盖变化概念

#陆地表面是人类生存的一个最主要空间，人类社会在其自身的长期发展中适应、改造了自然，这种适应和改造自然的痕迹在很大程度上表现为对土地的各种利用形式及陆地表面的土地覆盖变化。

土地覆盖

- **概念：**土地覆盖是指地球表面的生物物理状态，如森林、草地、湿地、作物用地、城市用地等，土地覆盖变化包括生物多样性、现实的和潜在的初级生产力、土壤质量以及径流和沉积速率中的种种变化。
- **类型：**
  - 土地覆盖换型：森林——耕地；
  - 土地覆盖渐变：土地退化

– 土地利用

- **概念：**土地利用是指人类为获取一定的经济、环境或政治福利(利益),而对土地进行保护、改造并凭借土地的某些属性进行生产性或非生产性活动的方式、过程及结果（李平）
- **类型：林地、草地、农田、工矿交通、城市、水体、裸地**

  - **农田：水田、坡地、梯田、坝地**

土地利用与土地覆盖变化的关系

- 从目前的自然界变化来看，无论是全球还是区域上的土地覆盖变化，在很大程度上是由人类的土地利用方式及其变化所引起的，因此，土地利用不是一个纯粹的自然现象。

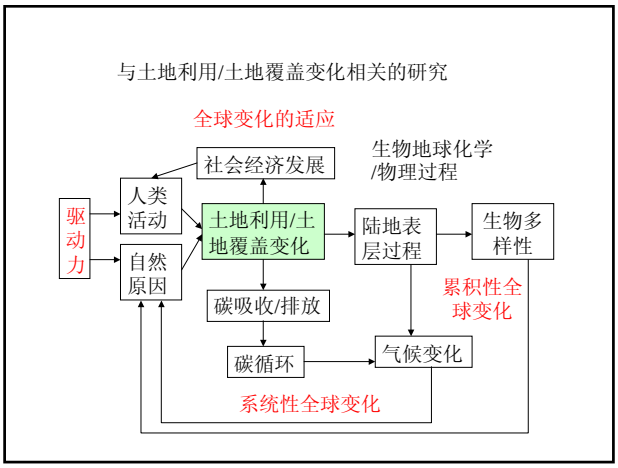
按人类影响强度分类的土地利用类型（Haber,1979;Yue T X,1999，引自历惠国，岳天祥，2000）

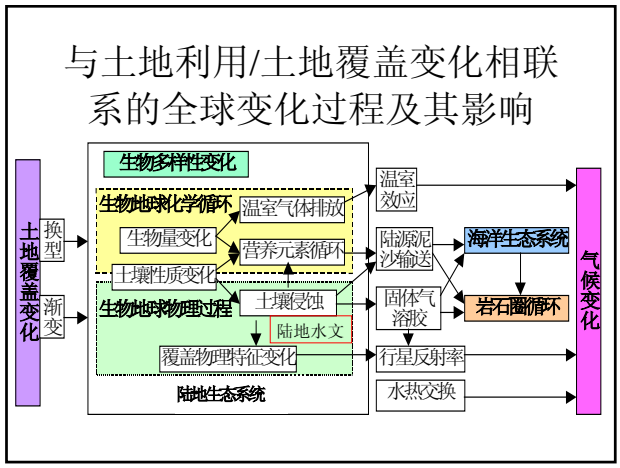
土地利用类型	注解	实例	人工影响程度
自然生态系统	没有人类的直接影响，有能力自我调节	原始森林	0.0~0.1
近自然生态系统	受人类的直接影响，有能力自我调节	国家森林公园	0.1~0.3
半自然生态系统	是人为作用的结果，有限的自我调节能力	人工林	0.3~0.5
人文生物生态系统	人类有意识的产生，完全依赖于人的管理	农地	0.5~0.7
人文技术生态系统	由技术结构和过程主宰，人类有意识地为工业、经济或文化活动而设计	工业区	0.7~1.0

土地覆盖在全球环境变化中扮演一个极其重要的角色。

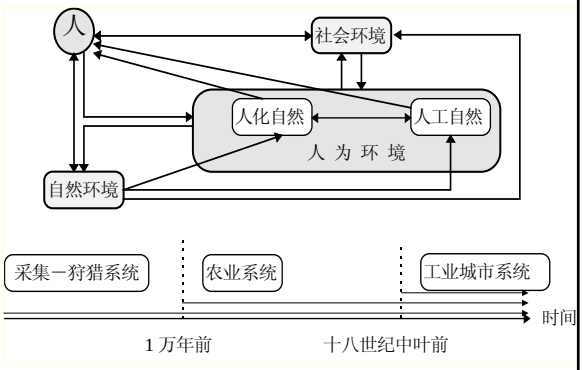
- 从地球系统的物质循环系统来看，土地覆盖是那些支撑地圈-生物圈中物质流和能量流过程的一个重要的源与汇，其中包括温室气体以及陆面的水文循环，它在相当程度上影响了地圈、生物圈及大气圈之间的物质交换过程，也是影响陆地与海洋之间物质交换的一个重要影响因素。
- 从陆地生态系统多样性来看，它的变化对地球生物多样性的变化产生极大的影响。

- 从人类社会的可持续发展及其对全球变化的响应方面来看，土地利用和土地覆盖又是人类社会生存和适应、改造自然的一个活动面，具体体现了人类社会对环境变化的各种主动和被动的反应与响应。
- 从预测全球变化未来趋势这个国家目标来看，它是全球或区域模型的重要参数，直接影响到模拟结果的可靠性和预测的准确性。

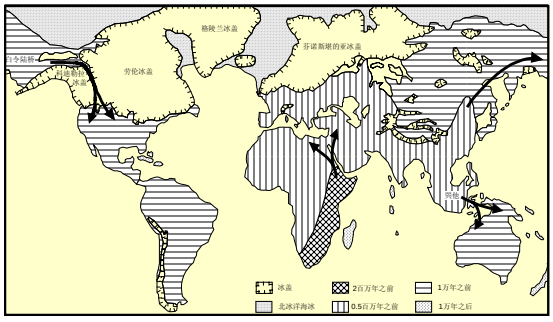




7.3 土地利用/土地覆盖变化历史

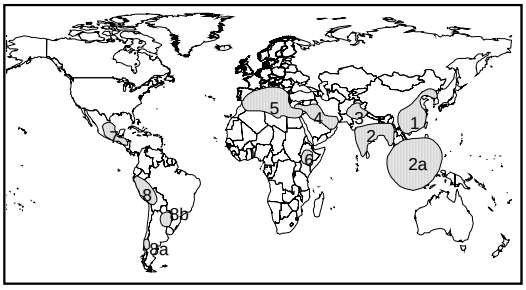


- 如果从原始人类在狩猎中使用火驱赶猎物算起，人类社会开始影响土地覆盖的历史至少应该上推至中更新世；
- 古人类的农业开发和农业技术的出现是人类利用土地的开始，从此以后人类便以其特有的力量逐渐地改变着全球陆地表面的土地覆盖。
- 进入工业社会以后，人类活动更是以前所未有的速率和规模改变着全球的土地覆盖，成为驱动全球变化的重要驱动力。

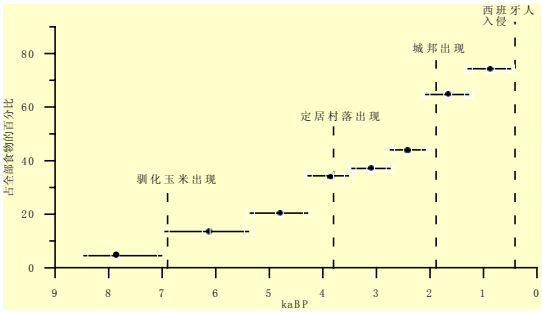


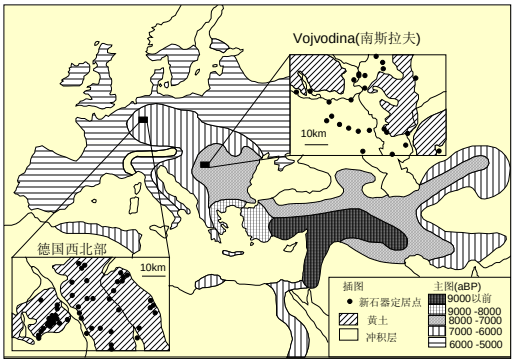
农业革命及其空间扩展

- 俄罗斯植物遗传学家Nicolai Vavilov(1926)提出，世界农业可能有8个起源中心，它们大多在欧亚大陆亚热带以南，呈带状分布（图 第七章 -32）

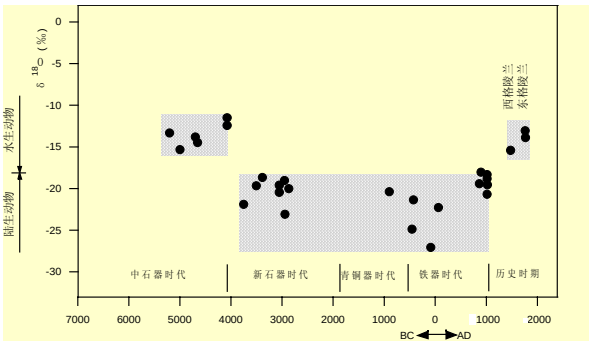


中美洲是玉米的驯化中心，其驯化的时间不晚于7kaBP





以农业从近东向欧洲的扩展过程约从9kaBP以后开始，经历了约4000年的时间才扩展到欧洲的西北端。



斯堪的那维亚人骨碳同位素的分析结果显示，农业达到该地区的时间大致在5kaBP前后。5kaBP以前的古斯堪的那维亚人象现代的格陵兰人一样，主要以海洋性食物为食，但5kaBP以来，斯堪的那维亚人突然改变为象许多欧洲人一样以农产品为食物

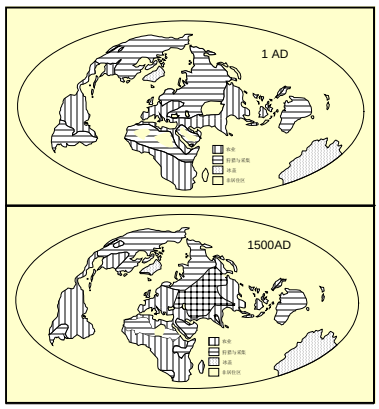
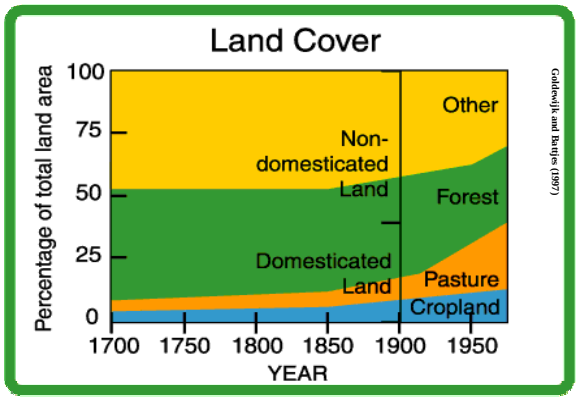


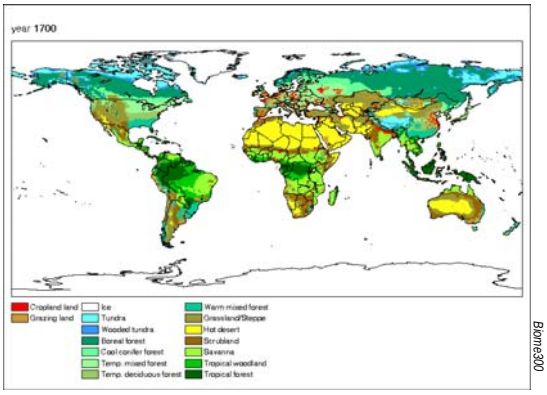
图 7-19 1AD前后和1500AD世界农业的地区分布（据Simmson,1989）

世界主要地区森林破坏概况

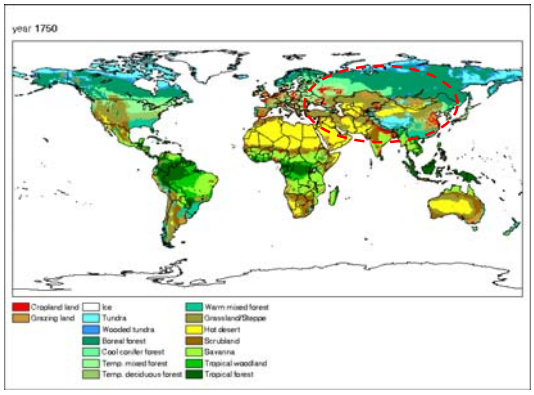
地区	5000BC	0 BC/AD	1000AD	1500AD	1800AD
欧洲	零星的	持续的，有些是永久性的	大规模地辟森林为农田	破坏速度减慢	西北欧木材出口，一定程度的恢复
地中海	零星的	大规模破坏（农田和放牧）	很少恢复		
西南亚	广泛的	大规模破坏	很少恢复		
南亚	有限的破坏	森林持续衰退			
东亚和东南亚	小范围的破坏	耕地以破坏森林为代价而大规模扩展			
北美		有限的衰退			大规模的破坏
中美和南美		森林因当地的农业和畜牧业而衰退			更多的森林因农业和引入的牲畜而破坏
大洋洲岛屿		土著文化一般保护森林和树木			森林随着欧洲的驯化动物的到来而破坏



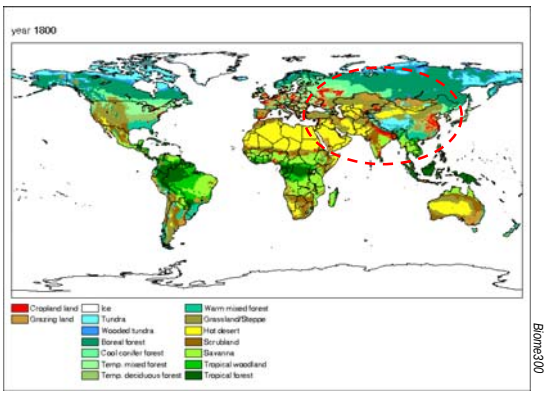
土地利用变化 Land Cover 1700



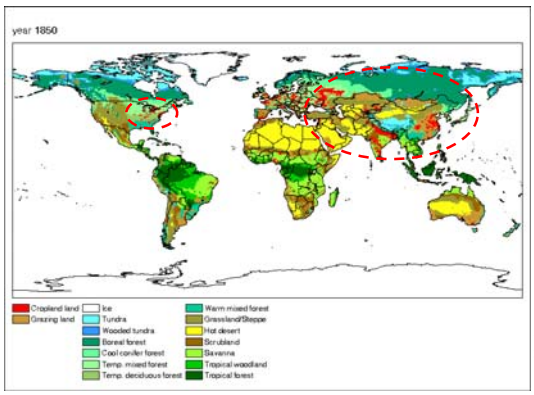
Land Cover 1750



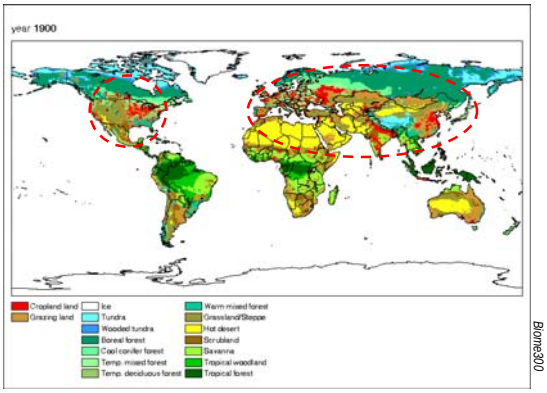
Land Cover 1800



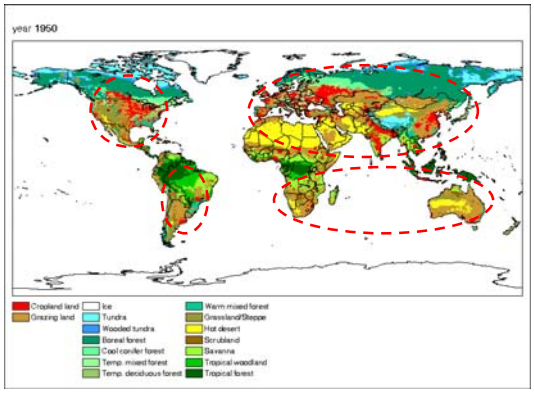
Land Cover 1850



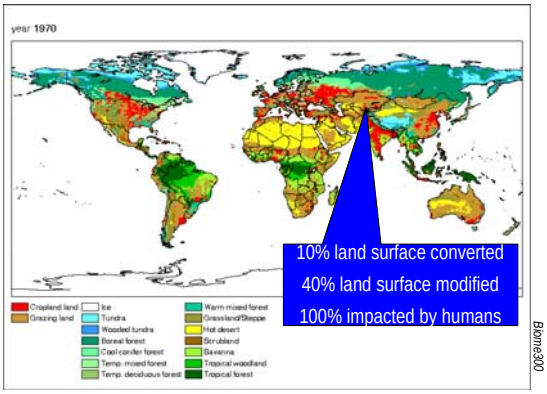
Land Cover 1900

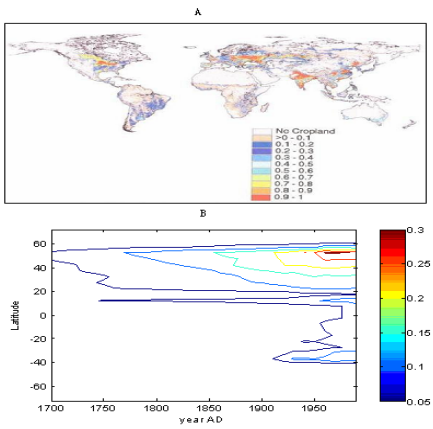


Land Cover 1950



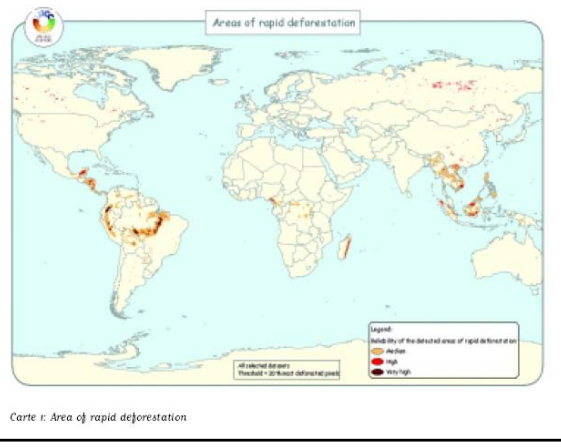
Land Cover 1970





(A)1992年的全球耕地比例分布（RF99, 原始分辨率)

(B) 1700-1992AD各纬度带森林覆盖比例的动态变化



Carte 1: Area of rapid deforestation

- 在过去300年里，农田面积增加了1200万平方公里，约为美国和墨西哥面积的总和，新增的地区主要为欧洲人殖民的北美和澳大利亚、前苏联、近年来大规模开发的热带地区。大多数耕地的增加以森林破坏为代价，同时也开垦了一部分草地和湿地。
- 同期，森林面积减少600万平方公里，略小于澳大利亚的面积；湿地的面积减少160万平方公里，相当于伊朗的面积。

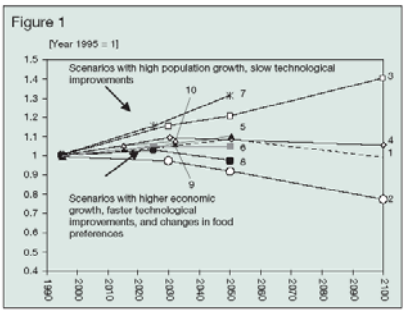


Figure 1: Global scenarios of agricultural land from 1995 to 2100. Sources: Scenarios 1, 2, 3, 4: IPCC-SRES scenarios "A1", "A2", "B1", "B2" (IPCC, 2000) computed with IMAGE model (IMAGE-Team, 2001). Scenarios 5, 6, 7, 8: Scenarios of Global Scenario Group "Market Forces", "Policy Reform", "Fortress World", "Great Transition" computed by PoleStar model (Kemp-Benedikt et al., 2002). Scenarios 9, 10: "GEO-3" scenarios (UNEP, 2004) "Markets First", "Policy First" computed with PoleStar model. "Agricultural land" comprises the land cover classes "Agricultural Land" and "Extensive Grassland" within the IPCC-SRES scenarios computed by the IMAGE model, and is the sum of "Cropland" and "Grazing Land" in the remaining scenarios.

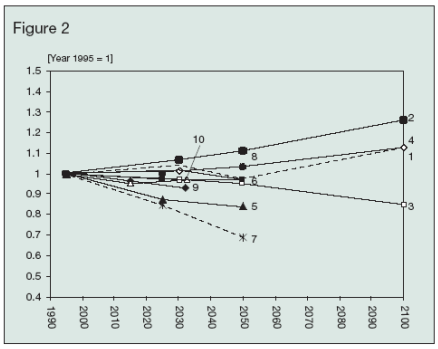
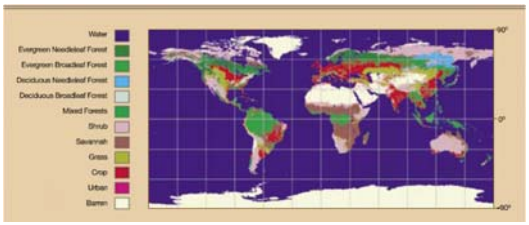


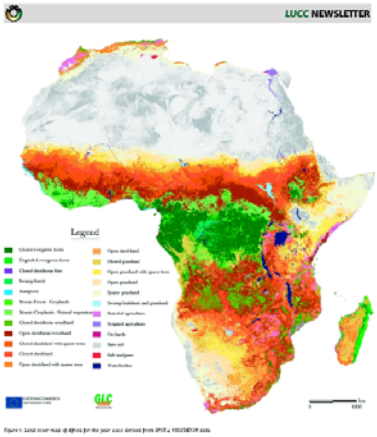
Figure 2: Global scenarios of forest land from 1995 to 2100. The key to scenario numbers is the same as in Figure 1. "Forest land" is defined as the sum of "Carbon Plantations", "Regrowth Forest", "Boreal Forest", "Cool Conifer Forest", "Temperate Mixed Forest", "Temperate Deciduous Forest", "Warm Mixed Forest", and "Tropical Forest" within the SRES scenarios computed by the IMAGE model. For the remaining scenarios forest land is the sum of "Natural Forest" and "Plantation".

- 如果除去冰盖、沙漠等人类无法居住的部分，在地球上约1.35亿km²的可居住地区中，
  - 只有近四分之一保持着自然状态；
  - 近四分之三的自然生境已遭人类改变，其中完全被改变和部分被改变的土地约各占一半。
  - 农田、城市、道路等人工景观替代自然景观是长期的人类活动所导致的大范围环境变化中最为直观的现象。



Box 13. Global Land Data Sets from Remote Sensing 土地覆盖分类12类

Recent advances in satellite engineering, biophysical algorithms and automated data processing have allowed the regular production of new global data sets of essential land variables regularly for open scientific use. The Earth Observing System, initially launched in December 1999, has now completed the fifth year of continuous global land data from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor. The MODIS Land Team now produces an annual 1 km resolution map of global land cover with 3-month change detection, 0.5 km vegetation indices with a 16-day refresh interval, 1 km Leaf Area Index with an 8-day refresh interval, and daily 1 km gross primary production and annual net primary production. Details of these and other global land data sets are available at modis-land.gsfc.nasa.gov with actual data available on-line at edcdaac.usgs.gov/modis/dataproducts.asp.



7.4土地利用/土地覆盖变化的人为驱动

土地利用变化驱动力的解释

土地利用是人与土地相互作用构成的动态系统,因而从本质上讲,土地利用的变化基本上源于三个方面的原因:

(1)在社会经济发展的不同时期,人们对土地产出(或服务)的种类或数量的需求发生改变,由此导致的土地利用变化,可称之为内生性变化或主动性变化;

(2)由于自然或人为原因导致土地的属性发生变化,或者社会群体目标发生变化,迫使人们不得不改变土地的利用方式,可称之为外生性变化或被动性变化;

(3)技术进步导致土地利用方式的改变,可称之为技术性变化。然而,无论哪种原因导致的变化,都源于土地所有者或使用者对于地用类型间边际效用的比较。

土地利用变化驱动力的层次和类型

(1)个体行为驱动　或称经济福利驱动,主要有两种类型。

1)生存型经济福利驱动;

2)最优经济福利驱动:

(2)社会行为驱动　主要有两种类型。

1)环境安全驱动,

2)食物安全驱动:

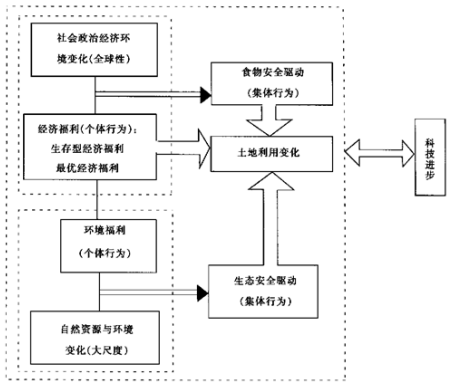
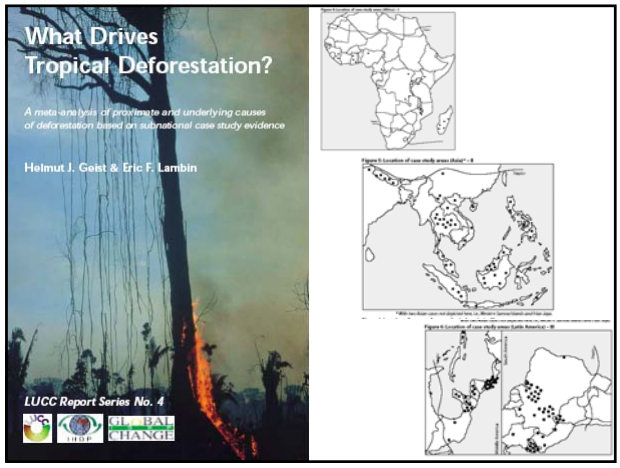
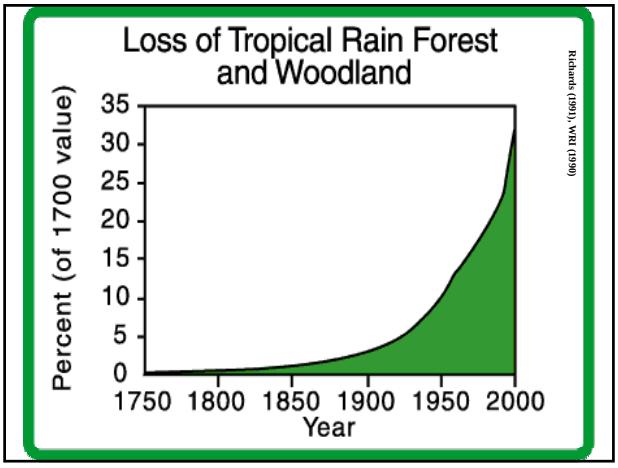


图1　土地利用变化驱动力宏观分析的逻辑框架

Fig.1 The framework on the analysis of driving forces in land-use change





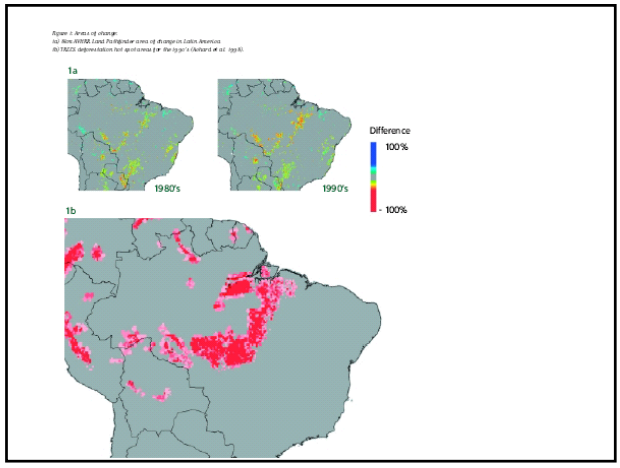
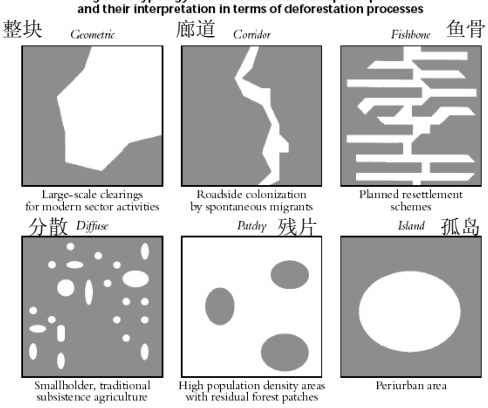


Table 5: Selected cases measured against the dynamics of forest cover change

	Losses in forest cover								Selected cases	
	1880-1990		1940-1990		1960-1980/90		1990-2000			
	10^6 km²	%	10^6 km²	%	10^6 km²	%	000 ha	%	abs.	%
Africa	0.18[1]	6	0.13[1]	8	0.06[1]	8	5264	51	19	13
Asia	1.83[2]	65	0.93[2]	60	0.41[2]	54	454[3]	4	55	36
Latin America	0.80	29	0.49	32	0.29	38	4588	45	78	51
TOTAL	2.81	100	1.55	100	0.76	100	10306	100	152	100

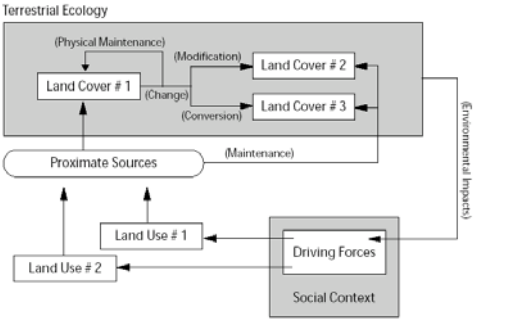
1 Tropical Africa; 2 Including China, but not Oceania; 3 Including China and Oceania.
Sources: Ramankutty and Foley (1999), pp.1018-19; FAO Global Forest Resources Assessment 2000 (1990-2000).[4]

Figure 8: Typology of the forest-nonforest spatial patterns and their interpretation in terms of deforestation processes



Source: Mertens and Lambin (1997). Spatial modelling of deforestation, p.149.

Figure 1: Links between human activities and land use and land cover



Source: Ojima et al. 1994, p. 301 (after Turner et al. 1993).

Table 1: List of variables (proximate causes) – I

Proximate causes		
Agricultural expansion (AGRO) 15	Shifting cultivation 迁徙农业2	Traditional shifting cultivation
		Colonist shifting cultivation
	Permanent cultivation 永久农业3	Subsistence (food, smallholder) agriculture
		Commercial agriculture (large-scale, smallholder)
		Agricultural (Integr. Rural) Development Projects
	Cattle ranching 牧场4	Smallholder cattle ranching (pasture creation)
		Large-scale cattle ranching (pasture creation)
		Unspecified
	Colonization, transmigration, resettlement 殖民移居定居6	Spontaneous transmigration
		Local transmigration (resettlement)
		Military transmigration (penal settlements)
		Estate settlement (agricultural, nucleus)
		Industrial forestry plantation settlement
		Unspecified

Wood extraction (WOOD) 14	Commercial wood extraction (clear-cutting, selective harvesting) 木材商业采伐5	State-run logging (selective, clear-cutting)
		Private company logging (selective, clear-cutting)
		"Growth coalition"-led logging
		Illegal (illicit, undeclared) logging
		Unspecified
	Fuelwood extraction 燃料3	Domestic uses (rural, urban)
		Industrial uses (rural, urban)
		Unspecified
	Polewood extraction 圆木3	Domestic uses (rural, urban)
		Industrial uses (rural, urban)
		Unspecified
	Charcoal production 烧碳3	Domestic uses (rural, urban)
		Industrial uses (rural, urban)
		Unspecified

Infrastructure extension (INFRA) 14	Transport infrastructure 交通3	Roads (public, military, logging, mining, etc.)
		Railroads
		Rivers & tributaries
	Market infrastructure 商业2	Public infrastructure (food markets, storage, etc.)
		Private infrastructure (sawmills, food markets, etc.)
	Public services 公共服务2	Water & sanitation facilities, electrical grids, etc.
		Unspecified
	Settlement expansion 聚落4	(Semi-)urban settlements
		Rural settlements
		Military defense villages
		Unspecified
	Private entreprise infrastructure 私人3	Hydropower development
		Oil exploration
		Mining (gold, coal, tin ore, etc.)

Table 2: List of variables (underlying causes) - II

Underlying causes (I)		
Economic factors (economic growth, change or development, commercialisation)	Market growth & commercialisation	Unspecified: rapid market growth (especially of the export-oriented sector), rise of cash economy, increasing commercialisation, incorporation into (world) economy
		Increased market accessibility (esp. of semi-urban and urban markets)
		Growth of sectoral industries (wood-related, agriculture-related, mineral-related, others)
		Lucrative foreign exchange earnings
		Growth of demand for consumer goods and services procured with cash due to a rise in well-being (unspecified, wood-related, agriculture-related, housing & transport)
	Specific economic structures	Unspecified
		Large individual (mostly) speculative gains
		Poverty & related factors (lack of income opportunities, joblessness, resource poverty, low living standard, etc.)
		Economic downturn, crisis conditions
		Indebtedness, heavy foreign debt
	Urbanization & industrialization	Urbanization: growth of urban markets
		Industrialization: rapid built-up of new basic, heavy and forest-based or –related industries
	Special economic parameters	Comparative advantages due to cheap, abundant production factors in resource extraction & use
		Special, mainly artificially low kept production conditions
		Price (value) increases (of fuel, land, cash crops)
		Price decreases (of cash crops)

Policy and institutional factors (change of political economy institutions)	Formal policies	On taxation, charges, tariffs, prices
		On credits, subsidies, licenses, concessions, (logging) bans
		On economic development (agriculture, infrastructure)
		On finance, legislation, investment, trade
		On population (migration)
		On land
		Other pro-deforestation policy (unspecified)
	Informal policies (policy climate)	Corruption, lawlessness
		Growth or development coalitions at work
		Poor performance, mismanagement
		Clientelism, vested (private) interests
		Redefinition of (forestry) policy goals
	Property rights regimes	Insecure ownership, land tenure insecurity (unspec.)
		Land race, race for property rights
		Titling, legalization, consolidation (of individual titles)
		Malfunct customary rights
		Low empowerment, deprivation, marginality
		Open access conditions

Table 3 : List of variables (underlying causes) – III

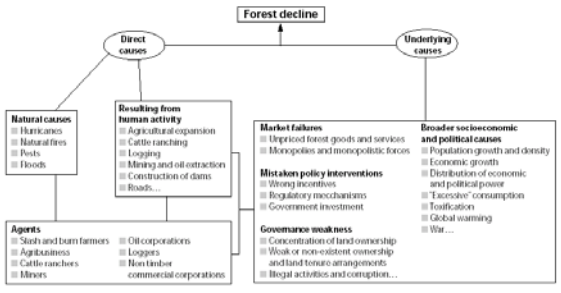
Underlying causes (II)		
Technological factors (technological change or progress)	Agro-technological change	Land-use intensification
		Land-use extensification
		Agricultural involution
		Other changes (landholding, production orientation, etc.)
	Technological applications in the wood sector	Damage & wastage due to poor logging performance
		Wastage in wood processing, poor industry performance
		Lack of cheap, technological alternatives to woodfuel; poor domestic & industrial furnace performance
	Other production factors in agriculture	Low level of technological inputs (unspecified)
		Land-related factors (landlessness, land scarcity)
		Labour –related factors (limited labour availability)
		Capital-related factors (no credits, limited irrigation)

Cultural (or socio-political) factors	Public attitudes, values, beliefs	Public unconcern or lack of (public, political) support for forest protection and sustainable use: low morale or education, frontier mentality, and dominance of other public attitudes (modernization, development, nation-building, etc.)
		Unconcern about the welfare of others and future generations, or disregard of the "sacredness of nature"
		Beliefs about how environmental conditions affect those things which individual values
	Individual and household behaviour	Unconcern by individuals about the environment as reflected in increasing levels of demands, aspirations, materials and energy consumption, commonly associated with commercialisation and increased income
		Situation-specific behaviour of actors: rent-seeking, non-profit orientation, tradition/imitation/continuation of inherited modes of resource use
Demographic factors (human population dynamics)	"Population pressure" (unspecified)	
	Population growth (unspecified)	
	Natural increment (fertility, mortality)	
	In-migration	
	Population density	
	(uneven) spatial population distribution	
	Life cycle features	

Table 4: List of variables (other factors) – IV

Other factors		
Land characteristics (biophysical environment)	Soil-related	Good/bad soil quality
	Slope & topography-related	Flat areas
		Gently sloping areas
		Lowlying areas
	Water-related	Location next to water resources
	Vegetation-related	Forest size & fragmentation
		Vegetation density (high, of marketable woods)
Biophysical drivers (triggers)	Soil-related	Soil compaction
		Soil fertility decline
		Land degradation (unspecified)
	Water-related	Drought conditions (aridity)
		Wet conditions (high humidity)
		Floods
	Vegetation-related	Weed intrusion
		Forest fires
Social trigger events	(Civil) war, rebellion, revolution, social unrest & disorder	
	Health & economic crisis conditions (e.g., epidemics, economic collapse)	
	Abrupt (& violent) population displacements (refugee movements)	
	Government policy failures (e.g., abrupt shifts in macro-policies)	

Figure 2: The causes of forest decline – I



Source: After Contreras-Hermosilla (2000), Underlying causes, CIFOR, p. 5.

Figure 7: Modes of causation in tropical deforestation case studies

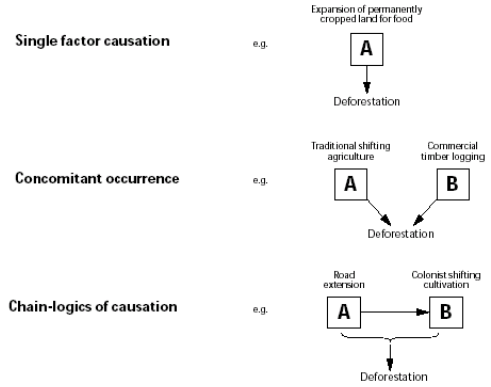


Table 17: Chain-logical connection of broad proximate causes (N=98)*

	Agricultural expansion	Wood extraction	Extension of infrastructure	Other factors[1]	Total row
Agricultural expansion	5	5	2	0	(12)
	3%	3%	1%	-	
Wood extraction	15	4	2	1	(22)
	10%	3%	1%	1%	
Extension of infrastructure	56	7	2	0	(65)
	37%	5%	1%	-	
Other factors[1]	12	2	1	6	(21)
	8%	1%	1%	4%	
Total column	(88)	(18)	(7)	(7)	(120)

* Row causes column; percentages relate to all cases of deforestation (N=152).
1 Land characteristics (or features of the biophysical environment), biophysical drivers, and social trigger events.

The infrastructure-agriculture tandem explains more than one third of all cases of deforestation **(37%),** and is a robust linkage widespread across regional cases. In 90% of these cases, the extension of road networks caused the expansion of permanently cropped land – both for food and commercial crops – and pasture for cattle, resulting in deforestation.

Table 18: Chain-logical connection of broad underlying causes (N=152)*

	POP	ECON	TECH	INST	CULT	Total (row)
Demographic Factors (POP)	3	10	16	4	0	(33)
	2%	7%	11%	3%	-	
Economic Factors (ECON)	17	33	16	23	15	(104)
	11%	22%	11%	15%	10%	
Technological Factors (TECH)	17	5	12	5	4	(43)
	11%	3%	8%	3%	3%	
Policy & institutional Factors (INST)	13	12	29	38	9	(101)
	9%	8%	19%	25%	6%	
Cultural Factors (CULT)	4	9	19	23	6	(61)
	3%	6%	13%	15%	4%	
Total (column)	(54)	(69)	(92)	(93)	(34)	(342)

* Row causes column; percentages relate to all cases of deforestation (N=152).

Table 19: Chain-logical connection of broad underlying causes driving broad proximate factors*

	Agricultural expansion	Wood extraction	Extension of infrastructure	Other factors[1]	Total row
Policy and institutional factors	98	62	29	6	(195)
	65%	41%	19%	4%	
Economic factors	58	63	33	3	(157)
	38%	41%	22%	2%	
Cultural factors	62	48	22	0	(132)
	41%	32%	15%	-	
Technological factors	65	42	3	3	(113)
	43%	28%	2%	2%	
Demographic factors	72	9	4	1	(86)
	47%	6%	3%	1%	
Total column	(355)	(224)	(91)	(13)	(683)

* Row drives column; percentages relate to all cases of deforestation (N=152).
1 Land characteristics (features of the biophysical environment), biophysical drivers, and social trigger events.

policy and institutional factors exert the highest impact upon the proximate level. They drive, in particular, agricultural expansion (in 65% of all cases), wood extraction (41%), and the expansion of infrastructure(19%).

Table 20: Chain-logical connection of broad proximate causes having a feedback upon broad underlying factors*

	Demographic factors	Economic factors	Technological factors	Policy/ institutional factors	Cultural factors	row
Agricultural expansion	0	0	1	1	1	(3)
	-	-	1%	1%	1%	
Infrastructure extension	9	18	1	1	3	(32)
	6%	12%	1%	1%	2%	
Wood extraction	3	0	0	1	3	(7)
	2%	-	-	1%	2%	
Other factors[1]	8	4	3	7	6	(28)
	5%	3%	2%	5%	4%	
Column	(20)	(22)	(5)	(10)	(13)	(70)

*Row drives column; percentages relate to all cases of deforestation (N=152).
1 Pre-disposing environmental factors (or land characteristics), biophysical drivers (or triggers), and social trigger events.

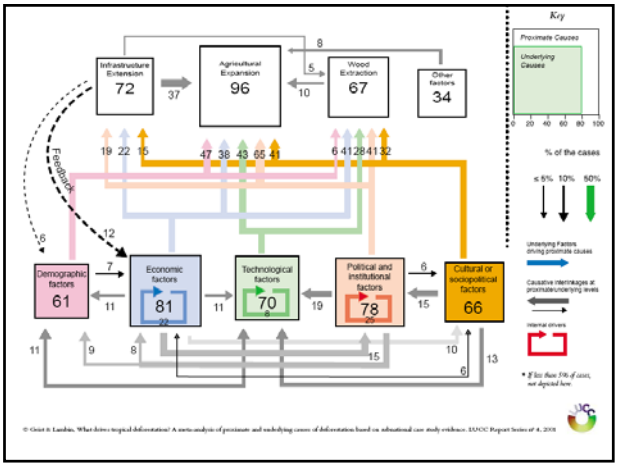


Figure 1.
A systemic view upon the causative pattern of tropical deforestation from 1850 to 1997 [3]. Neither single factor causation (e.g., population growth) nor irreducible complexity explain the pattern of tropical forest losses. Sub-national case study evidence (N=152) proves that infrastructure extension (mainly roads), agricultural expansion and wood extraction are the main causes at the proximate level. They are underlain by synergetic driver combinations, in which economic factors, institutions, policy impact and remote (cultural) influences are prominent. Other factors such as pre-disposing environmental features, biophysical forces, and social trigger events relate to one third of all deforestation cases, and feedbacks from proximate causes upon underlying factors are fairly low. However, since regional and time variations of chain-logical cause/driver connections are considerable, this poses a major challenge for the generation of realistic projections (simulations) of land-cover changes. A "universal" model of deforestation, and universal policies to control deforestation, seem to be out of reach.

1850－1997年导致热带森林砍伐的原因模式，指出土地利用变化的驱动因素是复杂的，单纯的人口压力或贫困压力不能成为世界各地土地覆被变化的主要解释；经济刺激以及政策制度因素可能起到更重要的作用

设施建设、农业发展、木材采伐是主要的直接原因

经济、体制、政策、文化是主要的间接原因

7.5 土地利用/土地覆盖变化的环境效应

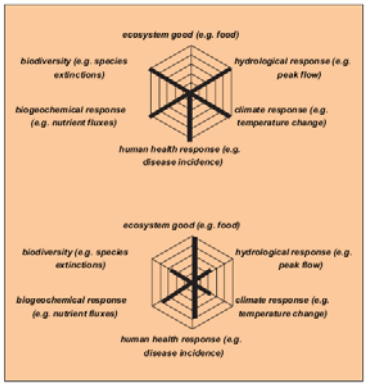


Figure: Spider diagram illustrating hypothetical trade-offs between ecosystems goods and ecosystem responses before (top) and after (bottom) land-use change (DeFries, Asner and Houghton, 2004; DeFries, Foley and Asner, 2004).

生物地球化学过程变化

- 过程机制
  - 生物量
  - 土壤化学性质
- 结果
  - 碳循环——气候变化：土地覆盖和土地利用变化在温室气体的平衡中扮演了一个重要的角色。因为其是这些气体的重要的源和汇，直接影响到这些气体的富集 (Leemans 1995)，因此，它的变化会改变大气温室气体的平衡，并因此改变全球和区域气候；
  - 营养元素循环——海洋生态系统（N富营养化）

陆地生态系统植物生物量与净初级生产力

(Houghton and Skole, 1990)

生态系统类型	面积 /$10^{12}m^2$	平均生物量 /($kgC.m^{-2}$)	C 素总储量 /pg	平均NPP /($gC.m^{-2}.a^{-1}$)	NPP 总量 /($pgC.a^{-1}$)
热带湿润森林	10.4	15.0	156.0	800	8.3
热带干旱森林	7.7	6.5	49.7	620	4.8
温带森林	9.2	8.0	73.3	650	6.0
北方森林	15.0	9.5	143.0	430	6.4
热带疏林草原	24.6	2.0	48.8	450	11.1
温带草原	15.1	3.0	43.8	320	4.9
沙漠	18.2	0.3	5.9	80	1.4
冻原	11.0	0.8	9.0	130	1.4
湿地	2.9	2.7	7.8	1300	3.8
农田	15.9	1.4	21.5	760	12.1
岩石与冰川	15.2	—	—	—	—
全球总计	**145.2**		**558.8**		**60.2**

森林生态系统变化对温室气体排放的影响

	热带	温带	寒带	全球
森林面积	32.9%	24.9%	42.1%	41.61 亿 hm^2
C 贮量	37%	13.8%	49.2%	1146Mt
其中土壤 C	～50%	62.9%	84%	39%
生长－收获	种植园 20%～50%次生林和砍伐 30%～80%			管理森林的 C 是初级森林的 30%，收获后 20 年土壤 C 降低
森林－农田	80%～90%生物量燃烧 1m 内土层中 C 减少 25%～30%			

森林生态系统管理与碳循环

- 全球森林生态系统的碳贮量约1 1 4.6Ｐｇ Ｃ
- 森林砍伐与碳循环 :热带地区种植园的森林地上生物量较自然森林低 2 0 %～ 50 % ;温带地区生产性森林的地上生物量较自然森林低 40 %～ 50 % 。次生森林和不定期砍伐森林的木本植物生物量较自然森林低 30 %～ 80 % (Ｆ Ａ Ｏ ,1 981)
- 森林收获早亦将引起固碳量的降低。平均而言 , 经过几个“生长 收获”周期后 ,人工林的碳贮量仅是未干扰立地或原始林的 30 %。

- 森林收获后土壤碳含量一直处于下降状态 ,一般需要经过 2 0～ 50年才可使土壤碳含量增加 , 但经过多个“生长 收获”长期经营森林的土壤碳贮量如何变化还不清楚
- 森林转变成农田与碳循环 :至 1 998年已有约 750× 1 0 6h m2 的森林被用作农田 ,占土地利用变化的 45% 。一般而言 ,1m深度土层内的土壤碳损失 2 5%～ 30 %,耕作层 (0～2 0 c m)损失最大 , 可达 40 %。森林用作农田后 ,土壤碳含量一直处于下降状态 ,尤其在前 5年 ,与森林砍伐类似 ,一般需经过2 0～ 50年才可使土壤碳含量增加

草地转换成农田与碳循环

- 全球的草地面积 ,包括热带草原、温带草原、冻原及高寒草原 ,约为 44. 5亿 h m2 ,碳贮量达 76 1Ｐｇ Ｃ ,其中植被占 1 0 . 6 % ,土壤则占 89. 4%
- 至 1 998年 ,全球已有约 6 6 0M h m2的草地被开垦成农田 , 占土地利用变化的近 40 %。
- 这些草地开垦成农田使得碳贮量由草地的 1 1 6ｔ Ｃ·h m-2 减少到农田的 87ｔ Ｃ·h m-2 ,亦即碳贮量损失了 1 9Ｇ ｔ (2 8.8ｔ Ｃ·h m-2);同时 ,地上生物量损失了 7.7Ｇ ｔ (2 8.8ｔ Ｃ·h m-2)。这些碳贮量的减少超过了热带森林转化为农田导致的土壤碳损失的全球平均值 2 4.5ｔ Ｃ·h m-2
- 就全球碳平均而言 ,草地开垦成农田导致 1m深度土层内的土壤碳损失 2 0 %～ 30 %,与森林被用作农田后 1m深度土层内的土壤碳损失 2 5%～ 30 %相当

其它生物圈改变

- Maltby(1992) 估计全球共有泥炭地面积3985万hm^2，每年积累碳素的总量为9850万t，固定在泥炭中的碳的总储量达4600亿t。湿地开发后，由CO_2的汇变成CO_2的源，改变了湿地碳循环模式。从工业革命到1980年，因土地利用方式改变，造成66～81亿t碳从泥炭地中释放，平均每年转化1. 820～2. 720亿t。
- 水稻田是人为甲烷气体排放的主要来源

Box 8. Urban Carbon Dioxide

Human-dominated land systems such as cities, are still significantly influenced by ecological processes such as plant and soil biogeochemistry. The Biosphere-Atmosphere Stable Isotope Network (BASIN) initiated within GCTE uses isotopic tracers to detect the influence of ecosystem processes on the atmosphere, and to determine how these processes are modified by global change.

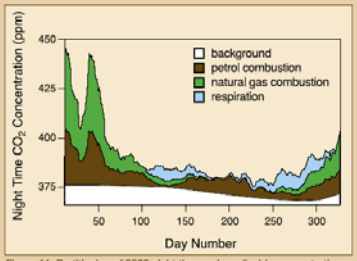


Figure 11. Partitioning of 2002 night time carbon dioxide concentrations for Salt Lake City, Utah. From Pataki et al. (2003).

Carbon isotope measurements in Salt Lake City, Utah, USA were used to separate night time carbon dioxide concentrations into a biogenic component from urban forest respiration and anthropogenic components from fossil fuel burning. The results show that despite the large influence of fossil fuel emissions on the urban atmosphere, biological processes are easily detectable. These processes contribute to the urban carbon cycle and provide a variety of services for urban residents, including carbon sequestration, removal of atmospheric pollutants, and the cooling effects of transpiration and altered albedo.

生物地球物理过程变化

- 过程机制
  - 土壤物理性质
  - 土地覆盖物理特征
- 结果
  - 土壤侵蚀—河湖沉积/大气尘埃——海洋沉积/生态系统：由于不适当的土地利用和由此形成的土地覆盖变化而引起表土层的质量退化以及土壤侵蚀的问题是许多地方面临的环境问题之一。

    ——大气尘埃物质——气候变化
  - 陆地水文过程变化
  - 地表水热交换——气候变化：土地覆盖和土地利用的方式在很大程度上决定了地表的反照率、粗糙程度以及水气通量，它们的变化可以改变区域或是全球水气和热量平衡，对区域气候及全球气候变化产生影响。

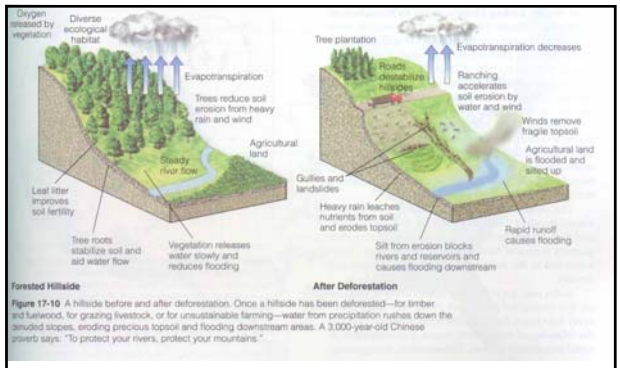
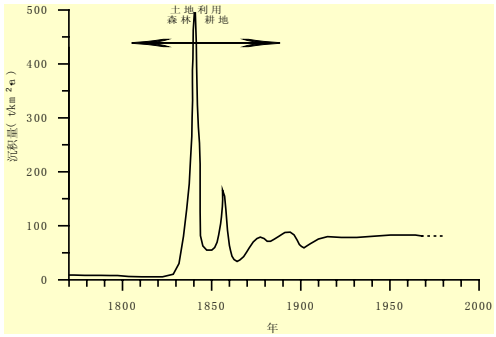
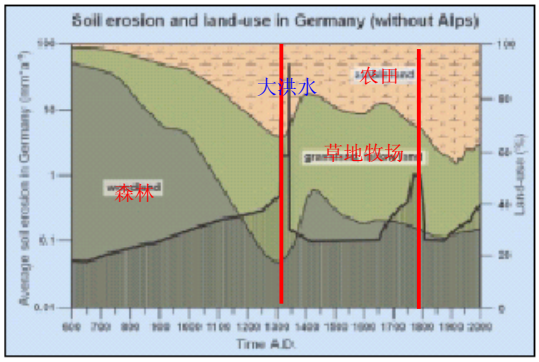


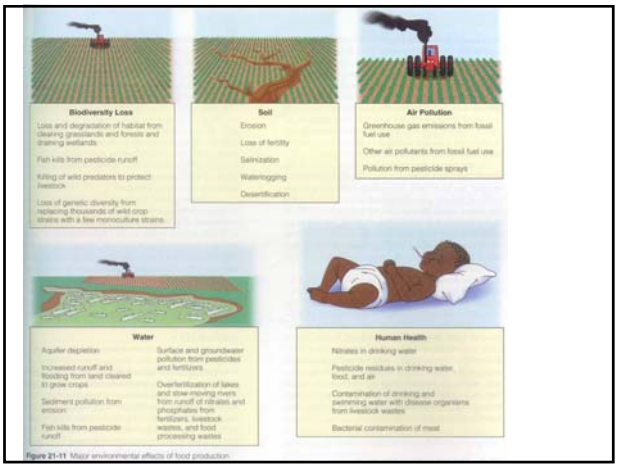
Figure 17-10 A hillside before and after deforestation. Once a hillside has been deforested—for timber and fuelwood, for grazing livestock, or for unsustainable farming—water from precipitation rushes down the denuded slopes, eroding precious topsoil and flooding downstream areas. A 3,000-year-old Chinese proverb says: "To protect your rivers, protect your mountains."





Impacts of Deforestation on Local Climate			
Surface Variable	**observed**	**Control***	**Deforested**
Evaporation (mm/d)	**3.34**	**3.12**	**2.27 (-27.2%)**
Precipitation (mm/d)	**5.26**	**6.60**	**5.26 (-20.3%)**
Soil moisture (cm)		**16.13**	**6.66 (-58.7%)**
Runoff (mm/d)	**2.76**	**3.40**	**3.00 (-11.9%)**
Net radiation (W/m^2)		**147.3**	**126.0 (-14.5%)**
Temperature (℃)	**24.0**	**23.6**	**26.0 (+2.4℃)**

- Hansen et al(1998)在对目前的气候强迫的回顾中强调了陆面覆盖变化的辐射效应，认为源于人类土地利用的植被变化的辐射强迫为-0.2±0.2W/m^2,从而使全球温度降低0.14ºC[5].
- Bonan et al(1992)认为北方大量的森林砍伐会导致北半球中高纬地区的温度显著降低，这除了森林砍伐的直接作用外，还有海冰－反照率反馈的贡献[6]；
- Henderson-Seller et al(1993)指出热带地区的森林砍伐会引起潜热通量的减少，从而对气候有增暖作用[7]。



Extent and causes of land degradation

Degradation extent	*Cause*
580 million ha	**Deforestation** — vast reserves of forests have been degraded by large-scale logging and clearance for farm and urban use. More than 220 million ha of tropical forests were destroyed during 1975–90, mainly for food production.
680 million ha	**Overgrazing** — about 20 per cent of the world's pasture and rangelands have been damaged. Recent losses have been most severe in Africa and Asia.
137 million ha	**Fuelwood consumption** — about 1 730 million m^3 of fuelwood are harvested annually from forests and plantations. Woodfuel is the primary source of energy in many developing regions.
550 million ha	**Agricultural mismanagement** — water erosion causes soil losses estimated at 25 000 million tonnes annually. Soil salinization and waterlogging affect about 40 million ha of land globally.
19.5 million ha	**Industry and urbanization** — urban growth, road construction, mining and industry are major factors in land degradation in different regions. Valuable agricultural land is often lost.

Source: FAO 1996

土地退化