Chinese Ecosystem Research Network (CERN): Achievements and Perspectives

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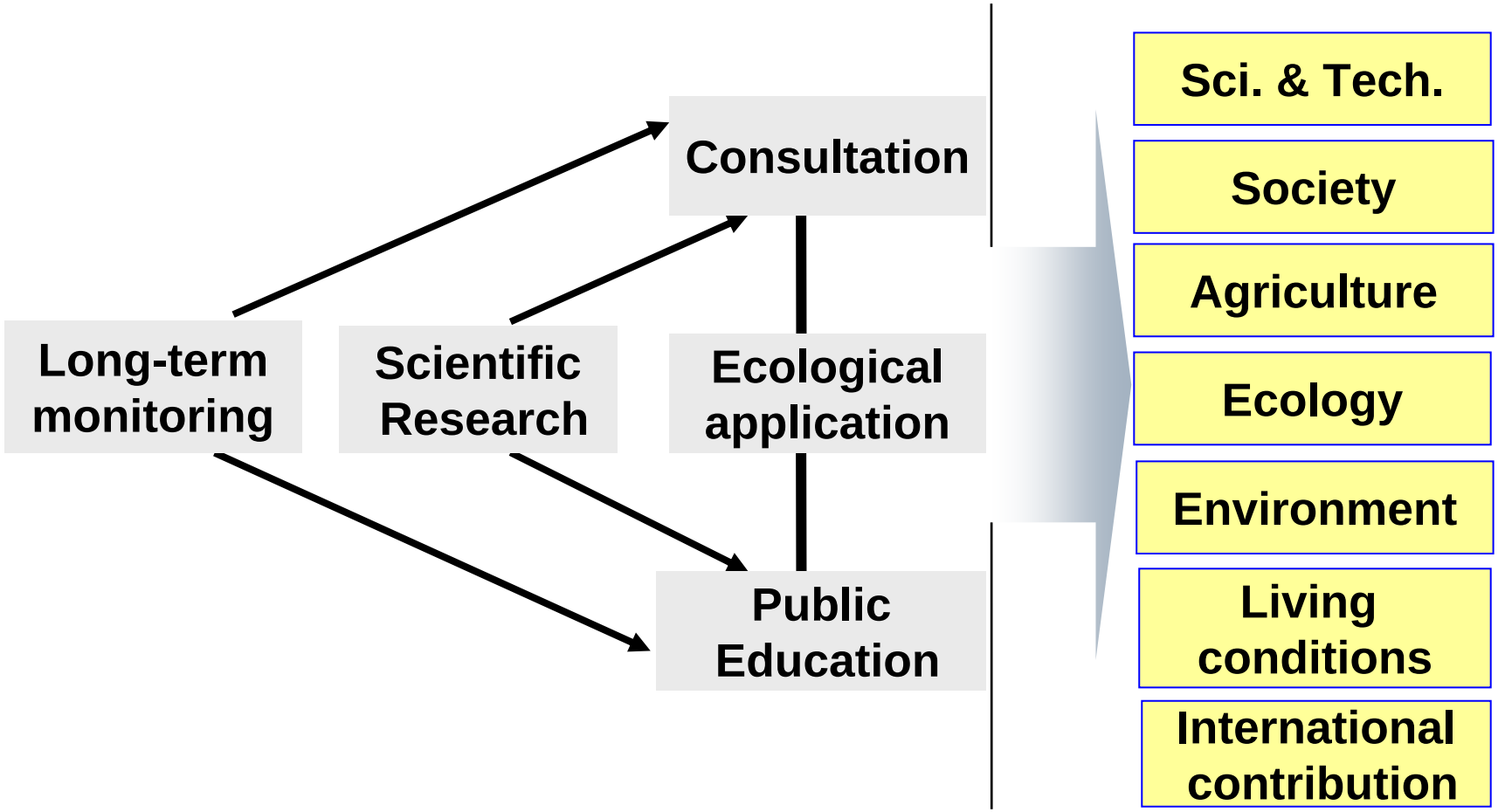
Outline

1. Missions and objectives of CERN
2. Developing history
3. Scientific achievements
4. Future directions

1.1 Missions of CERN



Core missions and objectives of CERN

✓ Ecological monitoring

To continuously measure and record changes in ecosystem structure, processes, and function

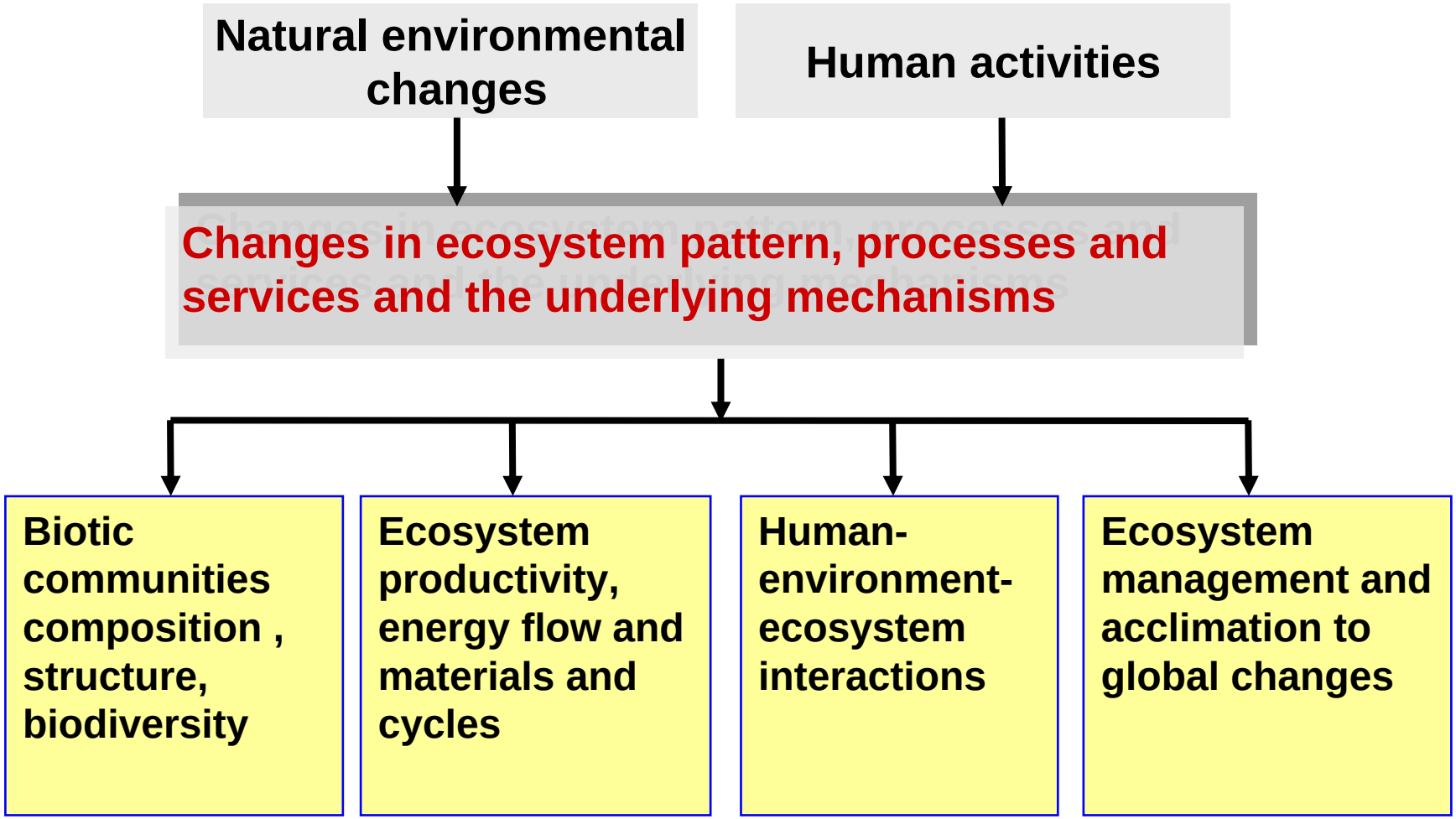
✓Ecological research

To understand ecosystem dynamics and the underlying mechanisms, in response to environmental changes and human activities

✓Ecological application

To develop and demonstrate ecological techniques and options to enhance and sustain ecosystem services

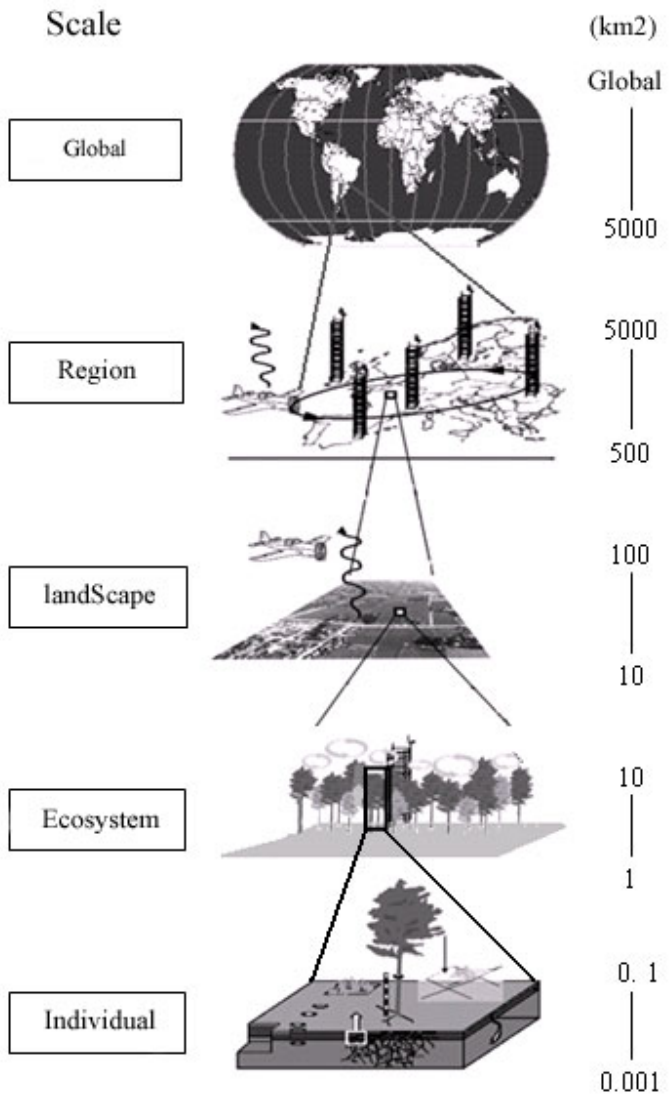
1.2 The research directions of CERN



1.3 Research thought of CERN

Research thought

- Multi-scale monitoring
- Multi-method validation
- Multi-process fusion
- Cross-scale cognition
- Cross-scale simulation



Scientific missions

Global Change Science
International environmental convention

Food production
Natural resources management
Environment protection

Ecosystem ecology
Ecosystem management

Ecophysiology
Biologic resource improvement

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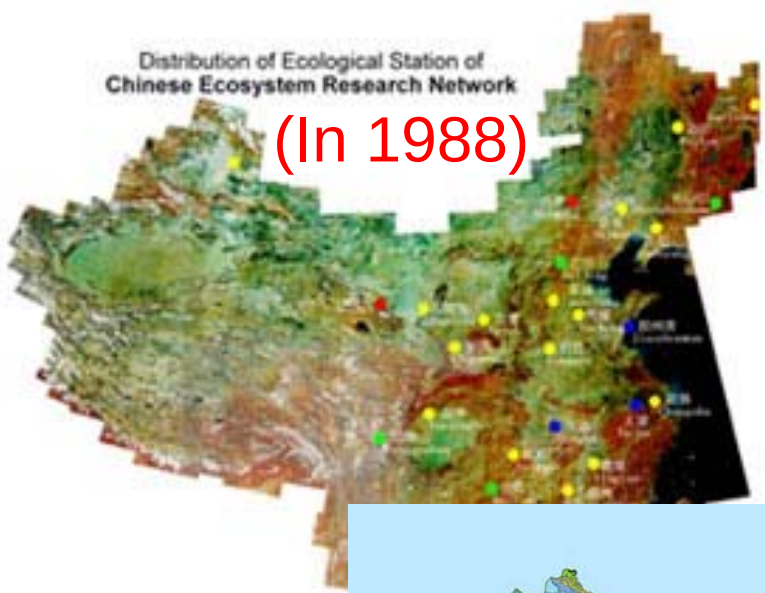
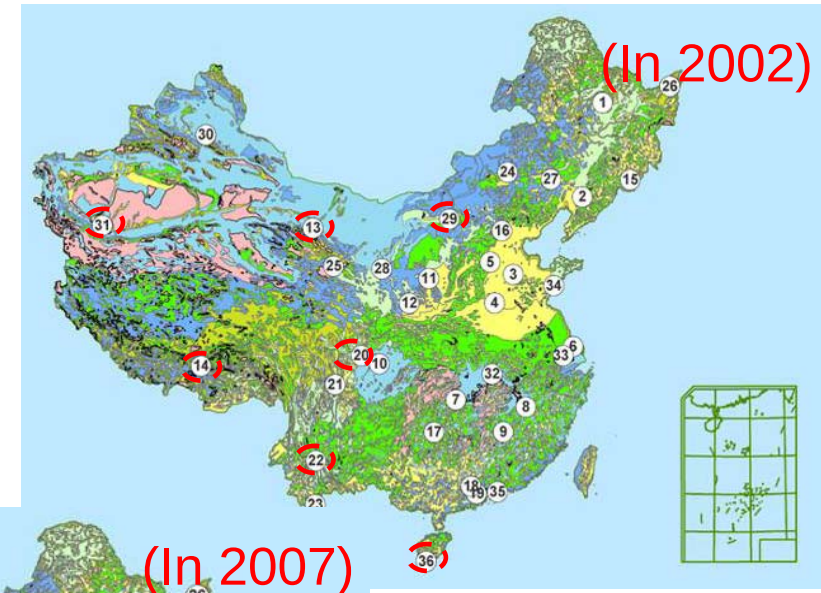
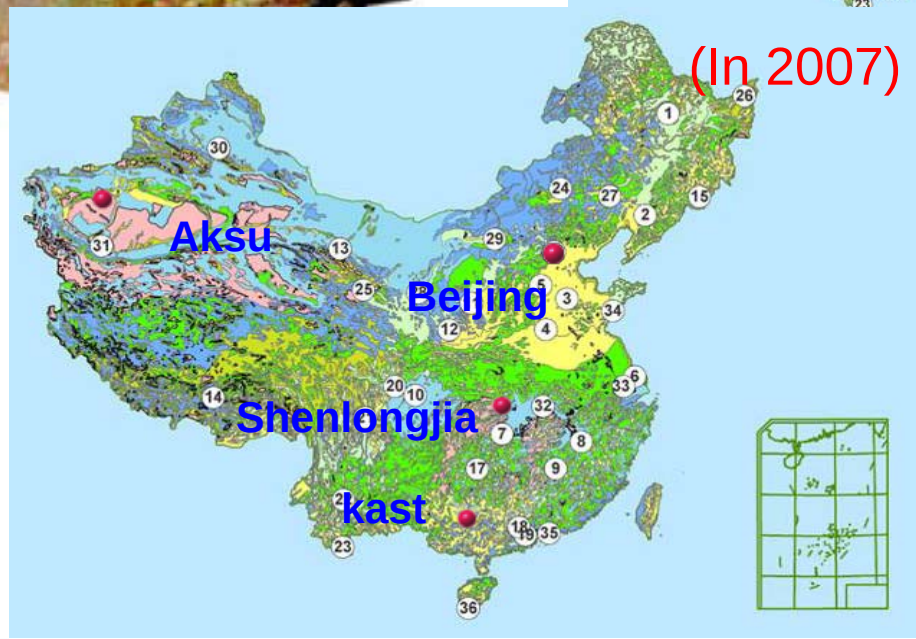
2.1 Historical development of CERN

- ✓ 1988: construction preparing of CERN, including 29 stations, 5 sub-centers and 1 synthesis research center
- ✓ 2002: phase II construction of CERN, 36 stations including 7 new stations; establishment of ChinaFLUX based on CERN
- ✓ 2005: establishment of National Ecosystem Network of China(CNEN) with 51 stations including 33 stations of CERN; establishment of synthesis research center of CNEN
- ✓ 2006: phase III construction of CERN, developing into 40 stations; constructing regional core station; special observation and control experiments

Three development phases of CERN

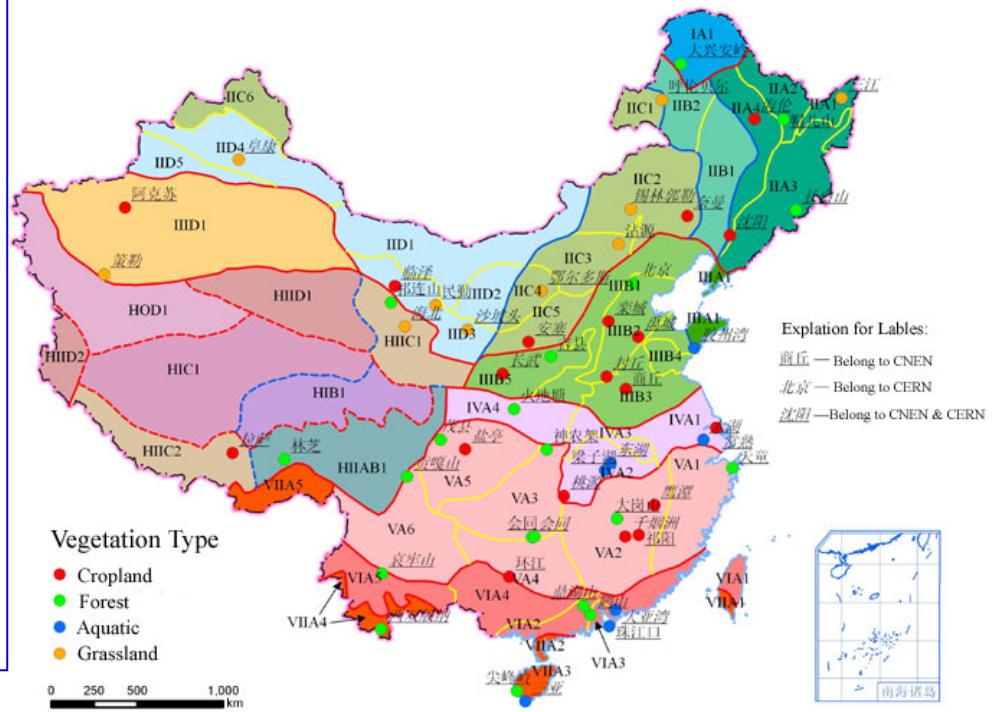




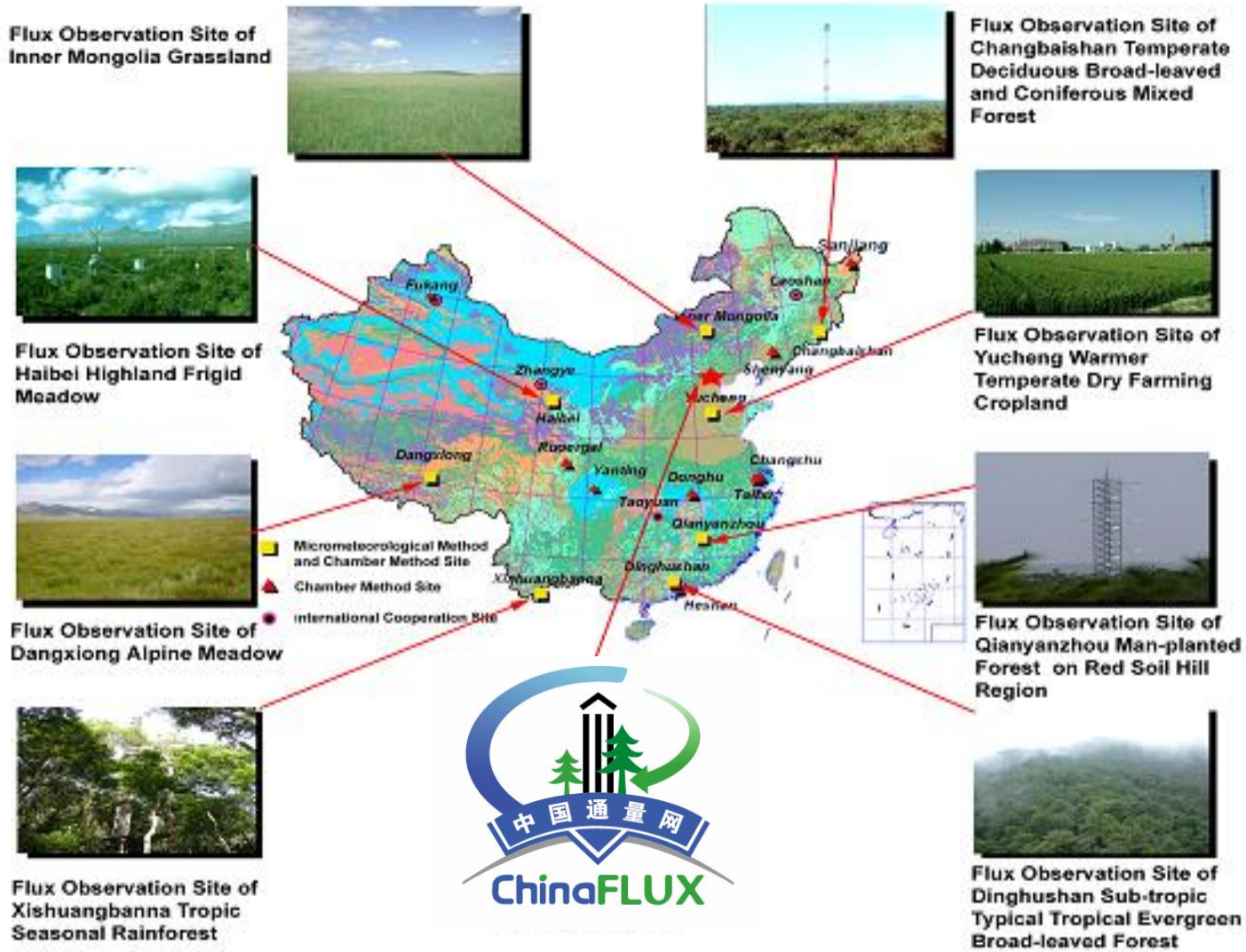


National Ecosystem Network of China（CNEN）

- ✓51 stations including
- Cropland :18
- Forest :17
- Grassland :6
- Desert :4
- Aquatic :6
- ✓Synthesis research center
- ✓Germplasm resources
- ✓Soil fertility network
- ✓ChinaFLUX

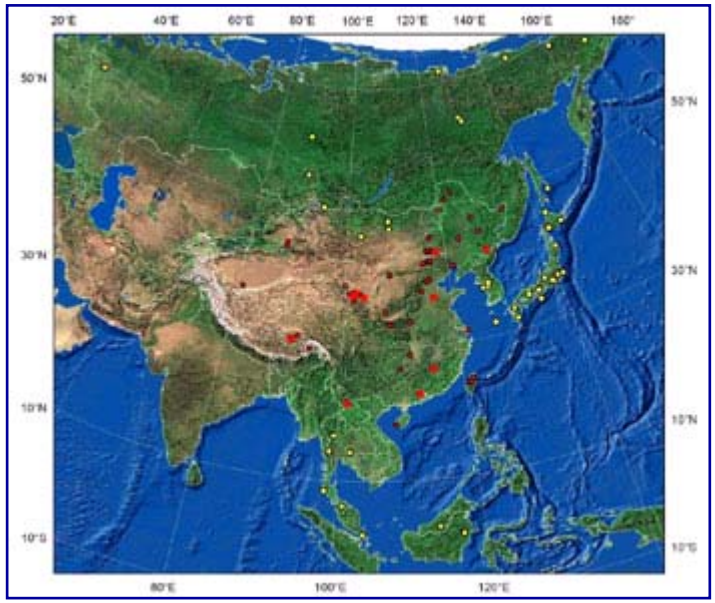


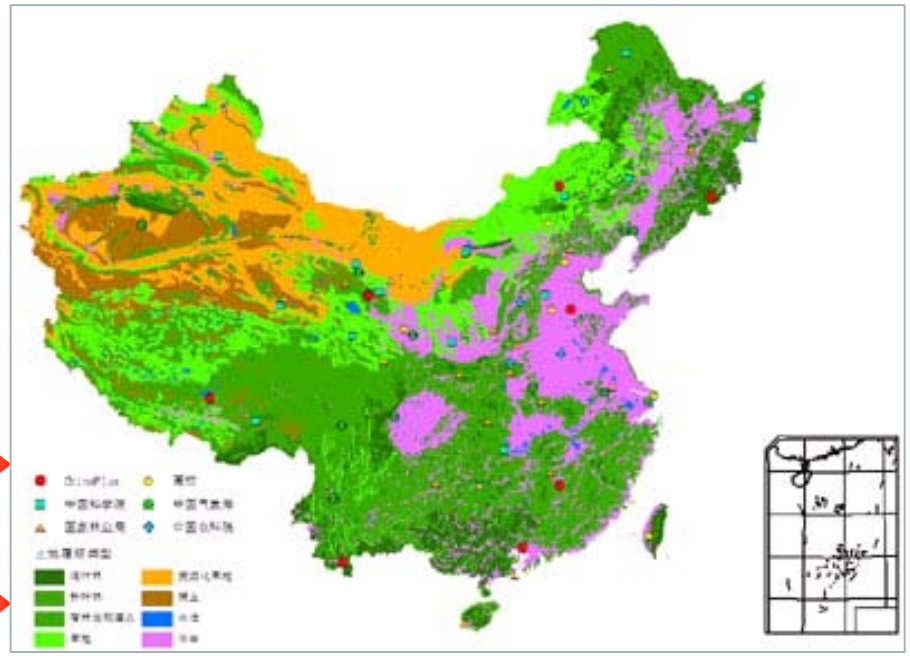
2.2 ChinaFLUX network based on CERN



10 ecosystems with eddy covariance flux measurements

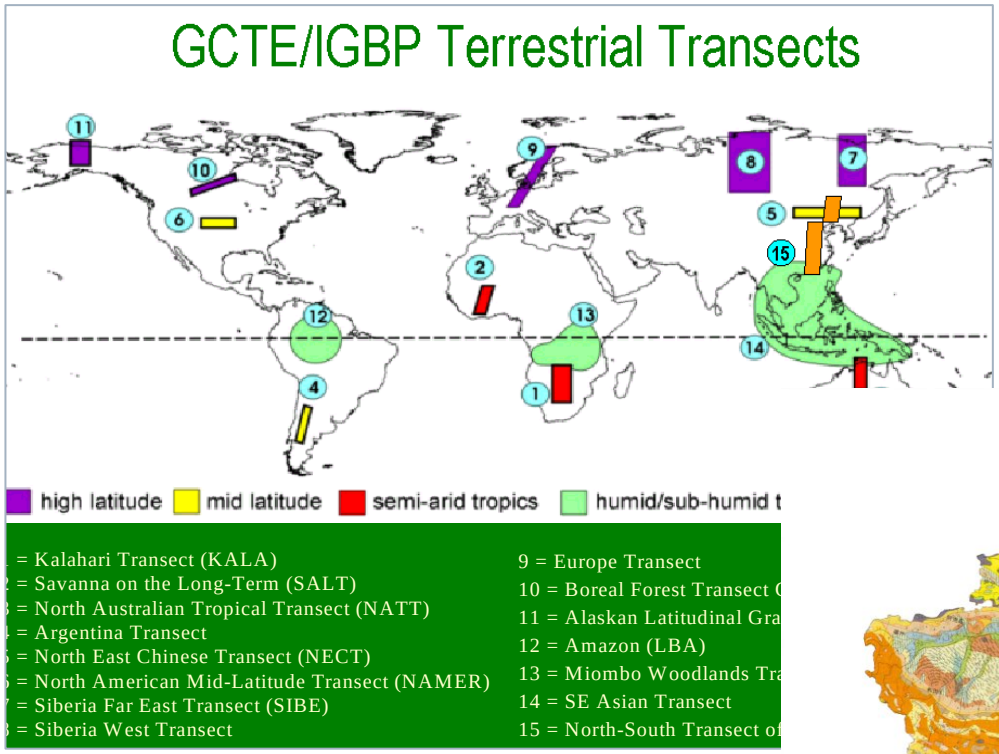
ChinaFLUX network based on CNEN

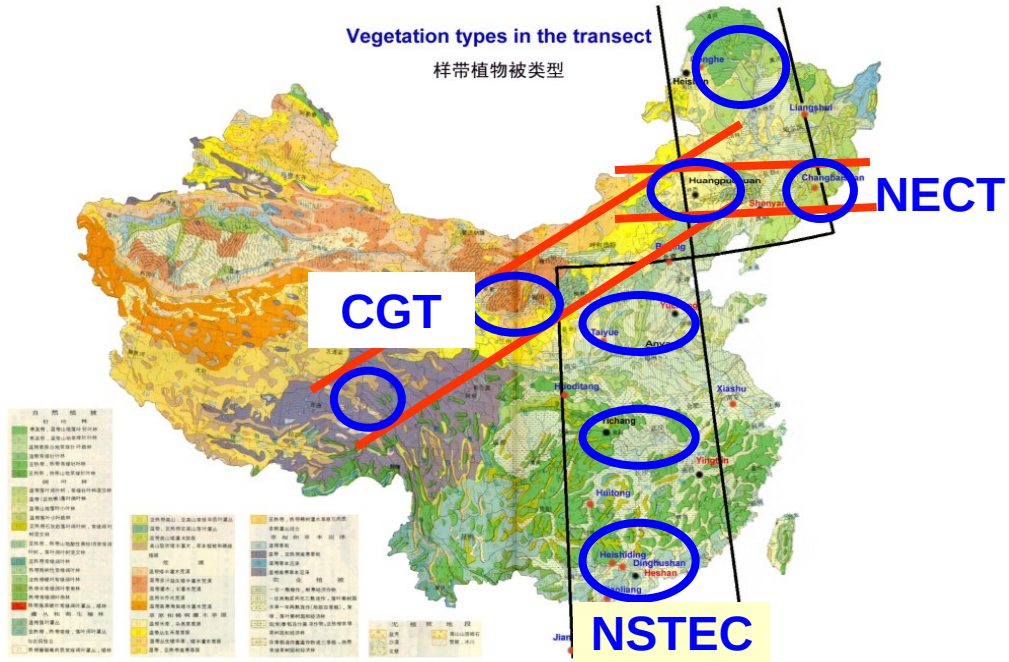




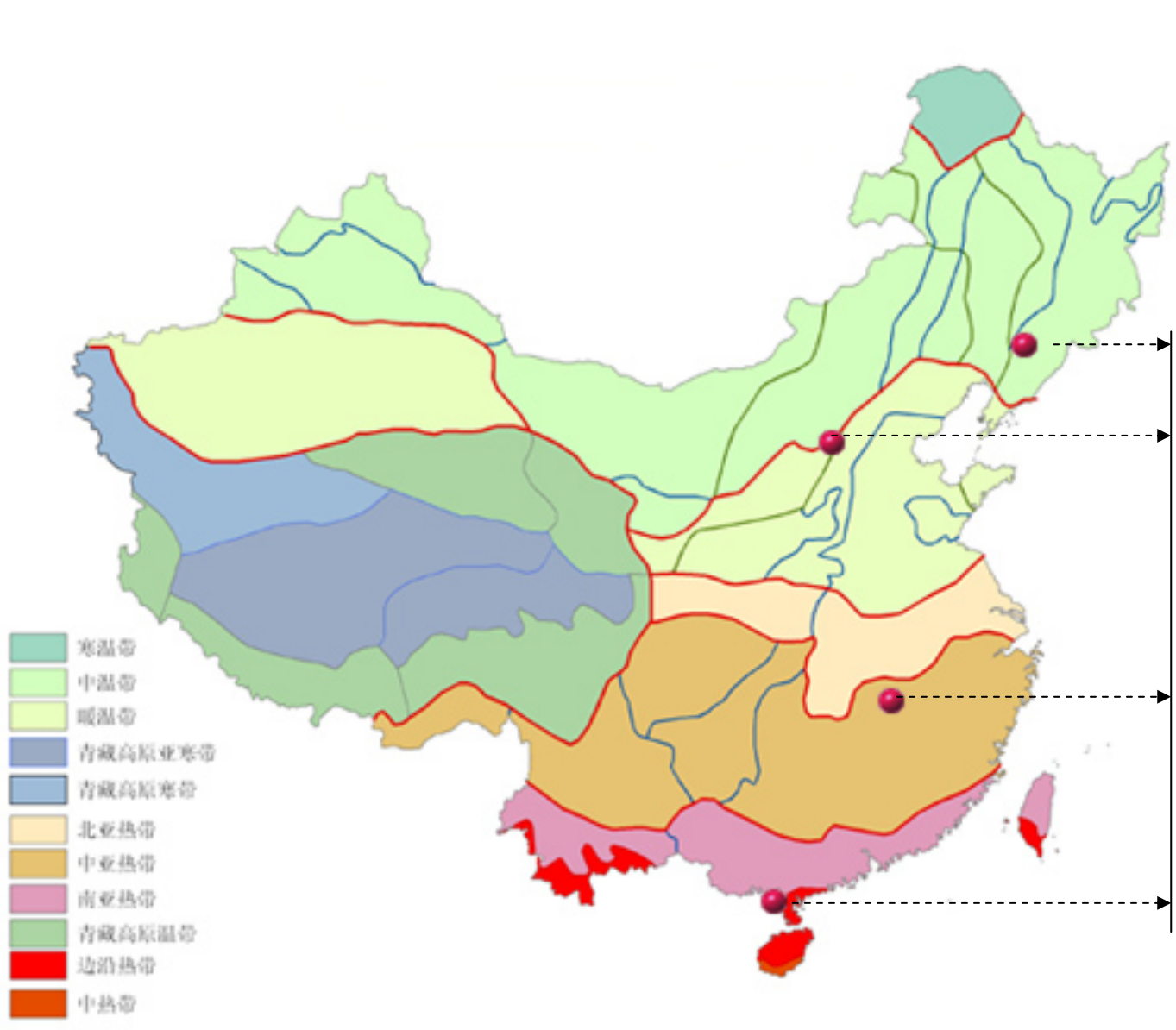
- ✓ based on CNEN
- ✓ 35 stations including 50 ecosystems
- ✓ 3-5 super stations
- ✓ Observation of C,N and H_2O

2.3 Terrestrial Transects based on CERN





2.3 Experimental platform for biodiversity and ecosystem function research

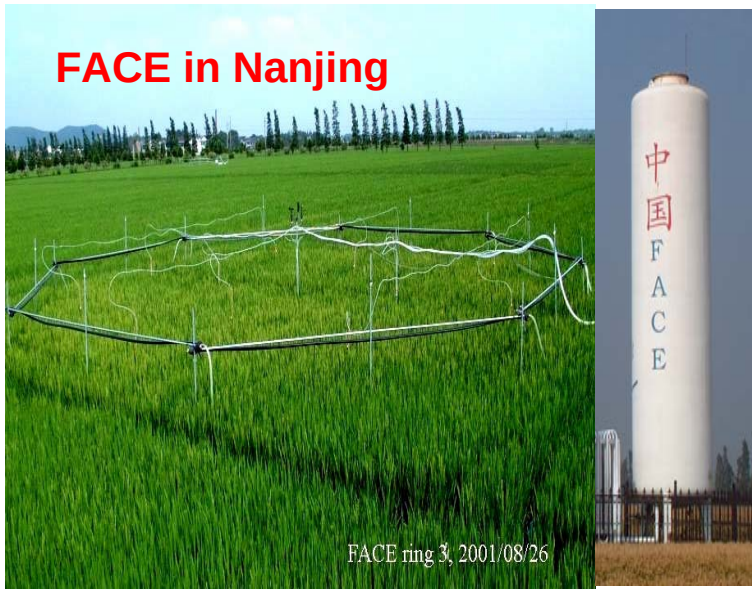


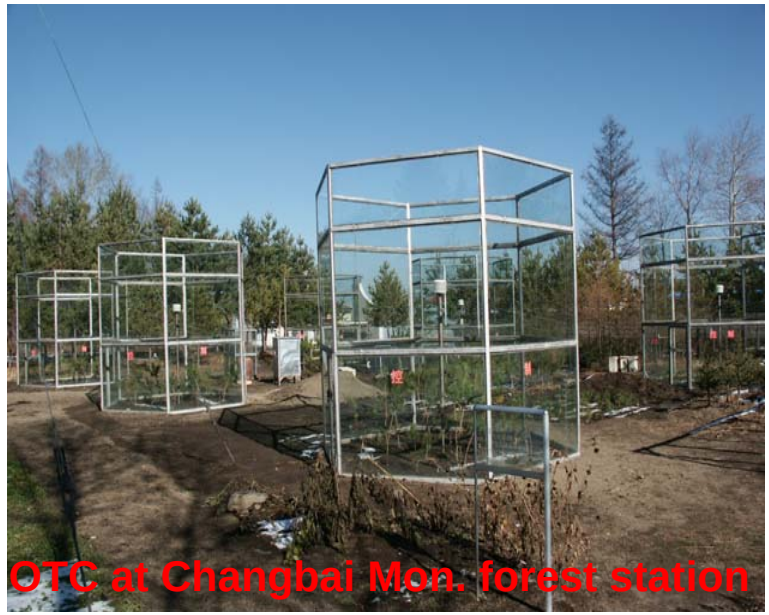
Large sample plot for biodiversity

2.4 Control experiment for studying responses of ecosystem to global change

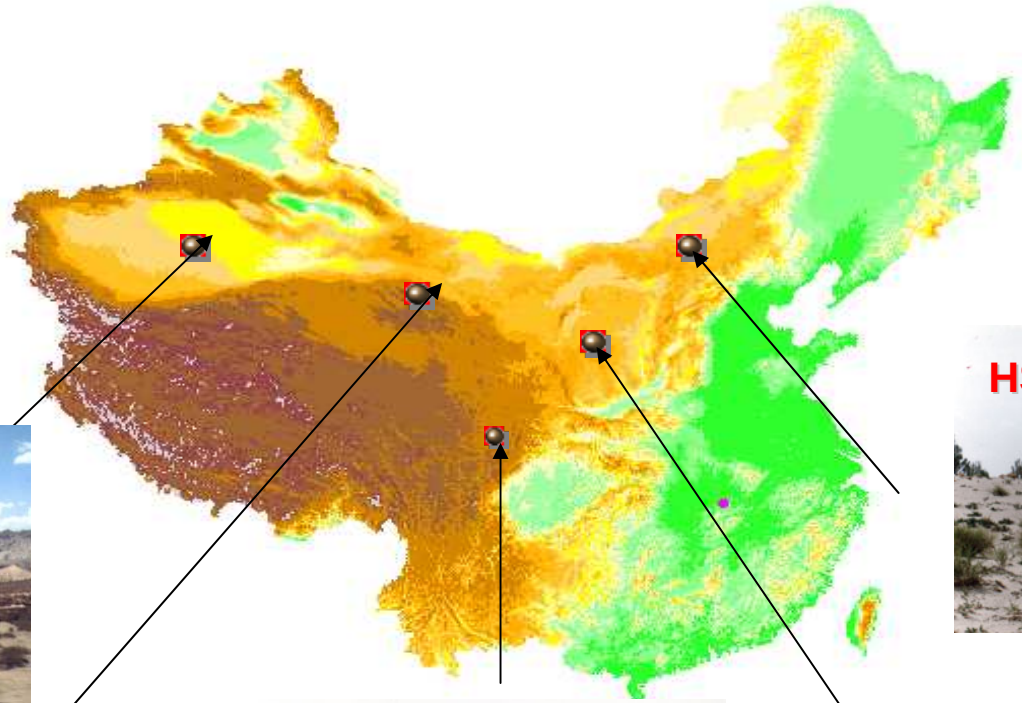
OTC at Inner Mongolia grassland station

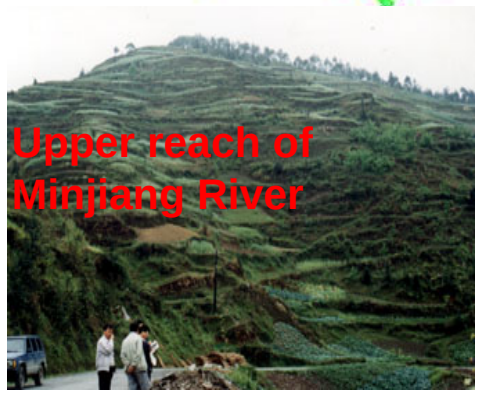
FACE in Nanjing





2.5 Research platform for demonstration of ecosystem restoration in western China





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3. Scientific achievements of CERN

3.1 Ecological and environmental change in China

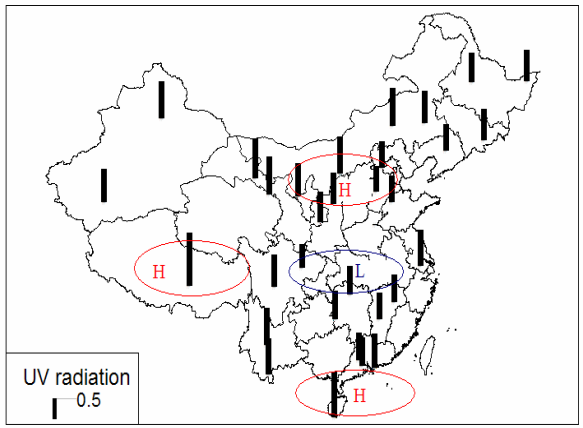
3.2 Temporal and spatial pattern of terrestrial ecosystem carbon budget in China

3.3 Ecosystem structure and function

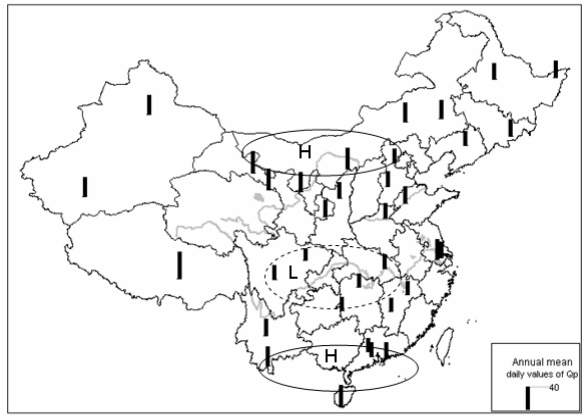
3.4 Ecosystem restoration and management

3.5 Ecological information technology & data management

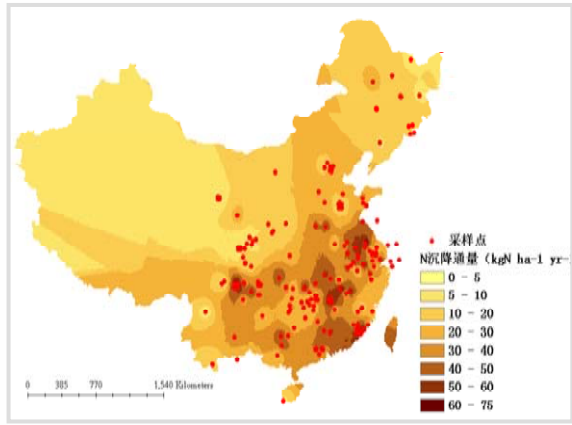
3.1 Environmental change in China: Atmosphere



Spatial pattern of UV-radiation



Spatial pattern of PAR



Spatial pattern of atmospheric N deposition

✓Atmospheric N deposition and aerosol optical thickness significantly increased

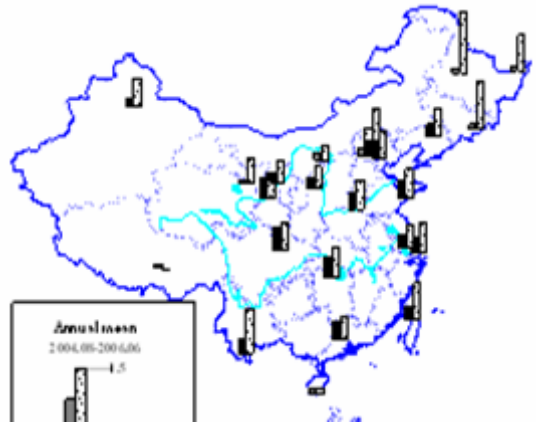
✓Pronounced spatial variation in PAR and UV

Source:

Synthesis research center, CERN;

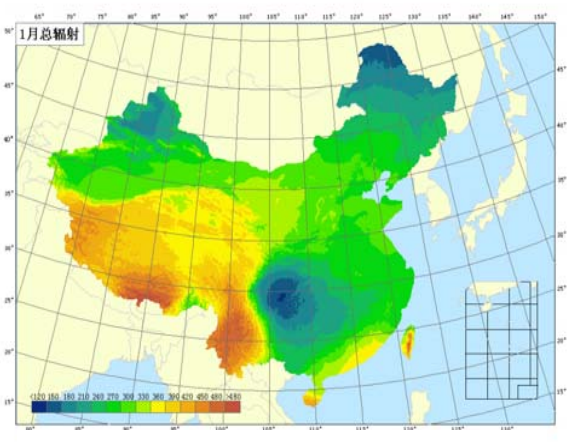
Xin et al., JGR, 2007

Hu et al., Atmospheric Environment, 2007

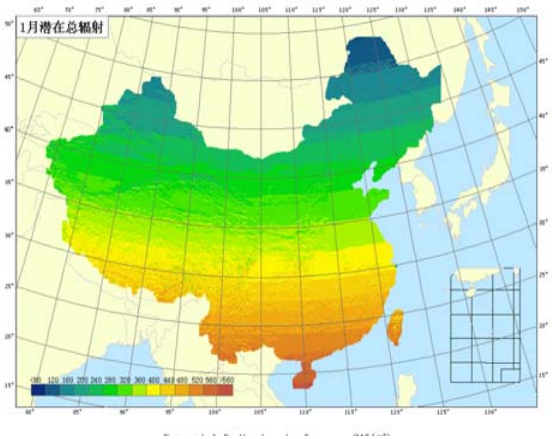


Spatial pattern of aerosol optical thickness

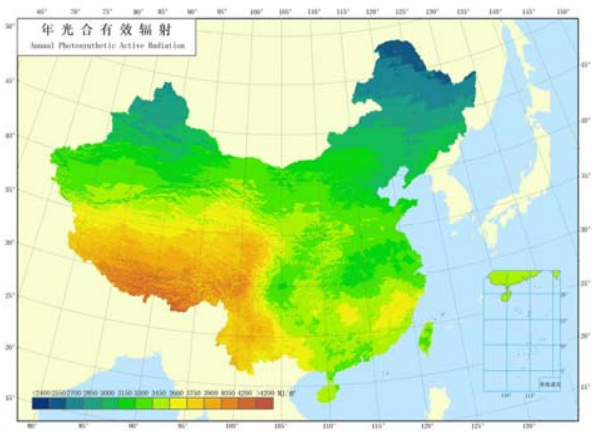
Temporal and spatial pattern of radiation in China



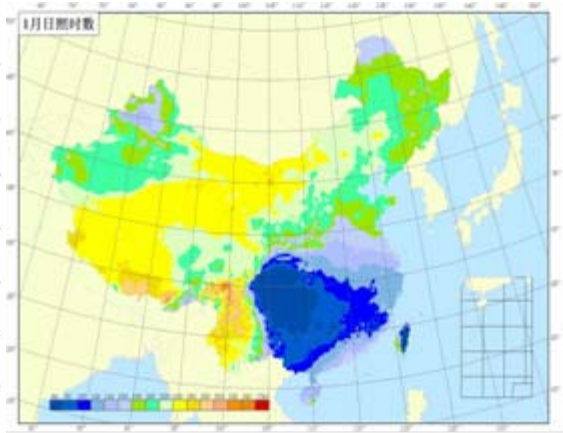
Radiation



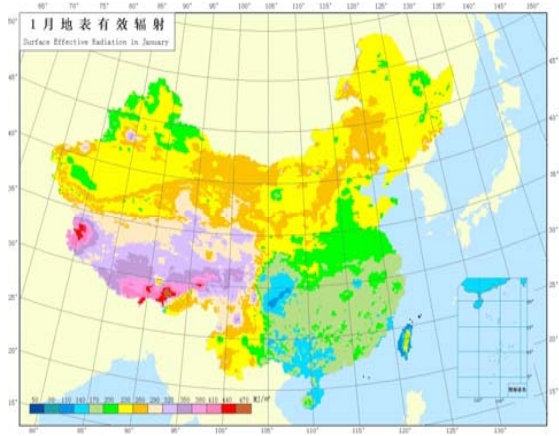
Potential radiation



PAR



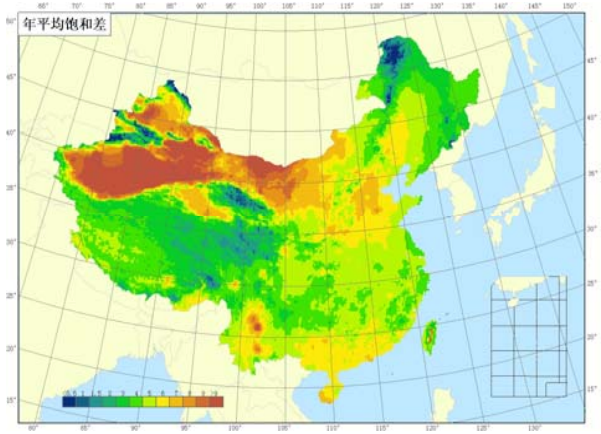
Sunshine Hours



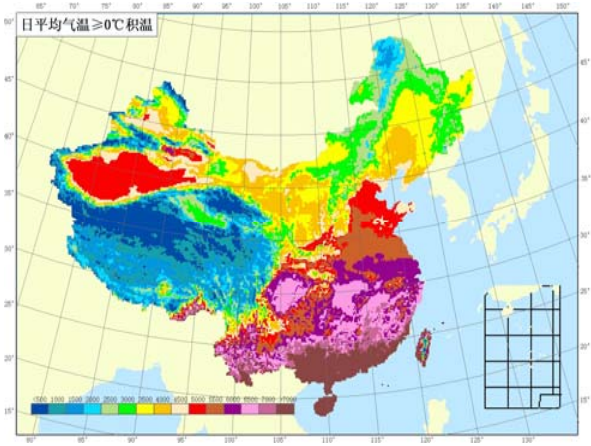
Surface effective radiation

Source: Synthesis research center, CERN

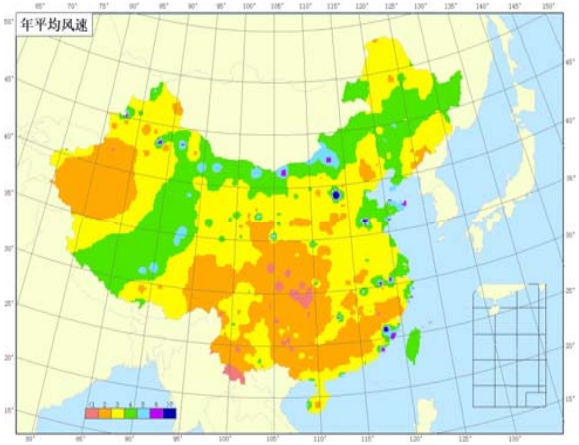
Temporal and spatial pattern of precipitation, accumulated temperature



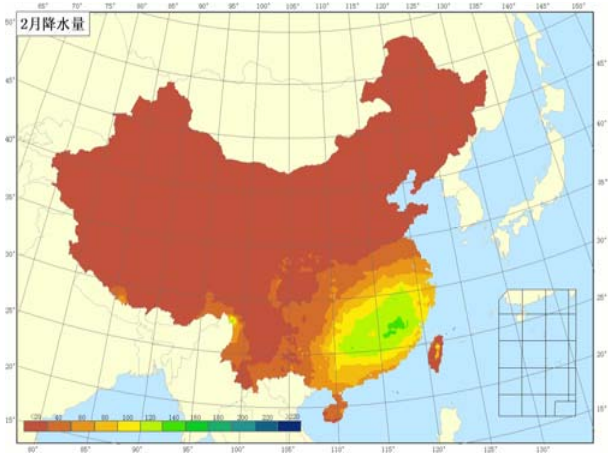
Saturation deficit



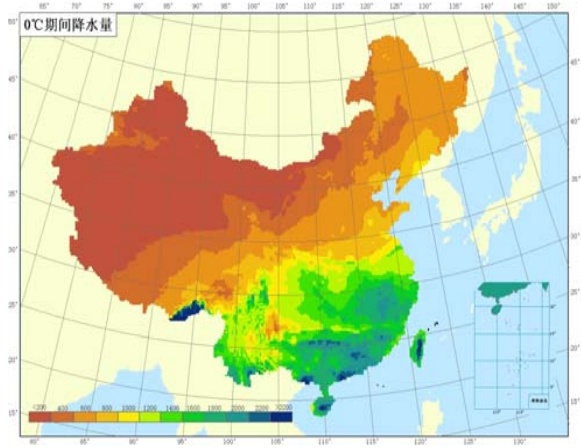
Accumulated temperature >0,5,10,20ºC



Mean wind speed



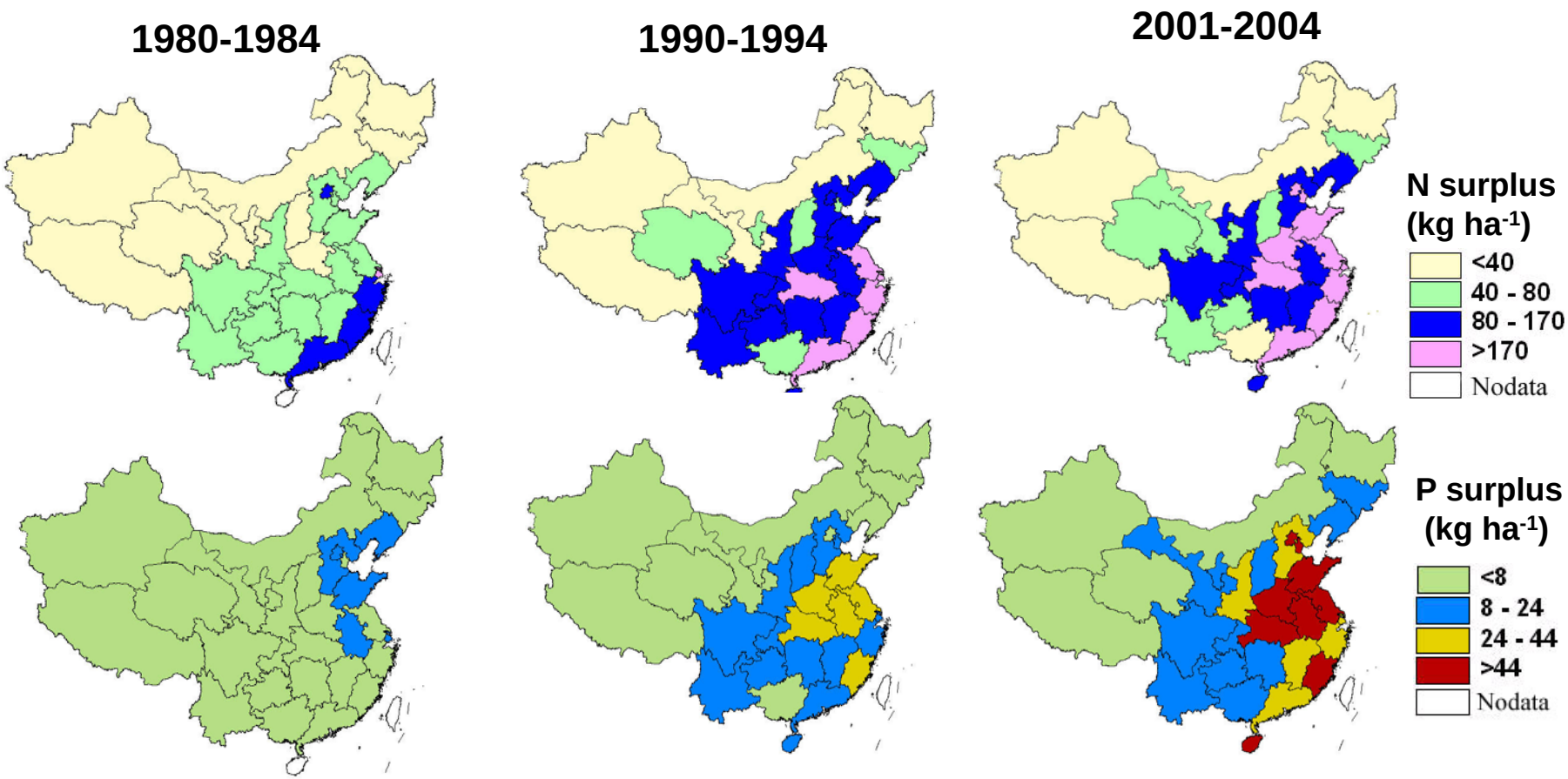
Mean annual precipitation



Precipitation at 0,5,10,15 ºC

Source: Synthesis research center, CERN

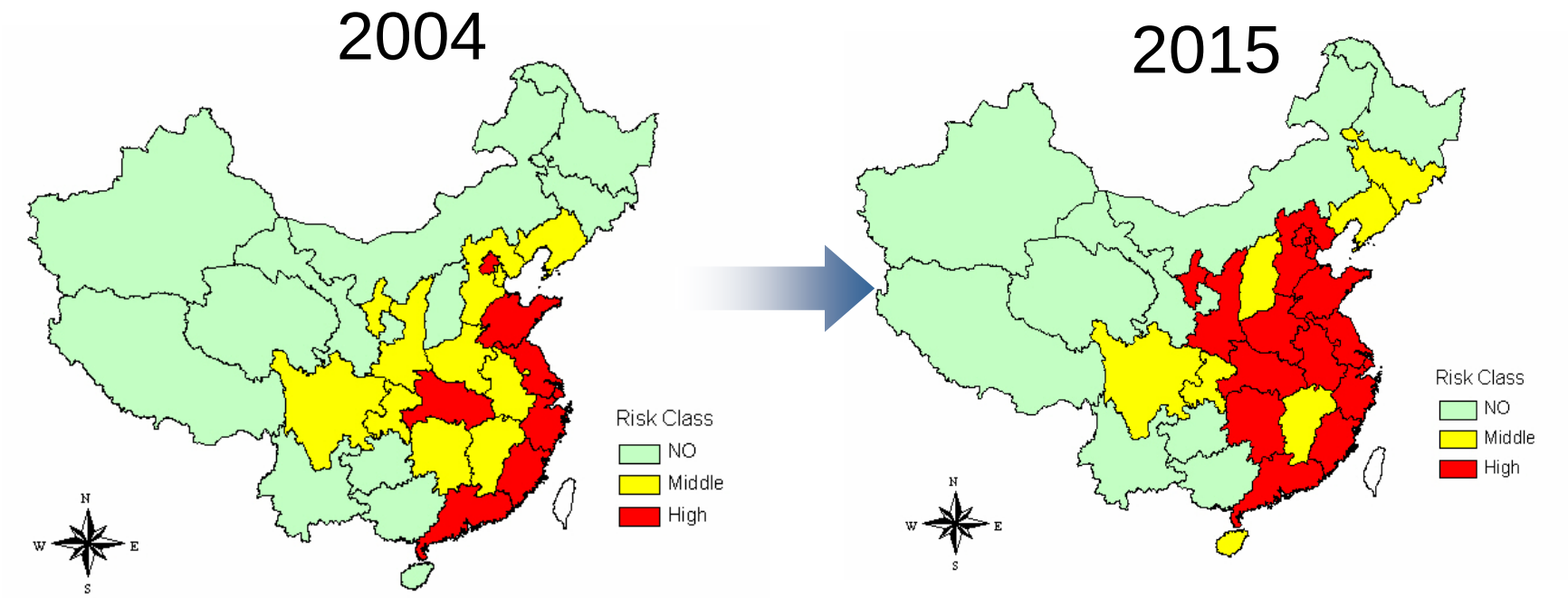
Temporal changes in soil nutrients



- ✓ N & P surplus in cropland increased continuously, higher surplus appearing in the coastal developed region.

Source: Shen et al., Pedosphere, 2005

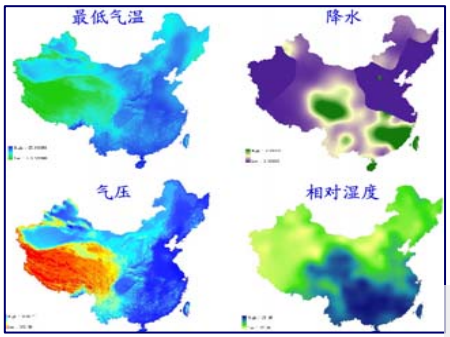
Predicting temporal changes in soil ecological environment



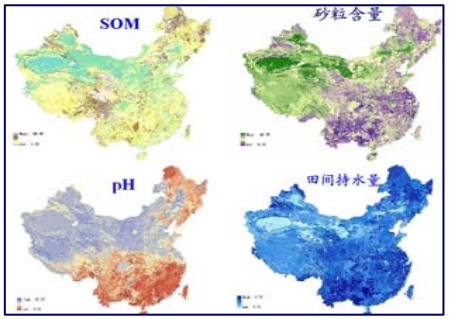
- ✓ Increased risks for water environment resulting from overuse of N fertilizer will extend from the coastal region in eastern China to middle China

3.2 Temporal and spatial pattern of terrestrial ecosystem carbon budget in China

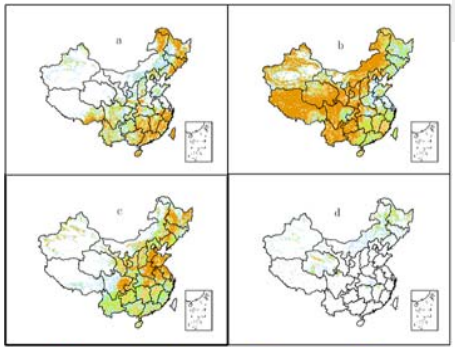
Climate



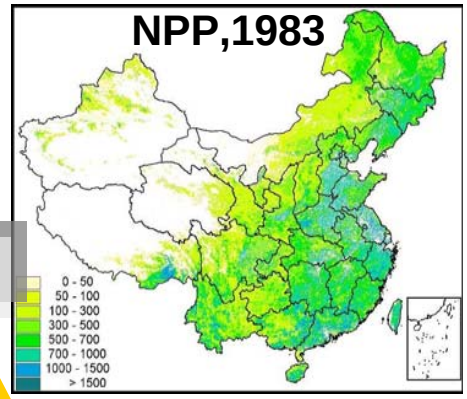
Soil

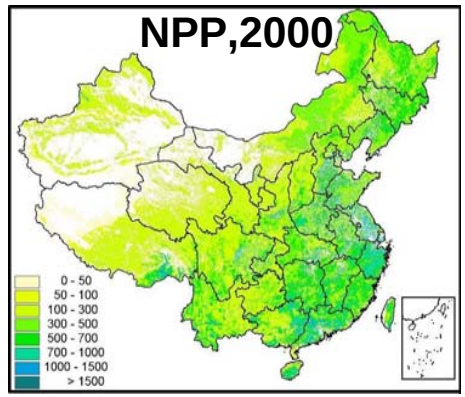


Vegetation



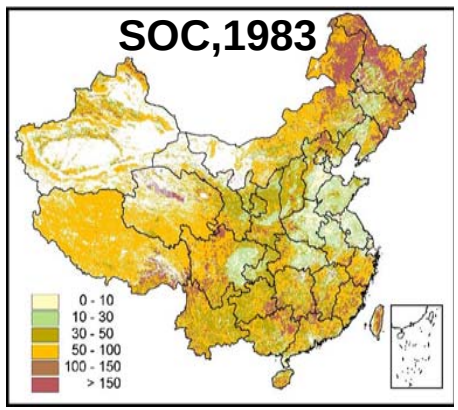
Observation

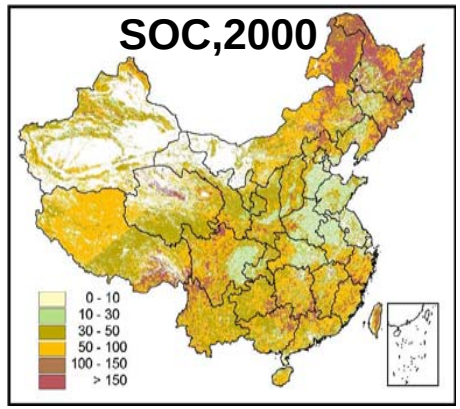




Model

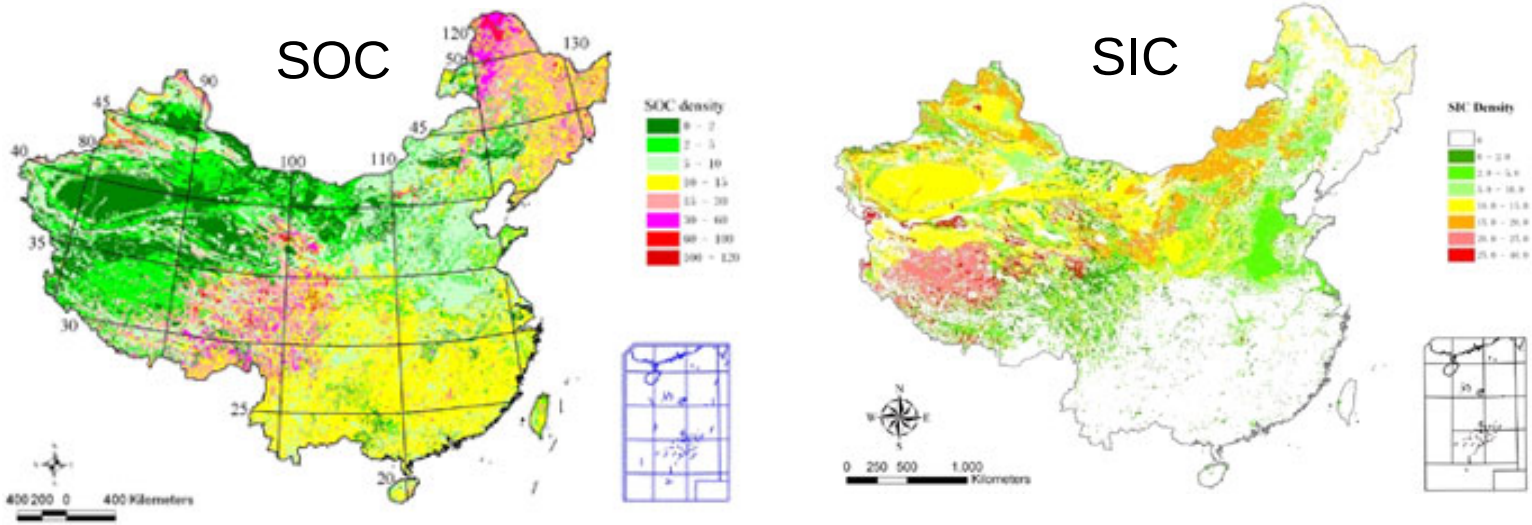
Temporal and spatial pattern





Source: Synthesis research center, CERN

Spatial pattern of SOC and SIC storage in China

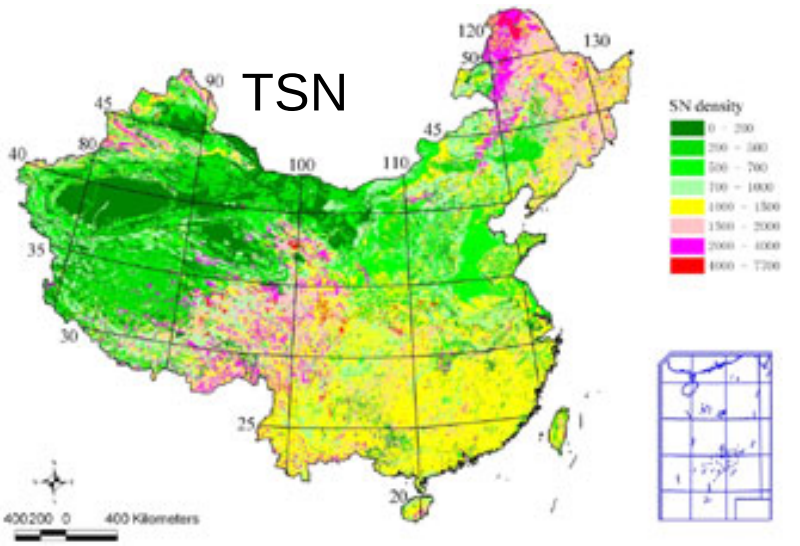


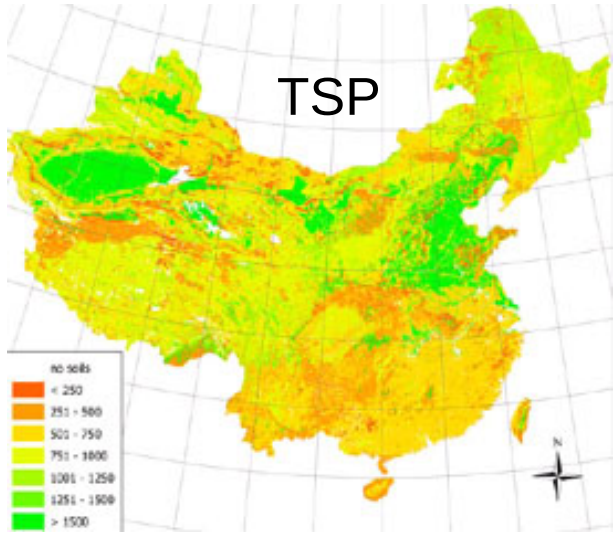
- ✓ SOC pool: 85.05±25.34 Pg (1m)
  Mean SOC density: 10.57±3.15 kg m^{-2}
- ✓ The SIC storage in China is 53.3±6.3 Pg C (taking measured soil depth into account)

  Mean SIC density: 4.29±0.36 kg C m^{-3}

Source: Wang et al., Journal of Geographical Science, 2001; Mi et al., GCB, 2008(Accepted)

Spatial pattern of total soil N and P storage in China





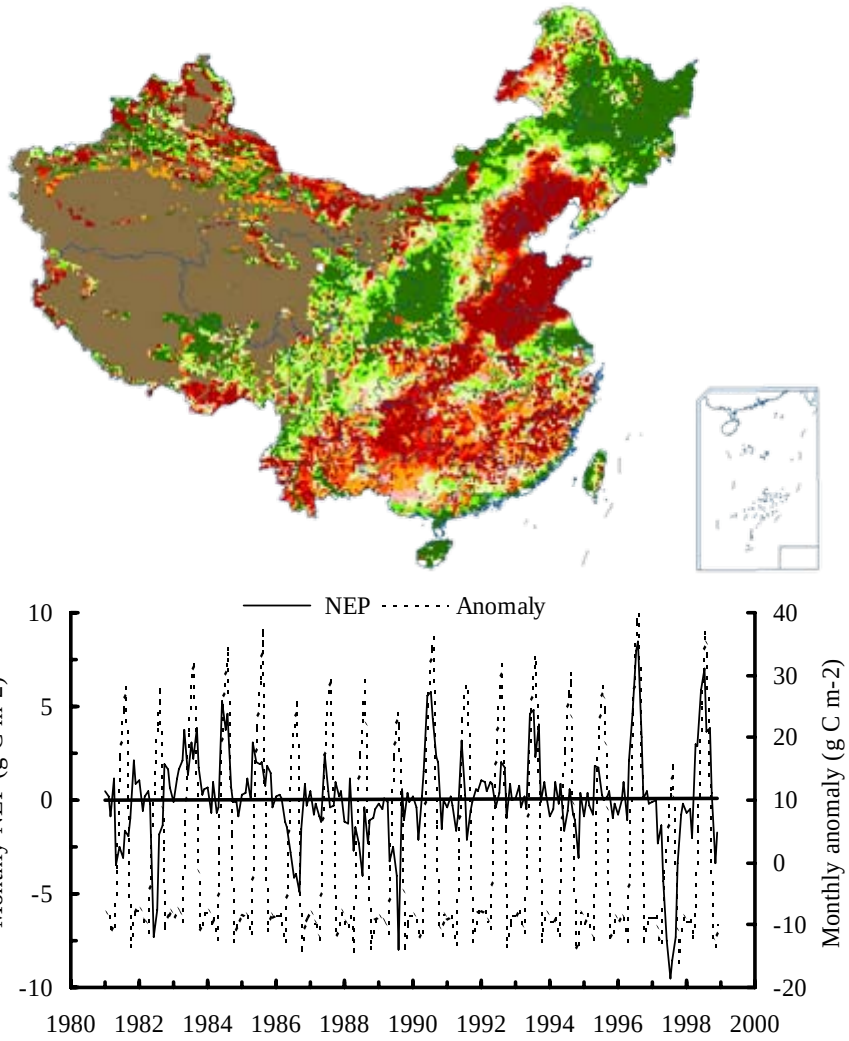
- ✓ Total soil N(TSN) pool: 8.29 Pg (1m)，5.9–8.7% of the total global N storage

  Mean TSN density: 1014.8±270.6 g m^{-3}
- ✓ Total soil P(TSP) pool: 85.05±25.34 Pg (1m)

  Mean TSP density: 830 g m^{-3}

Source: Tian et al., Global Biogeochemical Cycles, 2006
Zhang et al., Global Biogeochemical Cycles, 2005

Variation in NEP of China's terrestrial ecosystem-CEVSA

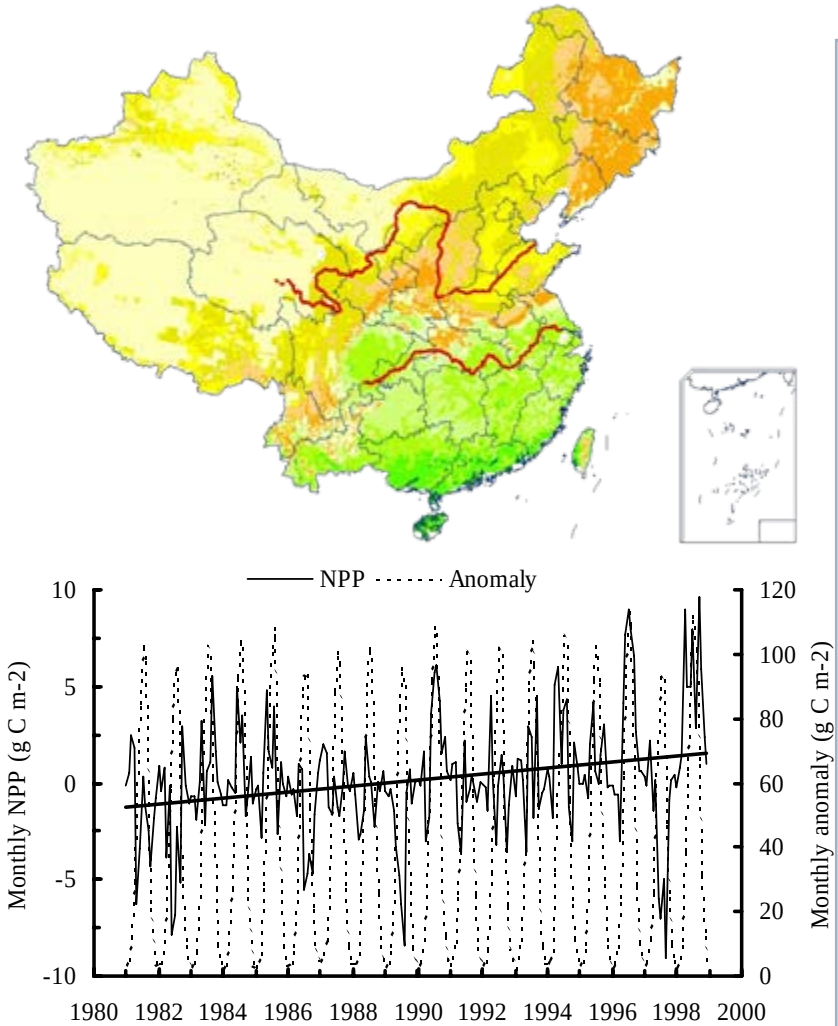


Mean NEP for the period 1980-1998 by CEVSA model

- ✓ NEP had no a statistically significant trend.
- ✓ The mean annual NEP for the 1990s was lower than for the 1980s as the increase in NEP in southern China were offset by the decreases in northern China.
- ✓ China's terrestrial ecosystems were taking up carbon but the capacity was undermined by the ongoing climate change.

Source:Cao et al., GCB,2003

Variation in NPP of China's terrestrial ecosystem-CEVSA

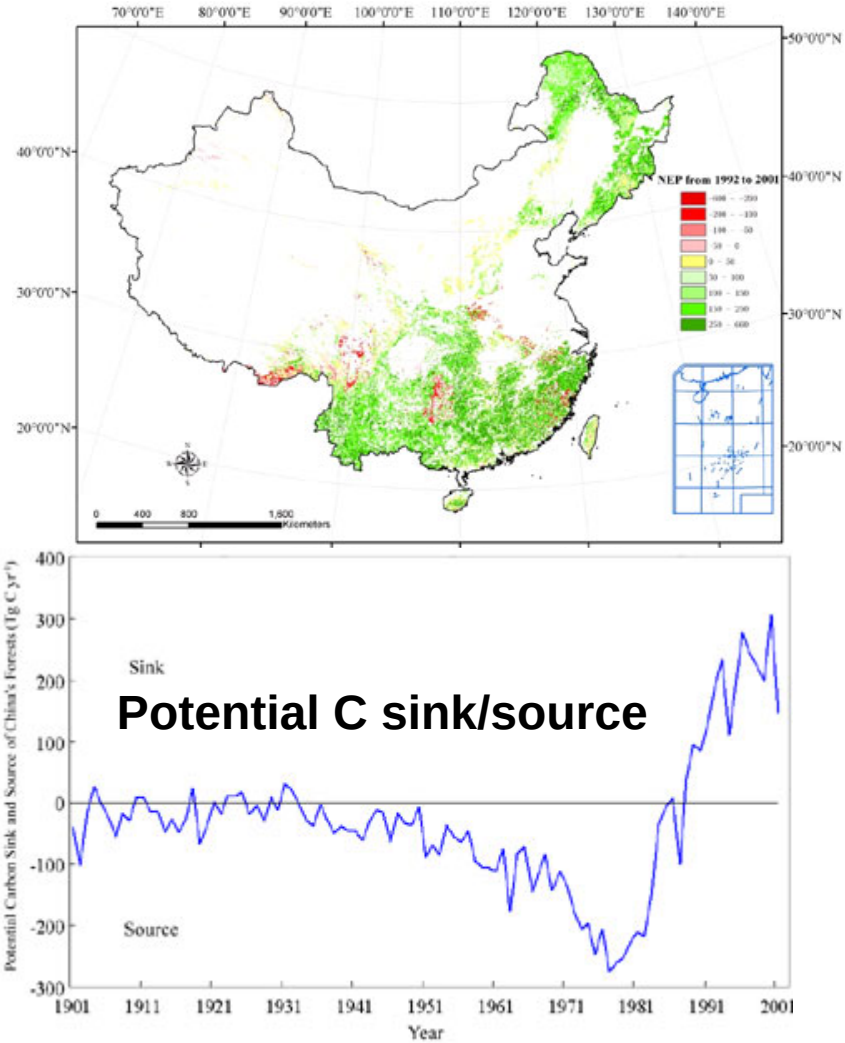


Mean NPP for the period 1980-1998 by CEVSA model

- ✓ China's terrestrial NPP varied between 2.86 and 3.37 GtC yr^{-1} with a growth rate of 0.32% yr^{-1} in the period 1981-1998.
- ✓ The increase in NPP were attributed to increase in precipitation and atmospheric CO_2.

Source: Cao et al., GCB, 2003

Variations in NEP of China's forests-InTEC



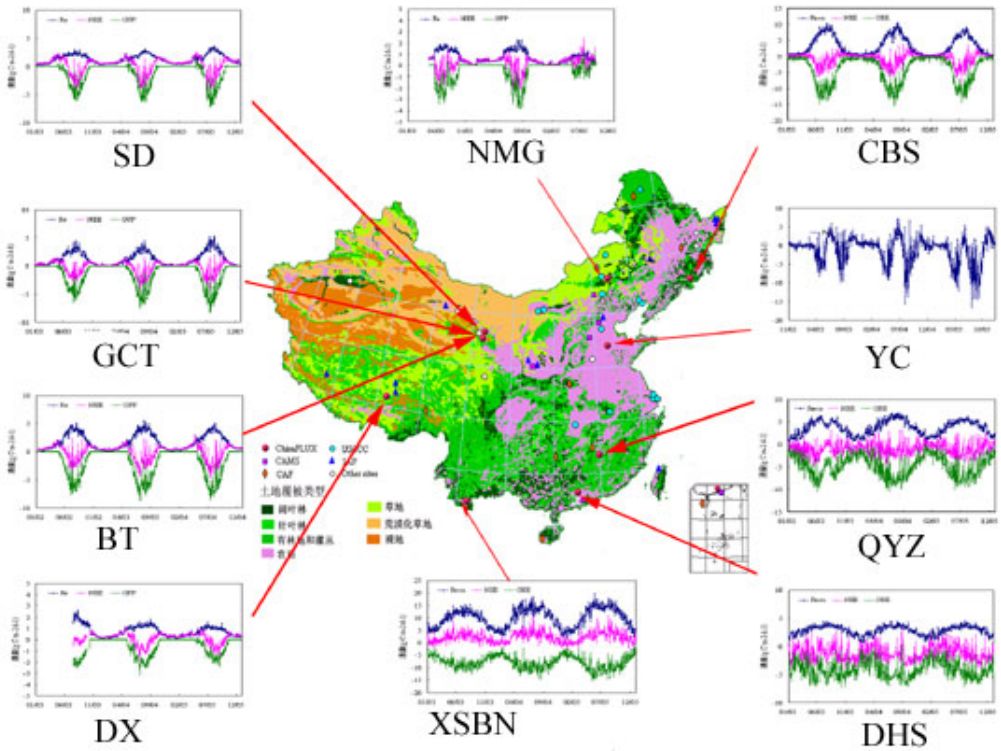
Potential C sink/source

NEP of China's forests from 1901 to 2001 by InTEC Model

- ✓Forest 's NEP in China based on InTEC model:
  - 1901-1949: -21.0±7.8 Tg C yr^{-1},
  - 1950-1987: -122.3±25.3 Tg C yr^{-1},
  - 1988-2001: 176.7±44.8 Tg C yr^{-1}
  - Total loss is about -3.32 Pg C from 1901 to 2001
- ✓NEP is around 0.21 Pg C/yr in 1990s.
  - (Including shrubland)

Source: Chen et al., Journal of Environmental Management, 2006

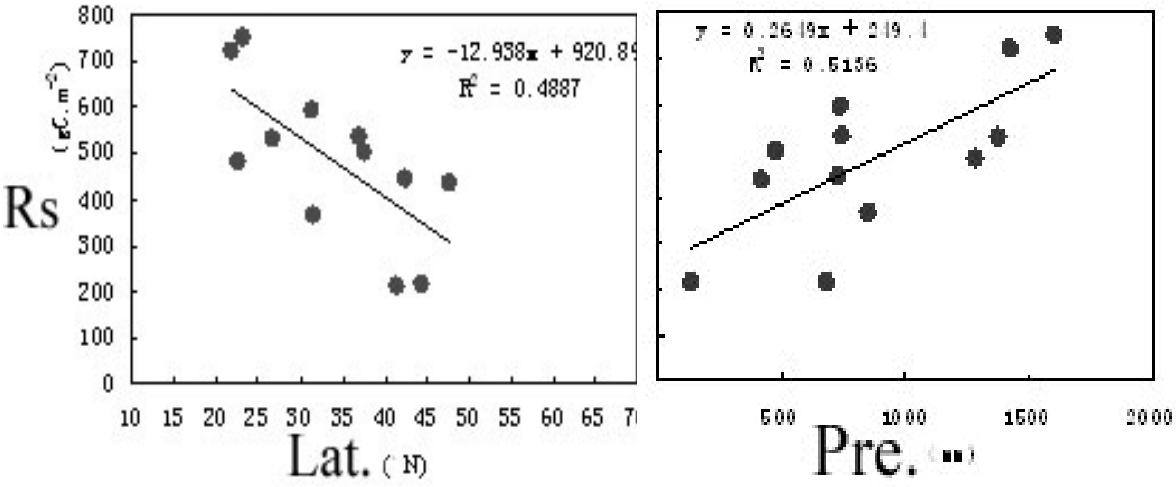
Seasonal and interannual variations of ecosystem carbon flux



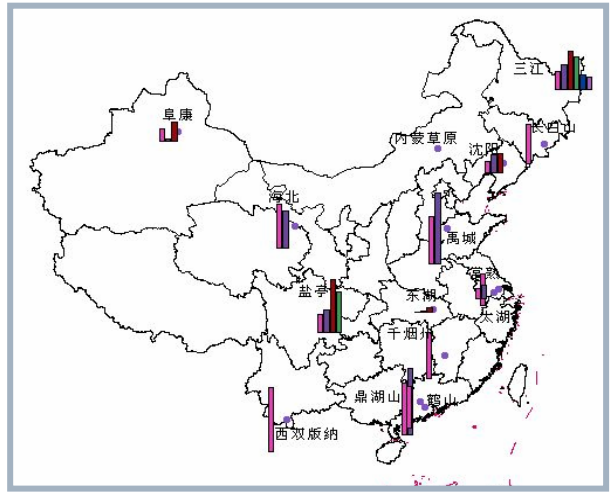
- ✓ Significant seasonal and interannual variations of GEP,NEE and RE in typical terrestrial ecosystems of China
- ✓ The continuous flux measurements provided scientific data for studying carbon cycle processes in terrestrial ecosystem

Source: **Synthesis research center, CERN; Fu, 2006; Zhang, 2006**

Spatial pattern of ecosystem respiration



Relation of soil respiration(RS) to altitude & precipitation



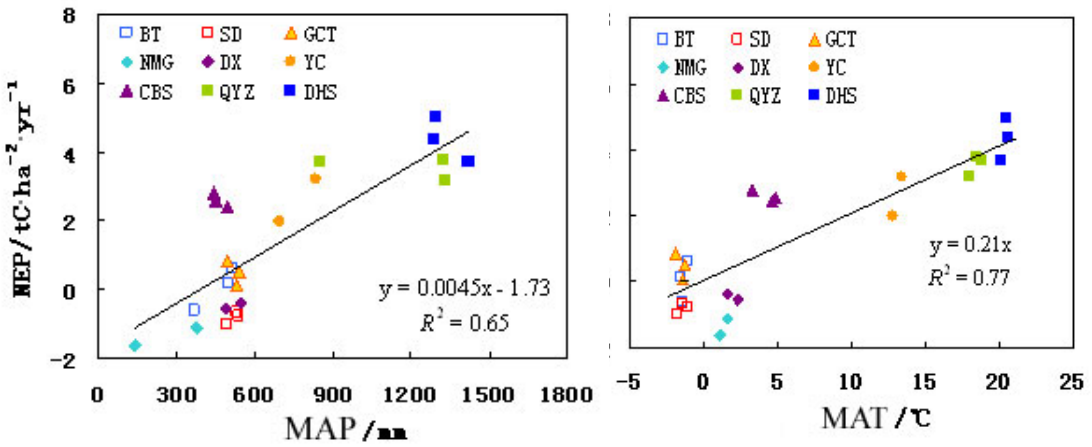
CO2 emission from soil and aquatic ecosystems

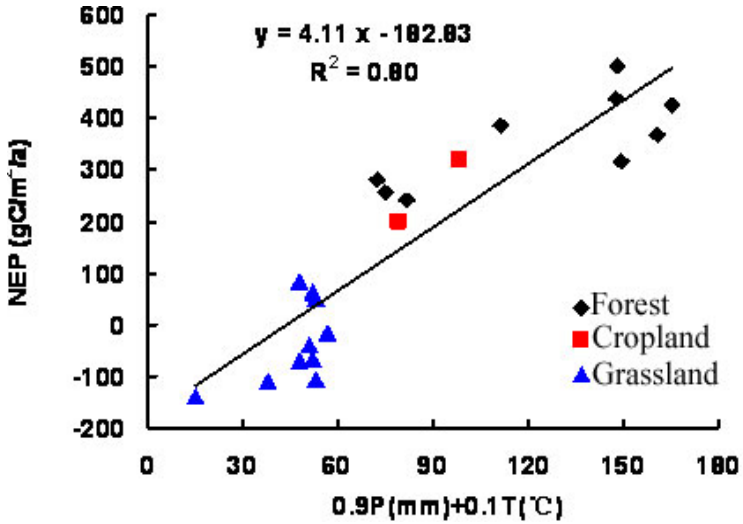
Spatial pattern:

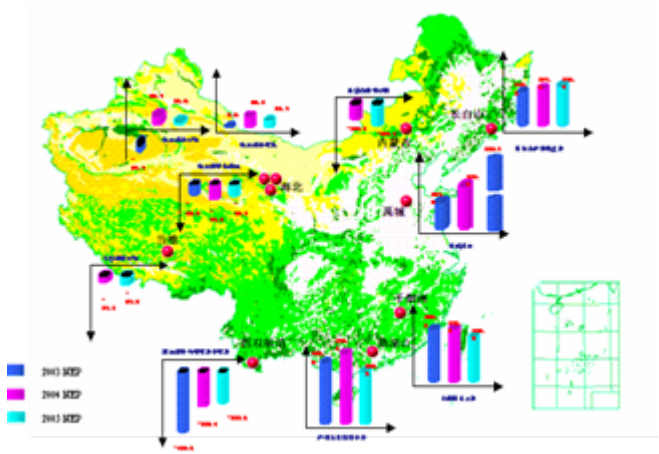
- ✓ negative relationship between Rs and latitude;
- ✓ positive relationship between Rs and annual precipitation

Source: Sub-center of atmosphere, CERN

Environmental controls on the spatial pattern of ecosystem carbon sink function







Spatial pattern of carbon budget

✓ Temperature and precipitation are the key factors controlling the carbon budget in terrestrial ecosystem in China.

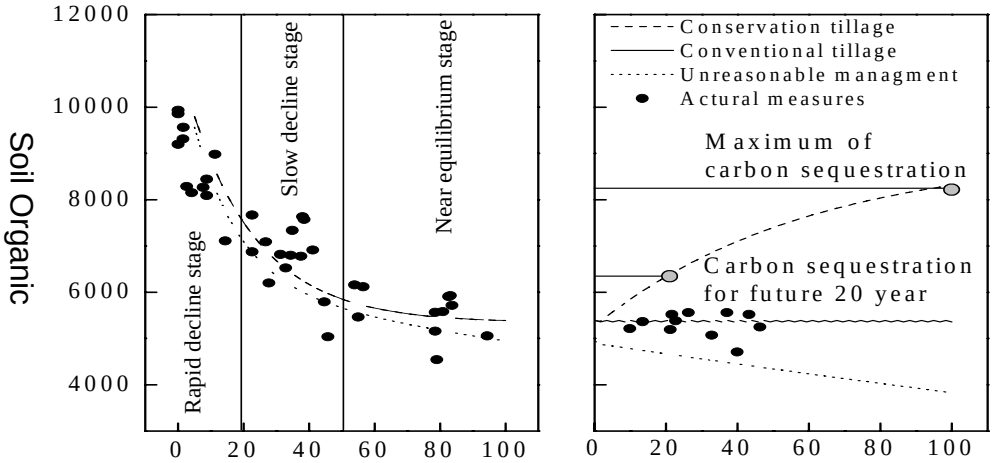
Source:Synthesis center of CERN;
Yu et al., Science of China, Series D, 2006

3.3 Ecosystem structure and function

（1）Major research contents in cropland

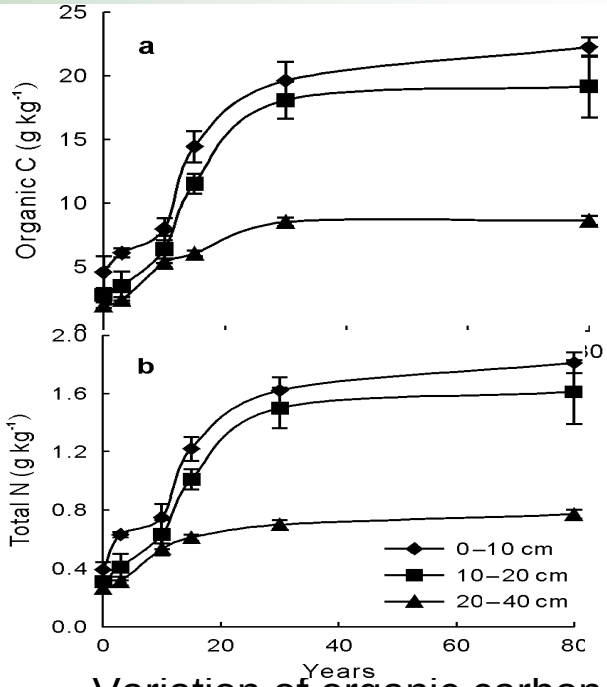
- ✓ Evolution of Black Soil quality in the Northeast China
- ✓ Carbon and nitrogen cycle in cropland and its environmental effect
- ✓ Moisture movement of soil-plant-atmosphere continusum (SPAC)
- ✓ Polluted chemical effects of fertilizer and pesticide on environment and biologic rehabilitation

Fertility evolution of Black Soil and Paddy Soil



Variation of organic carbon of Black soil in the Northeast China and it's potential carbon sink

Source: Yu et al., Ecological Research, 2006



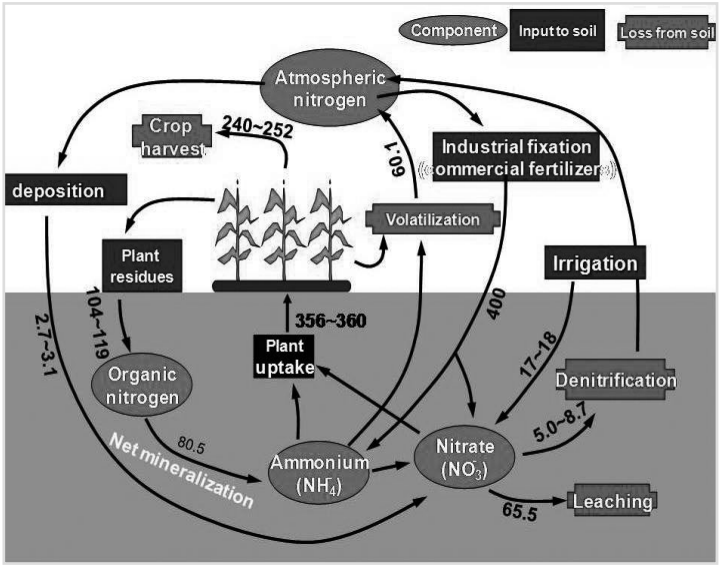
Variation of organic carbon (top) and organic nitrogen (below) with cultivation

Source: Yingtan (CERN)

- ✓ SOC content reach a balance after cultivating for about 40 years.
- ✓ To a certain extend, reasonable management could increase SOC storage.

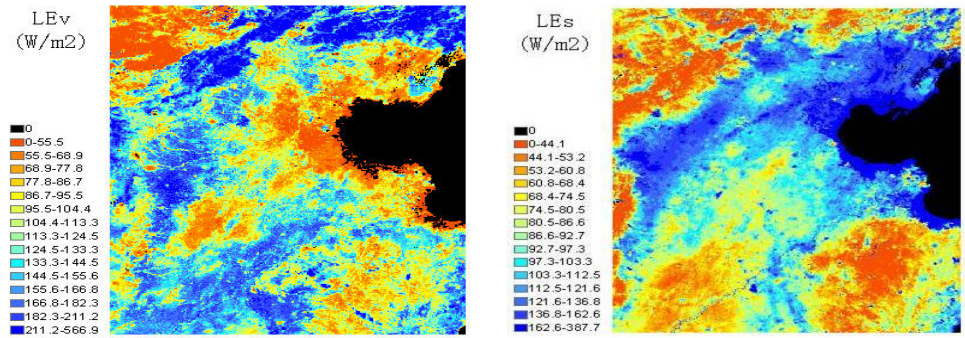
- ✓ Organic carbon and nitrogen in paddy soil accumulate with cultivation and reach a balance in 25 years.

Nitrogen & water cycle of cropland in the North China Plain



Nitrogen cycle in cropland in the North China Plain (kg N/ha)

Source: Luancheng site(CERN)

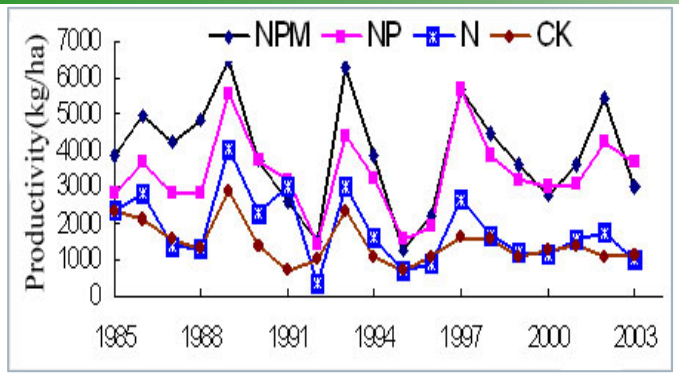


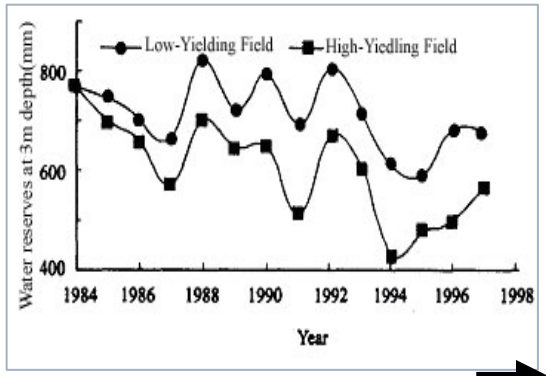
Spatial pattern of LEv& LEs during the growing season of wheat in the Huan-huai-hai Plain

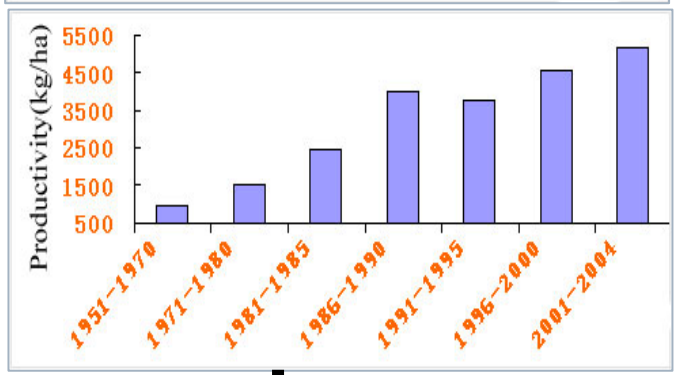
Source: Yucheng(CERN)

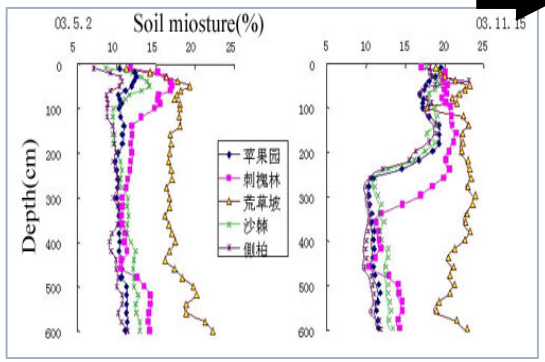
✓In the North China Plain, nitrogen loss and excessive NO_3^- in water resulting from rapid descent of underground water level, deficiency in irrigation water resource and excessive fertilization are becoming serious ecological problems.

Soil desiccation in Loess Plateau and environmental effect









✓**The pathway and intensity of ecosystem water cycle will change due to soil desiccation.**

✓**Grain production of Loess Plateau keeps at a new level**

✓**Dry-farming resulted in the variation of yield**

✓**The primary limiting factor for grain production increase was soil nutrient first and turned to water content gradually**

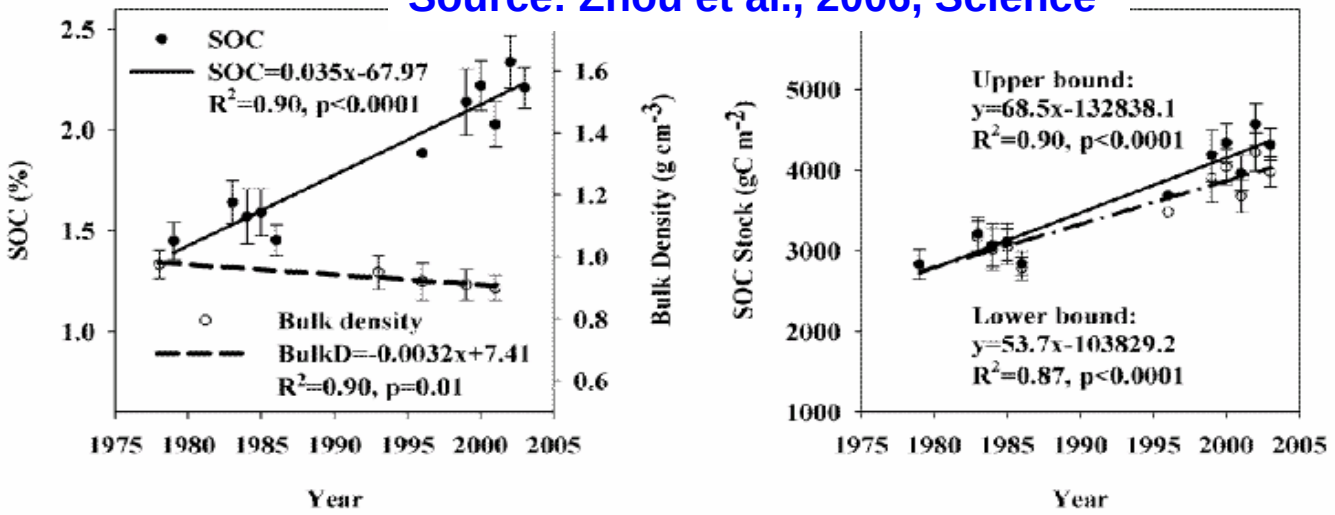
3.3 Ecosystem structure and function

（2）Major research contents in forest ecosystem

- ✓ C & N cycles and C sink/source function
- ✓ Roles and physical mechanism of water resource conservation
- ✓ Interaction among different species
- ✓ Characteristic of forest soil seed bank
- ✓ Breeding system and pollination biology
- ✓ Roles of bryophyte in ecological restoration

Soil carbon sequestration of old-growth forest in South China

Source: Zhou et al., 2006, Science



Based on 20 years' study at Dinghu Moun. station (CERN) :

- ✓ **Questioned an unconfirmed but popular opinion that carbon storage in mature forest ecosystem reached a balance, therefore many biogeochemical cycle models assume most of sequestrated carbon was offset by carbon emission in mature forest**
- ✓ **Promoting to establish the non-balance theory frame of ecosystem ecology**
- ✓ **Suggesting it's critical to study the process of ecosystem carbon balance under global change and regional acid deposition**

3.3 Ecosystem structure and function

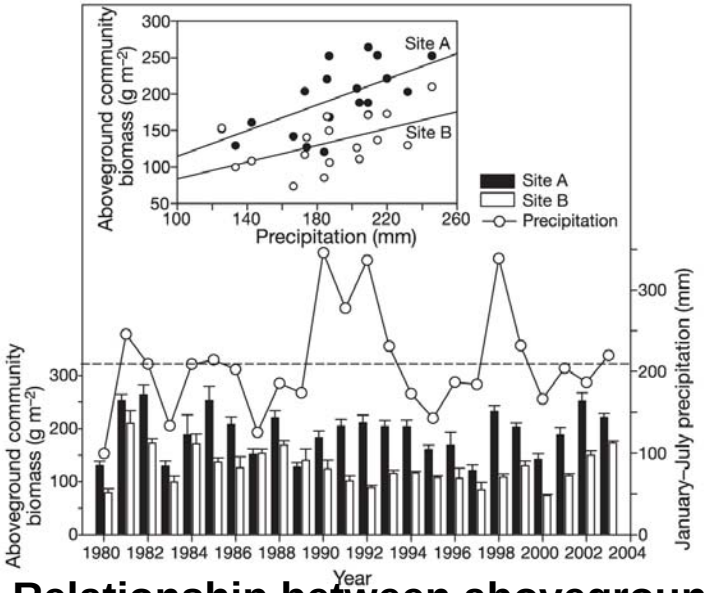
（3）Major research contents in grassland ecosystem

- ✓ Biogeochemical cycles in grassland ecosystem
- ✓ Relationship between biodiversity and stability
- ✓ Responses of grassland to global changes
- ✓ Biological evolution and adaptation in Qinghai-Tibet Plateau
- ✓ Biogeography of clonal plants

Relationship between biodiversity and stability in grassland ecosystem

Based on 25 years' measurement at Inner Mongolia grassland site:

- ✓ Ecosystem stability according to biomass variation increased with structure grade
- ✓ Community stability depended on the compensation between species and functional groups
- ✓ A contribution to ecology theory and a guidance to restoration and management of degenerated grassland



Relationship between aboveground biomass and precipitation (Jan.-July)

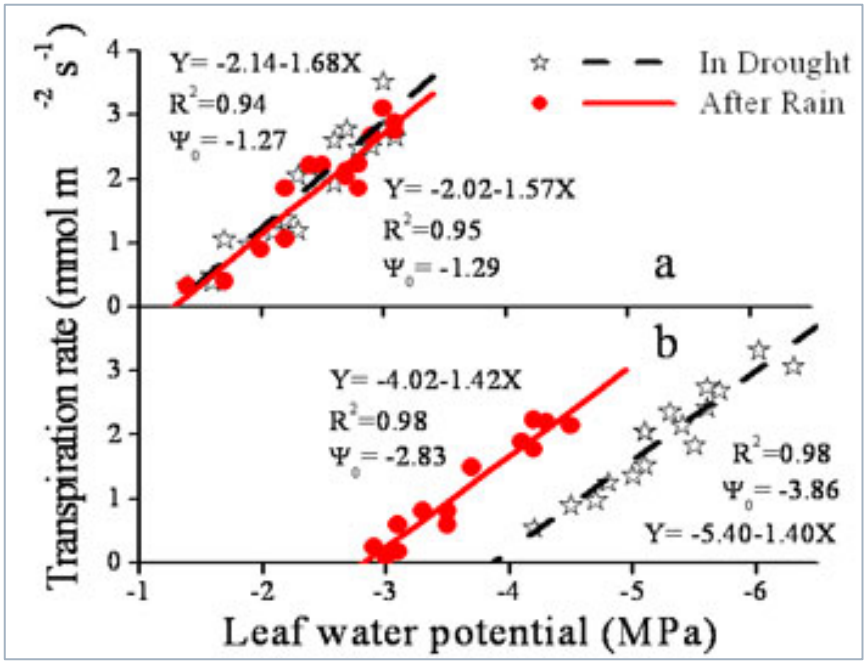
Source:Bai et al., Nature, 2004

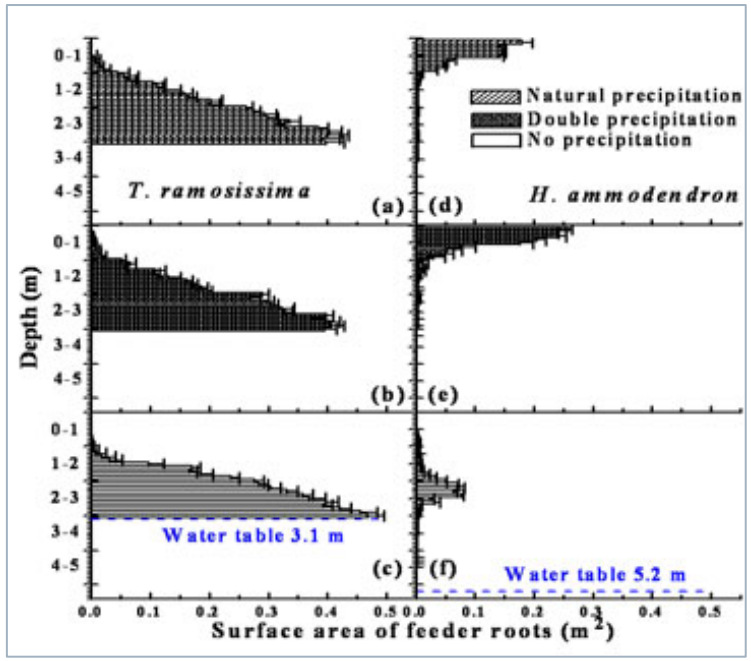
3.3 Ecosystem structure and function

（4）Major research content in desert ecosystem

- ✓ Plant resistance and its strategy of ecological adaptation under extreme environment
- ✓ Ecological mechanism of stability of desert vegetation restoration
- ✓ The role of biological crust in sandy soils in ecological restoration
- ✓ The relationship between clonal plant and species diversity in desertification land

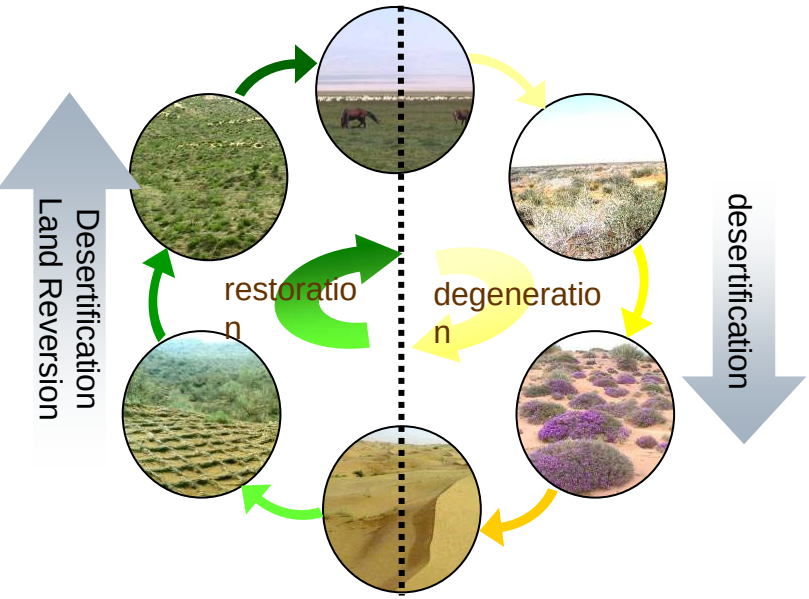
Stress resistance and ecological adaptability of plant under extreme environment





- ✓ **Acute change of soil moisture is the direct driving force to survival and evolution of desert plants;**
- ✓ **The mechanism of keeping physiological stabilization is the ability to maintain stable leaf water supply through changing root shape, size and quantity of branches and leaves.**

Ecological mechanism of stability of desert vegetation restoration



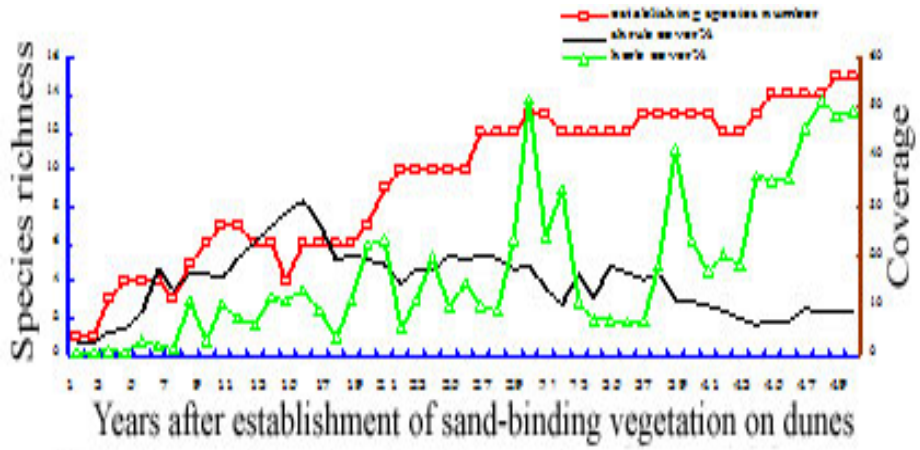


Fig.2 Change of plant species richness and coverage during 50 years after re-vegetation (site 1956)

- ✓ Succession pattern of desert vegetation during the development and reversion of desertification was revealed based on comparative ecology at temporal and spatial scales.
- ✓ Dynamic monitoring data for 50 years showed that the exist of xeric shrubs in desert had “fertility island effect“.
- ✓ The canopy of xeric shrubs accelerates the accumulation of litter, formation of biological crust, soil forming process through reallocating precipitation and atmosphere deposition, which favors of plant invasion and settlement

3.3 Ecosystem structure and function

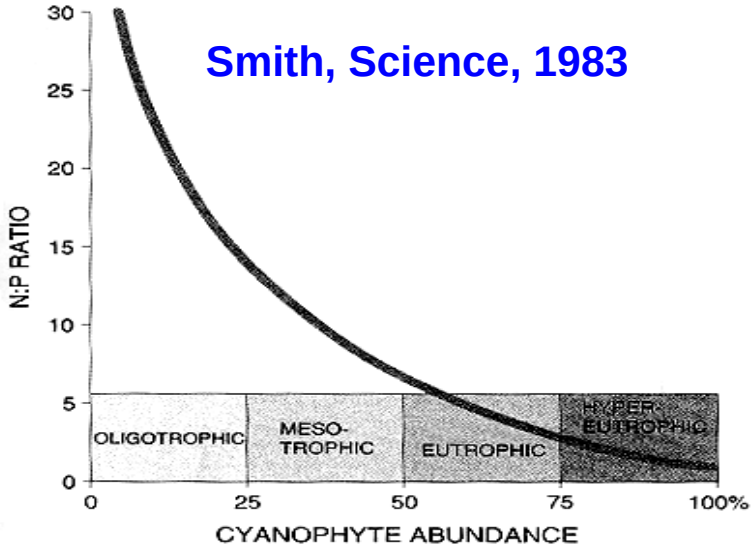
（5）Major research contents in aquatic ecosystem

- ✓ Ecological foundation on controlling eutrophic lakes
- ✓ Changes of marsh, sea beach mangrove and coral reef ecosystems
- ✓ Response of phytoplankton community to environmental changes
- ✓ Structure and dynamics of food webs in eutrophic shallow lakes
- ✓ Relationship between hydrodynamic characteristics and eutrophication in shallow lakes

"N:P rule" is not applicable to highly eutrophic systems

New finding:

Cyanobacterial blooms as a key biological mechanisms driving the seasonal changes in the internal loading of phosphorus in shallows



Important finding:

- ✓ *Microcystis* blooms induced massiive release of P from sediments, and a low TN:TP ratio is not the cause of *Microcystis* blooms, but a result of the blooms.
- ✓ Therefore, our results indicate that the "N:P rule" is not applicable to highly eutrophic systems.

Source: Xie et al. 2002, Water Res; Xie et al. 2003a, b Water Res, Environ Pollut Xie 2006, Scienc in China, Ser D; Wu et al. 2006, Science in China, Ser D

3.4 Ecosystem restoration and management

1) Integrated controlling of middle-low productive cropland in Huang-Huai-Hai Plain
2) Integrated utilization and vegetation restoration of hilly region in southern China
3) Controlling eutrofication of lakes and ecological rehabilitation
4) Integrated controlling of the soil and water loss in Loess Plateau
5) Integrated controlling of desertification and ecological restoration
6) Ecological protection of major desert projects in China

（1） Integrated controlling of middle-low productive cropland in Huang-Huai-Hai Plain

- ✓ Large area cropland with middle-low production had been improved in Huang-Huai-Hai Plain, the grain yield increased from 2902.5 kg ha^{-1} in the past to over 7492.5 kg ha^{-1} at present，which drives rural economics develop quickly.

Source:Yucheng station, CERN

（2） Integrated utilization and vegetation restoration of hilly region in southern China

- ✓ **Taking plantation/orchard as the key link and combining plantation, cropland and orchard, developing integrated *Qianyanzhou* mode of “plantation-grassland-cropland-fishpond”.**
- ✓ **This mode has played an important role in comprehensive utilization and vegetation restoration of hilly region in southern China.**

✓The mode of “plantation-orchard-gassland-fishpond” is used in ecological restoration at Heshan station

✓The technology of quick vegetation restoration is applied at Yingtan station

（3）Controlling eutrofication of lakes and ecological rehabilitation

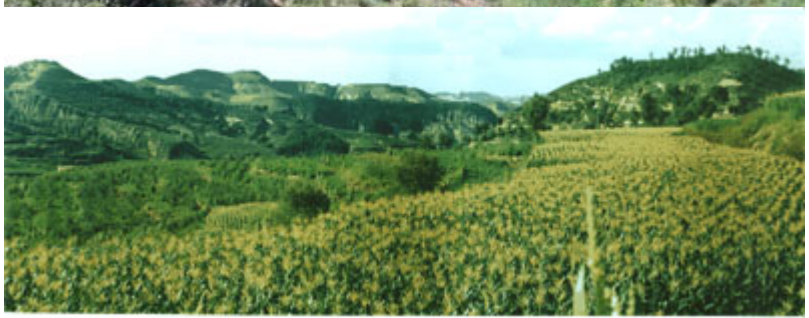
Controlling techniques of alga

- Algae control technology including bio-manipulation and associated with micro-organism
- Resuscitation and arrearage technology of algae hypnozoite
- Controlling algae using allelopathy of plants

Algae dominated stable states ⇢ **Grass dominated stable states**

A complete set of technology to control Cyanobacteria bloom in highly eutrophic lakes

（4）Comprehensive utilization and ecological restoration in Loess Plateau



- ✓**Different strategies on soil and water conservation, ecological construction and implementation technique are proposed by Ansai station according to different regional characteristics and geomorphic types, which accelerate the progress of eco-construction in Loess Plateau.**

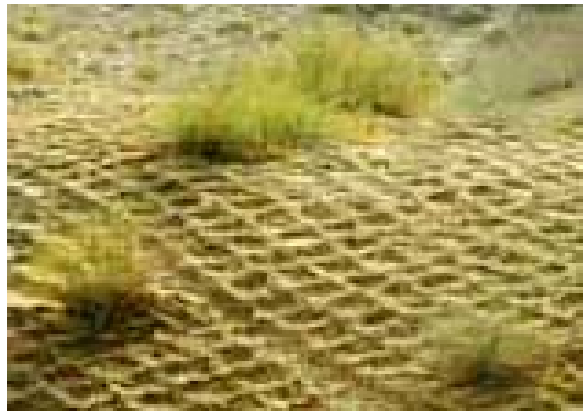
Ecological agriculture with soil and water conservation at Zhifanggou basin, Ansai

（5）Comprehensive controlling of desertification and ecological restoration

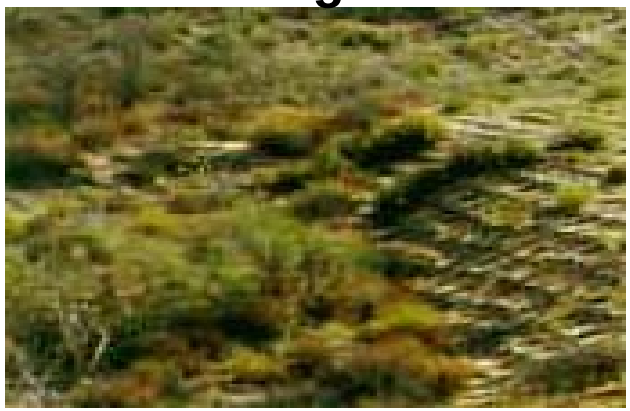
Restoration of desertified grassland in arid western China in the last 50 years

1.Shifting dune

2. Dune fixed by straws

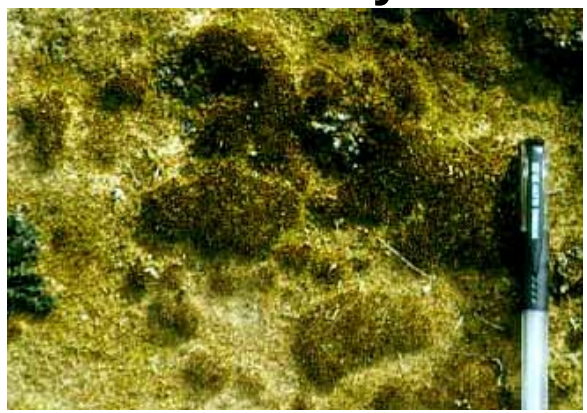


3. Dune fixed by bushes



4. Planted shrub

5. Naturally restored herbage



6. Microbe, lichen, moss

（6）Ecological protection of major desert projects in China

- ✓**The principle that giving priority to sand fixation, combined with sand binding, is widely applied to railway protection, which has insured the Baotou-Lanzhou railway smooth for 50 years and the direct economic benefit exceeds 10 billion RMB.**

✓**According to the two associated principles of “giving priority to sand fixation, combined with sand binding” with “straw checkerboard barriers +xerophyte+tree planting”, protection system of desert highway is conducted based on the two principles and applied in many desert roads.**



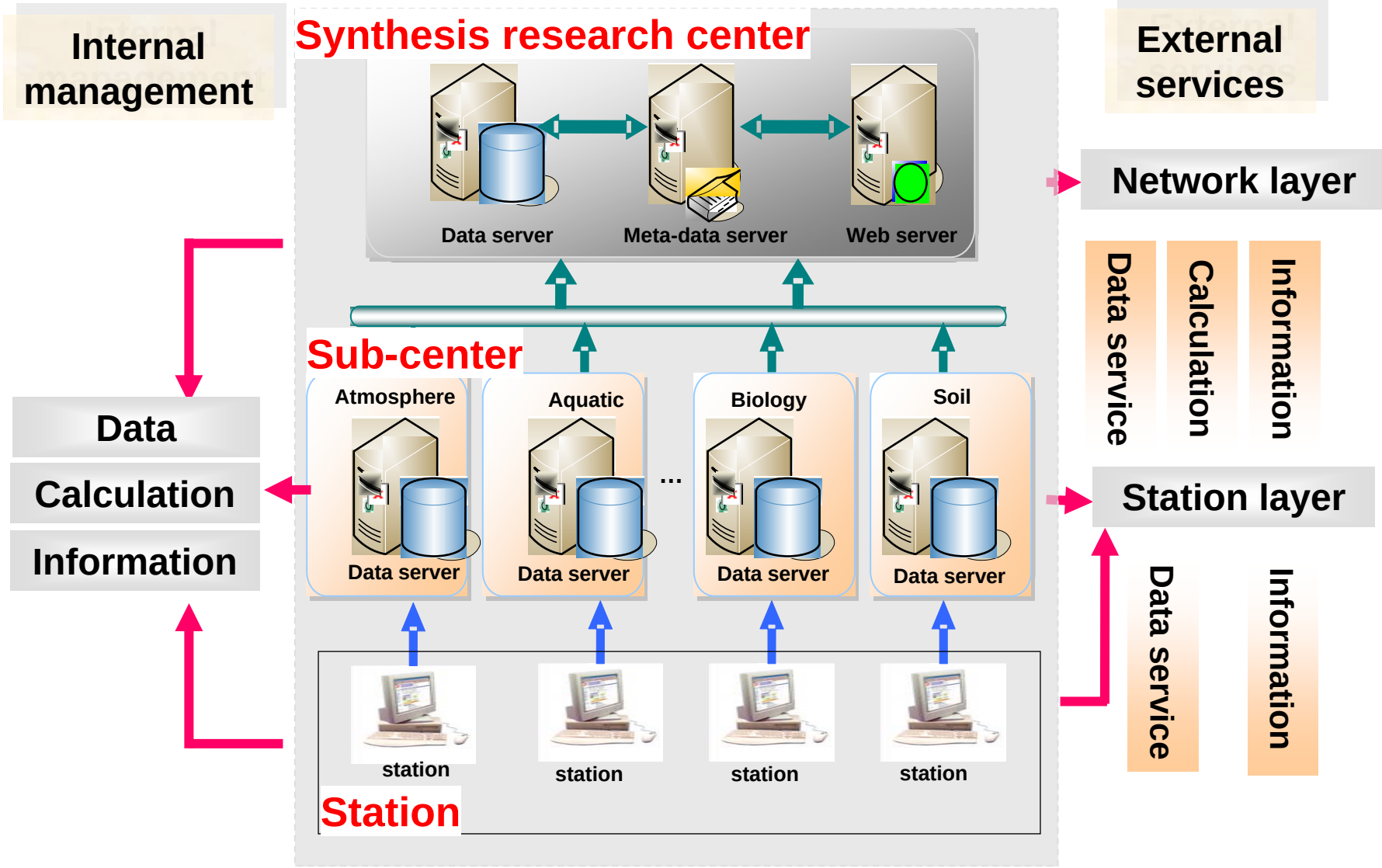


3.5 Ecological information technology and data sharing

Standard:

- ✓Observation and analysis of meteorological and atmospheric environment
- ✓ Soil physical and chemical analysis and profile description
- ✓ Observation and analysis of water environment
- ✓ Survey, observation and analysis of terrestrial biocommunities
- ✓ Survey, observation and analysis of lakes
- ✓ Survey, observation and analysis of bay ecosystems

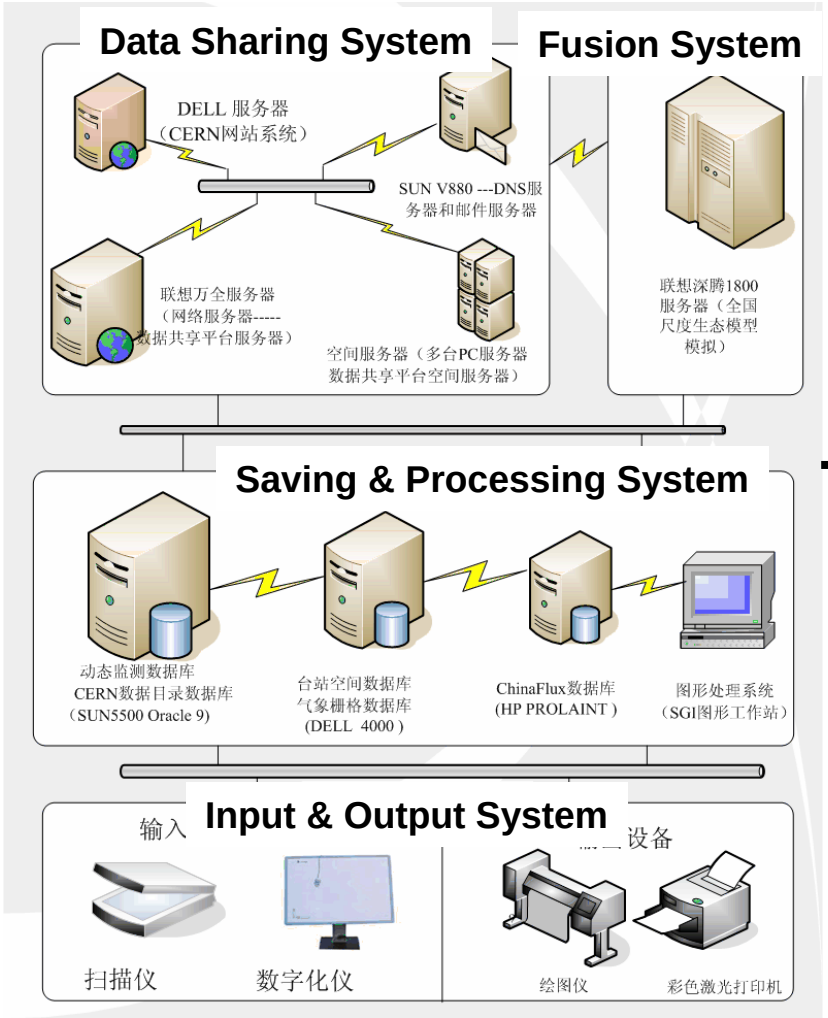
Three-level database for station→sub-center → synthesis research center



Centralized metadata, distributed storage of data

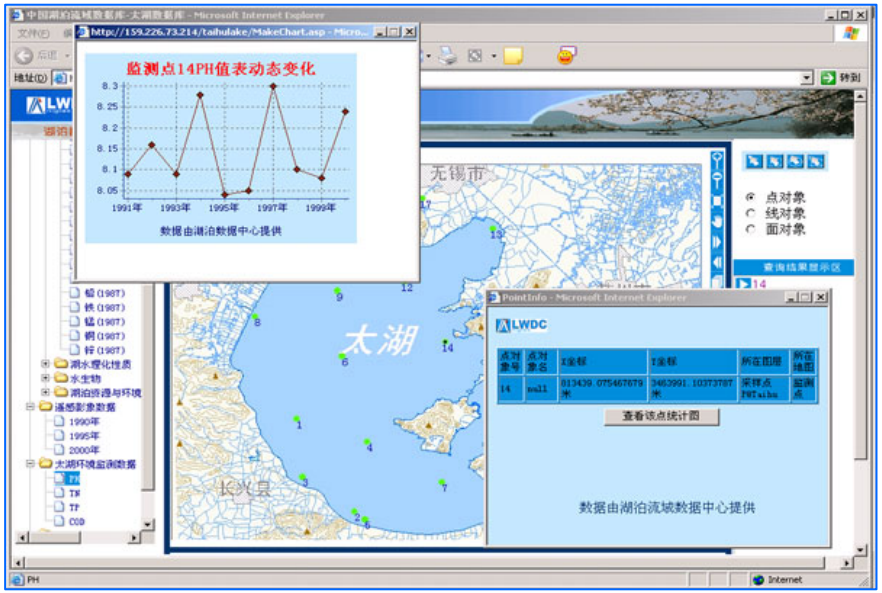
Management and services platform for data-information sharing

CERN Data Information System



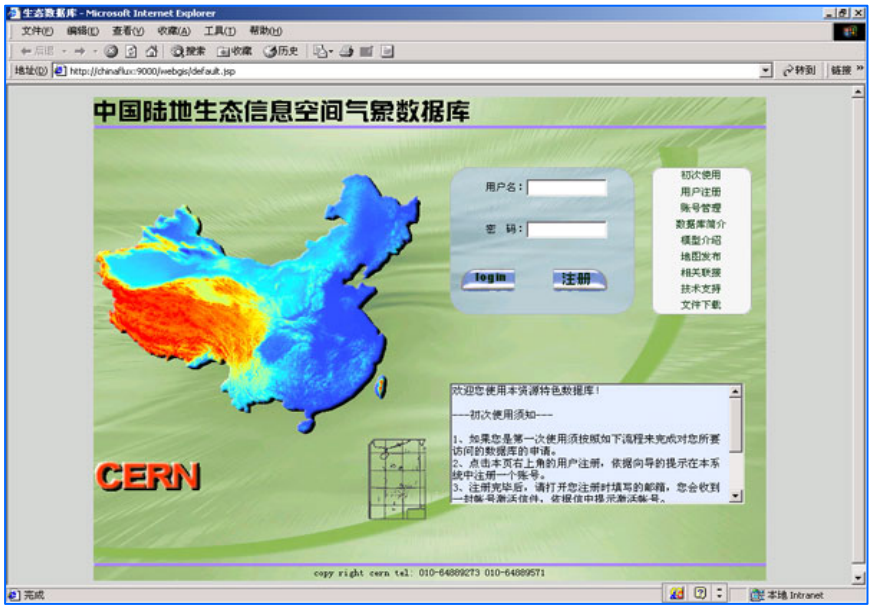
- CERN Metadata Catalog Database
- CERN Monitoring Database
- ChinaFlux Database
- 1km X 1km Raster Meteorological Database
- CERN Station Spatial Information Database
- Thematic Research Databases

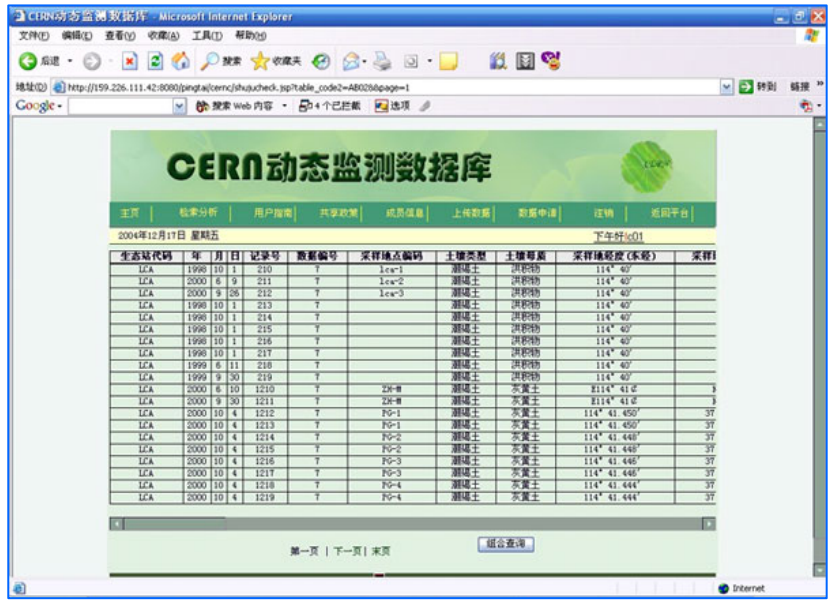
Website of data-information sharing system



The homepage of spatial meteorological database in terrestrial ecological information

www.cerndata.ac.cn



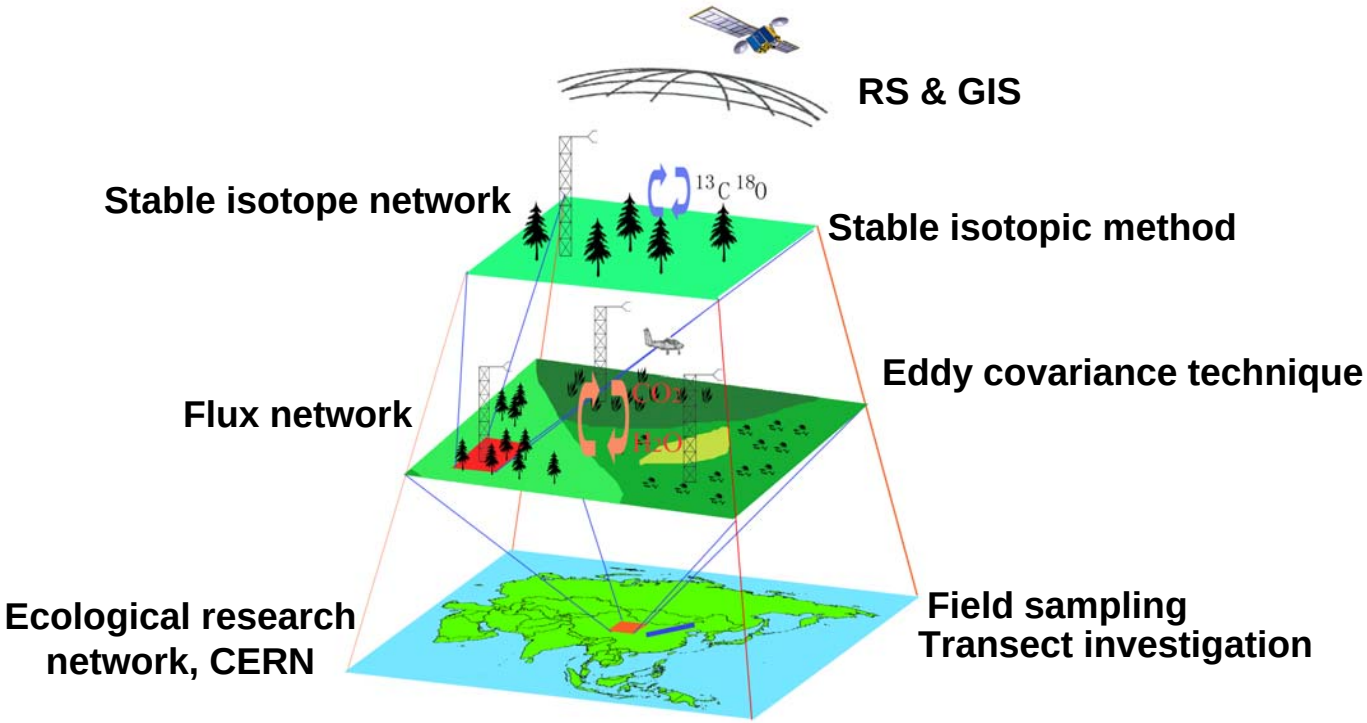


Outline

1. Missions and objectives of CERN
2. Developing history
3. Scientific achievements
4. Future directions

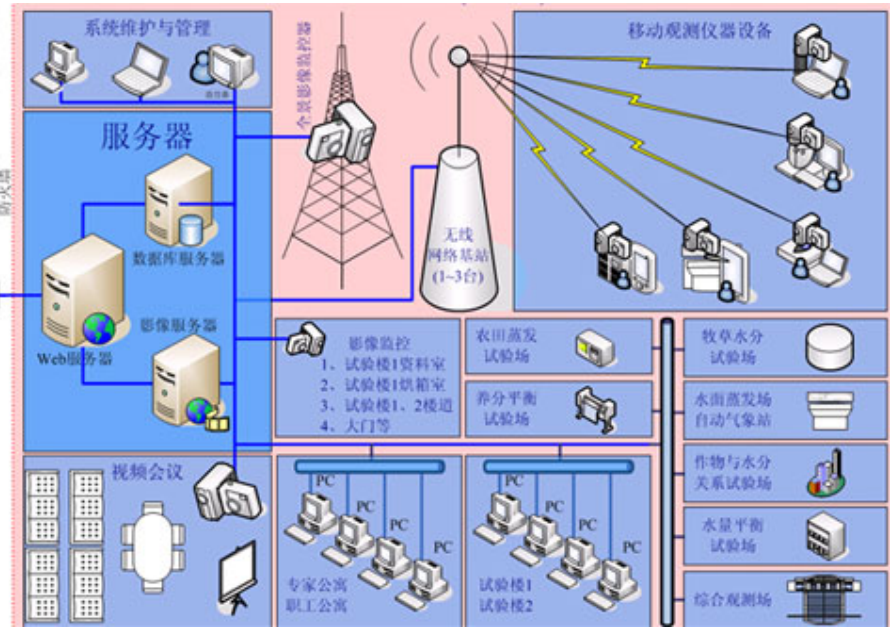
Monitoring and Observation

（1）Strengthening integrated observing system with dynamic position observation, moving observation along transect and satellite-based remote sensing monitoring



Integrated multiple-scale and multi-technique measurement for research on ecosystem coupling cycle of C, H_2O and N

(2) Establishing an automatic monitoring system for field data collection–remote transmission–data loader based on sensor network



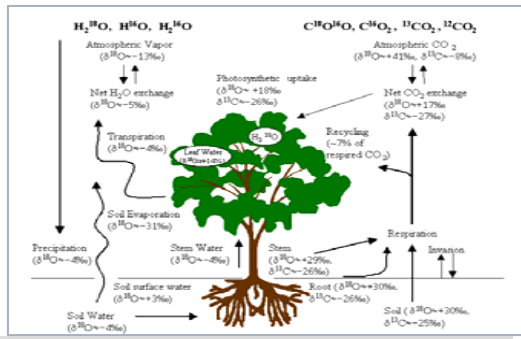
Example: Automatic process system at Yucheng station

(3) Exploiting observation technology with multi-approach and multi-scale in ecological research





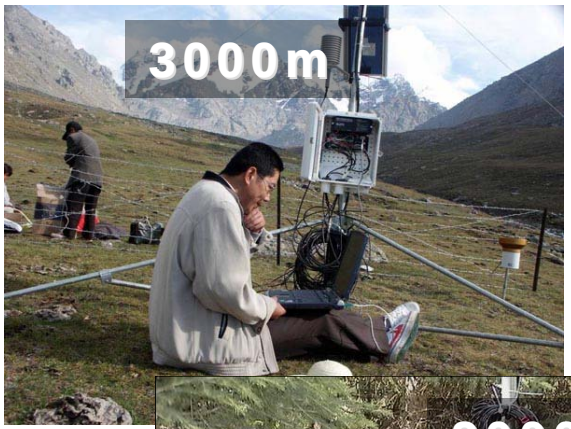


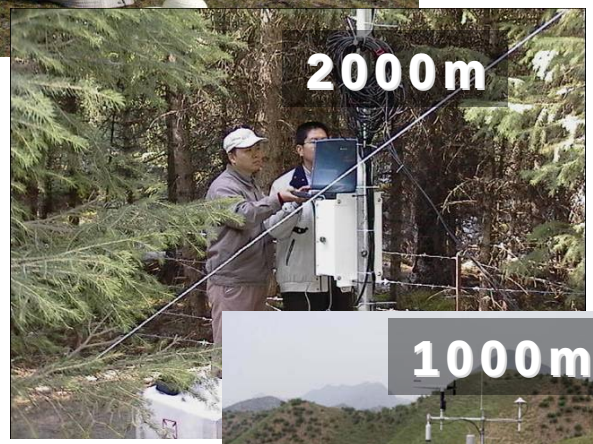


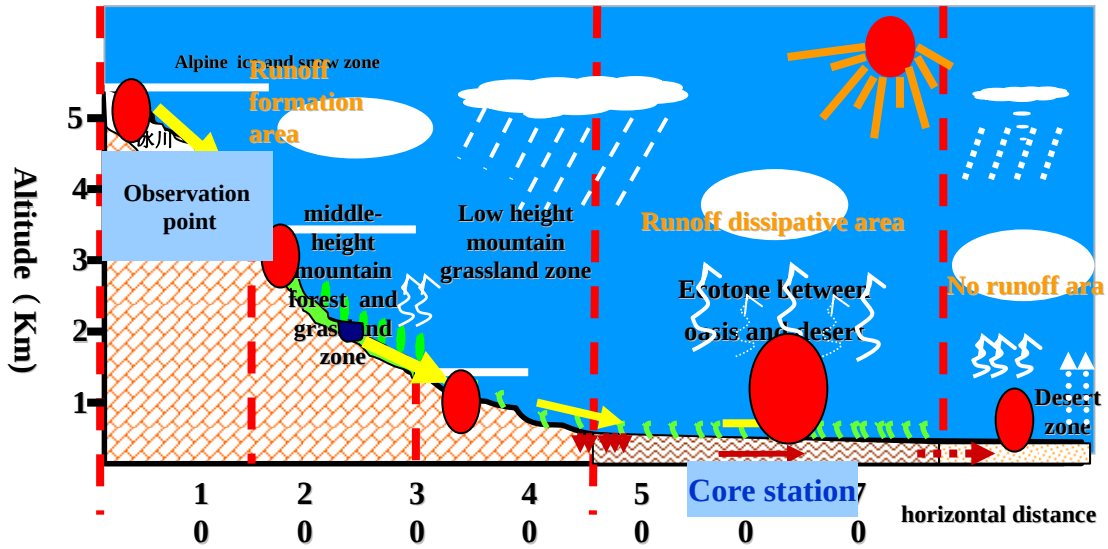




（4） Promoting the integrated observation in basins and critical ecological region based on regional core station



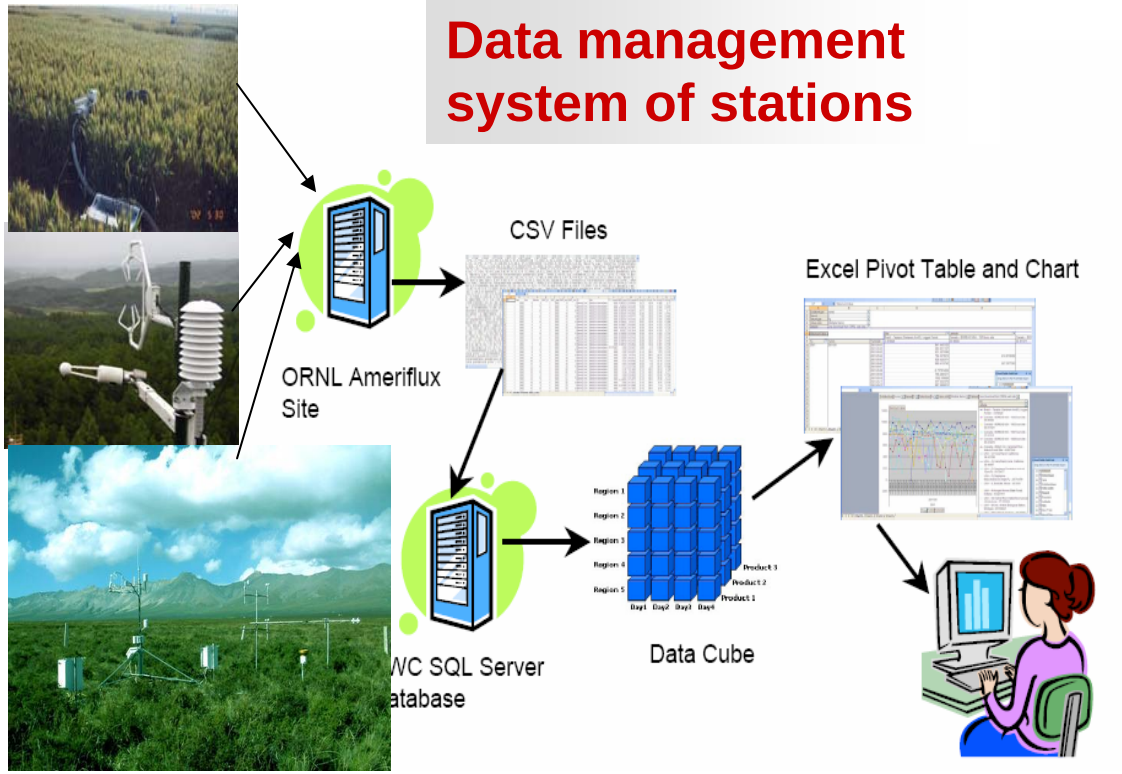


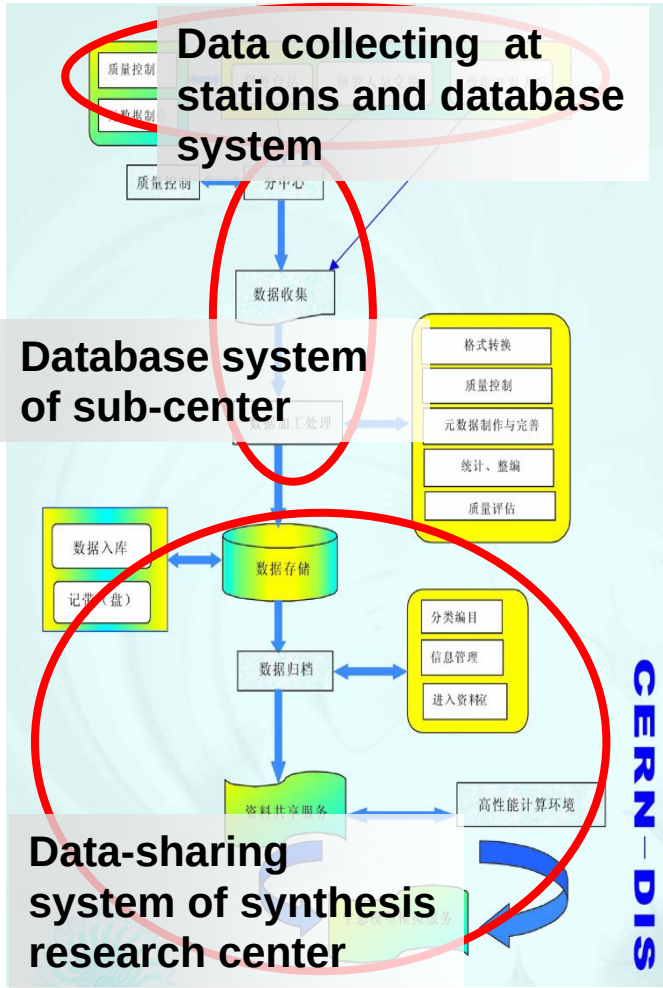


The profile of Sangong River Basin in Xinjiang, an enclosed small watershed in Inland river

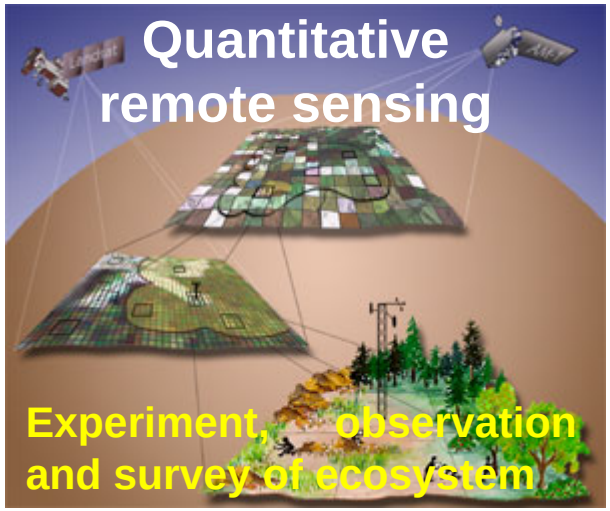
Mountain——Oasis——Desert

(5) Building up a remote management and sharing system with multi-sources data fusion

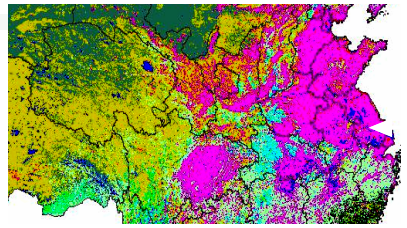




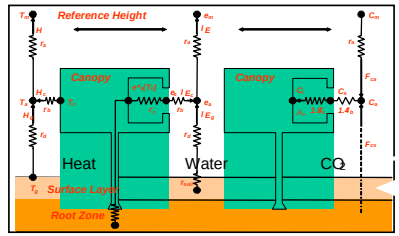
（6）Developing an integrated data-model fusion system of synchronous observation at cross-scale mechanism simulation



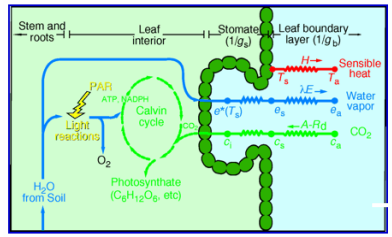
Landscape and regional ecosystem



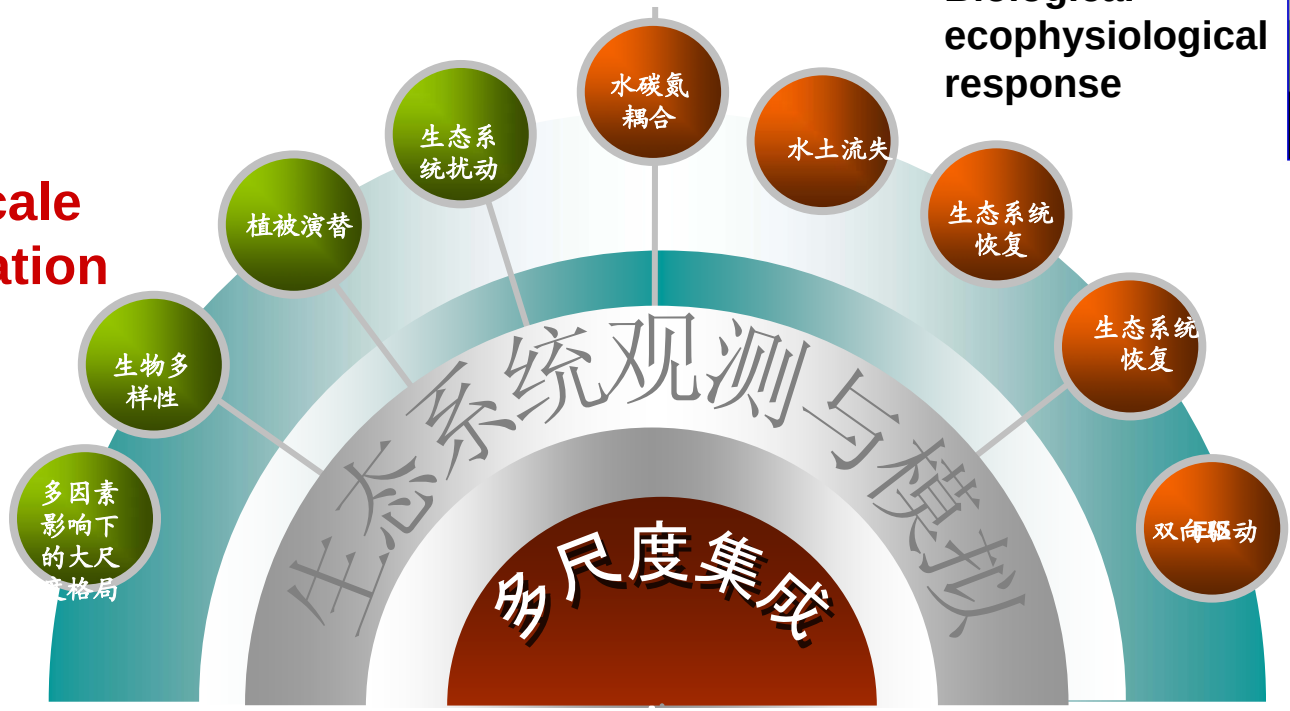
Soil-plant-atmosphere system



Biological ecophysiological response



Multi-scale observation



Cross-scale mechanism analysis and simulation

Research and Application

Key issues for research and application

(1) Observation and experiment study on ecosystem responses and adaptation based on transect method

(2) Ecosystem C and N fluxes and global change based on ChinaFLUX

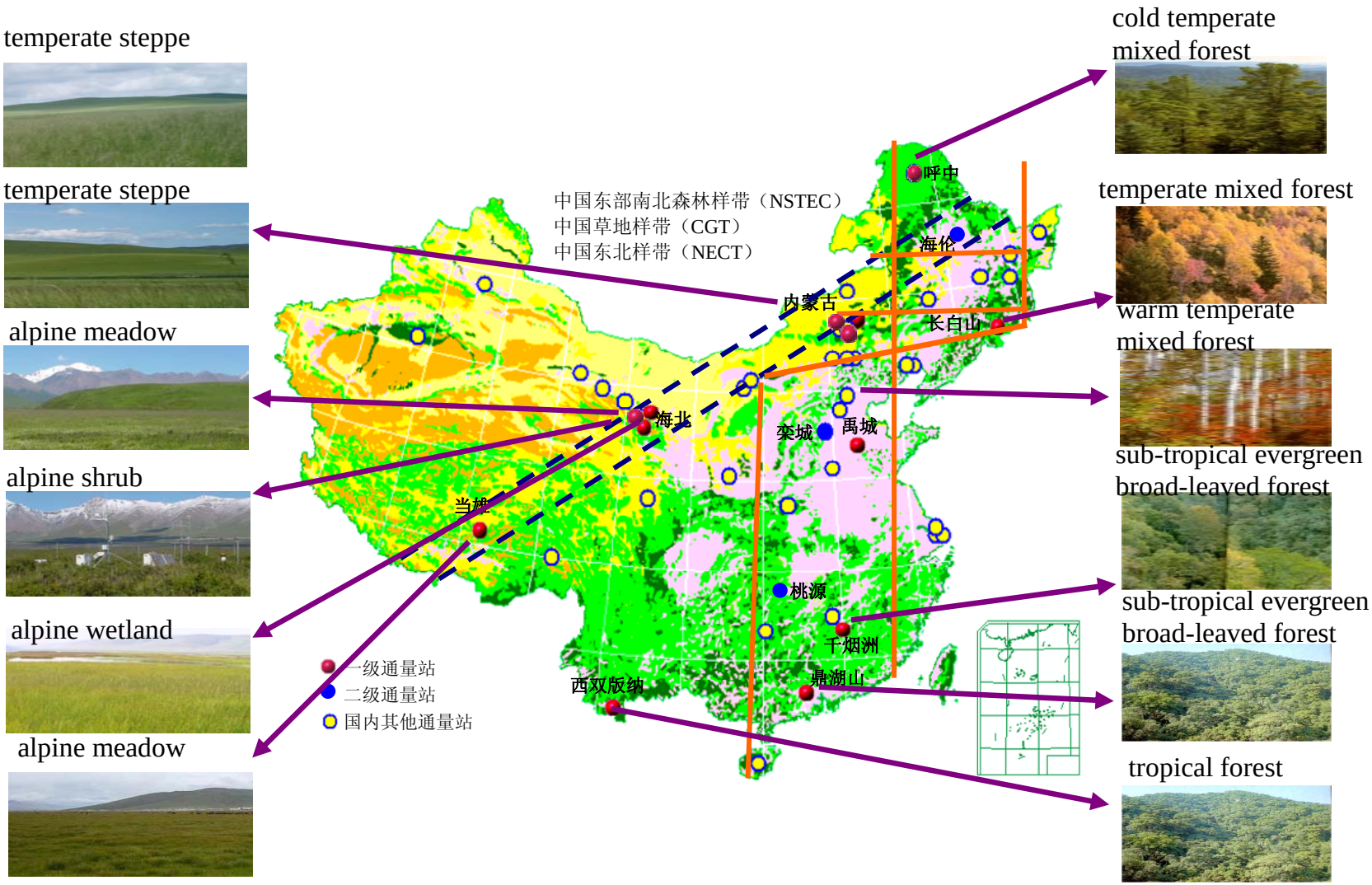
(3) Relationship between biological diversity and ecosystem function

(4) Experimental study on ecological restoration and demonstration in the western China

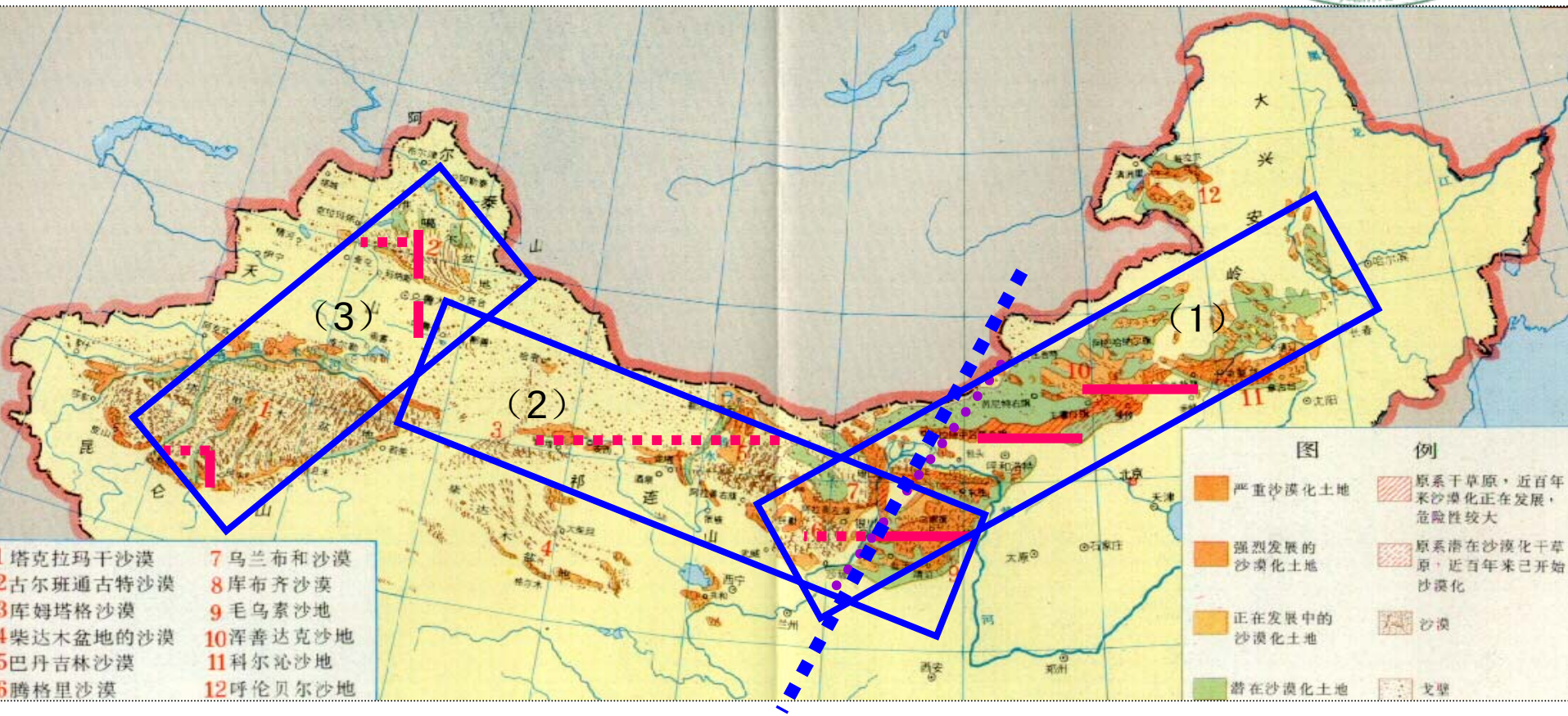
(5) Processes and control for agricultural non-point source pollution in the eastern China

(6) Mechanism and controlling technology of lakes eutrophication

(1) Observation and experiment study on ecosystem responses and adaptation based on transect method

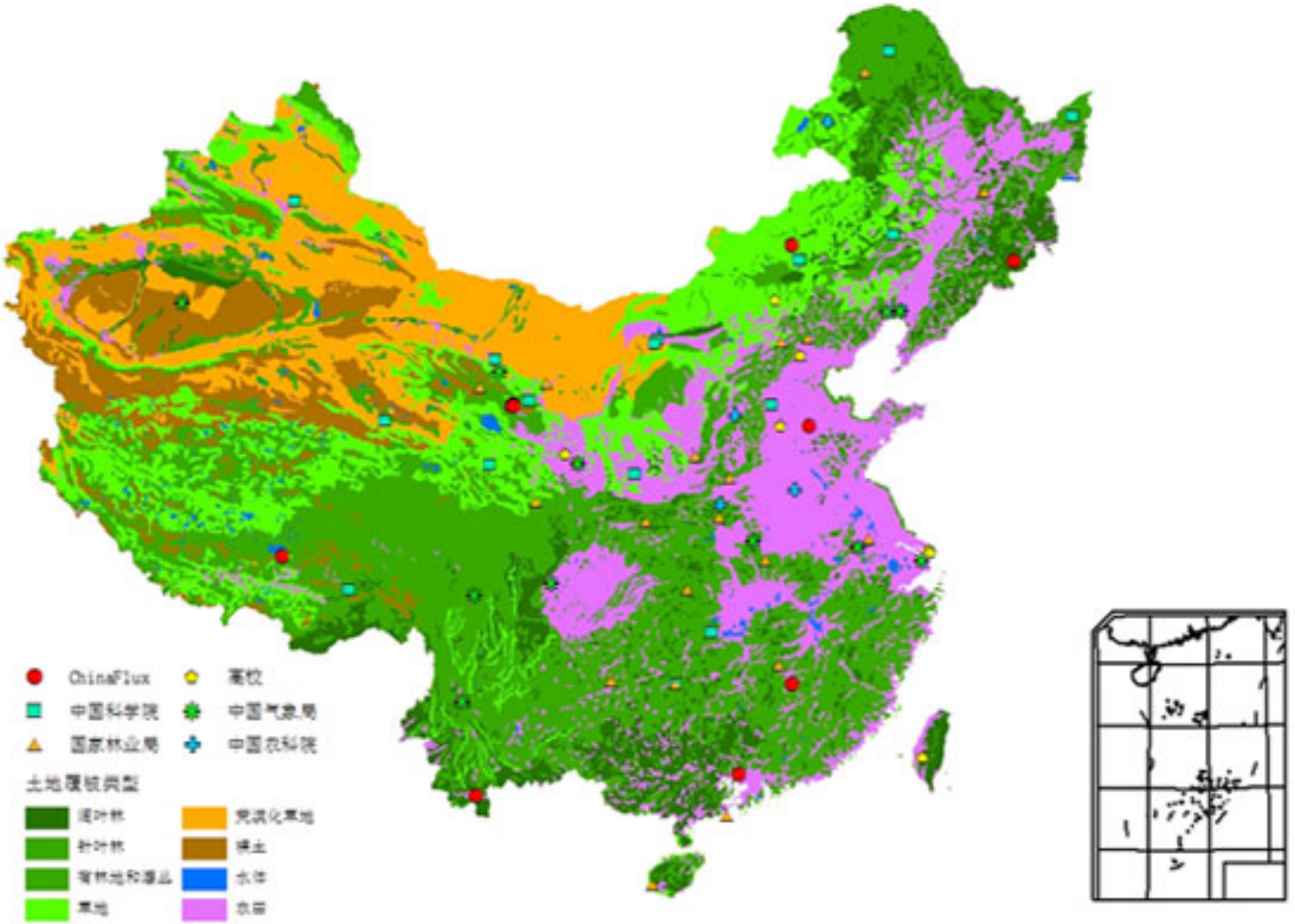


Study on the relationship between vegetation and moisture along the West-East desert transect in northern China



- ✓ **Elucidating the mechanism of maintaining vegetation's structure and functions based on eco-hydrological characteristics**
- ✓ **Illustrating the spatial variation of vegetation-moisture relationship along the desert transect in northern China**
- ✓ **Proposing management countermeasures of typical ecosystems and restoration mode of degraded vegetation along the desert transect in Northern China**

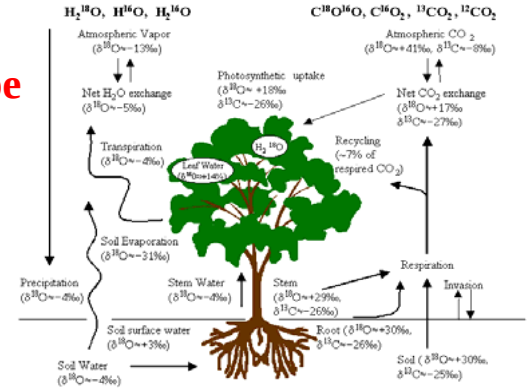
(2) Study on Ecosystem C and N fluxes and global change based on ChinaFLUX

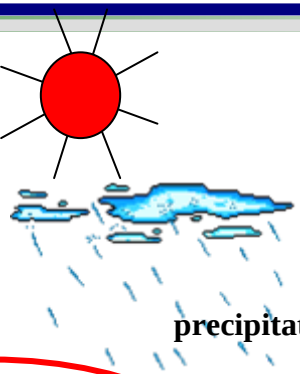


Spatial distribution of flux observation sites in China

Comprehensive observation of C, N &H_2O cycles

isotope





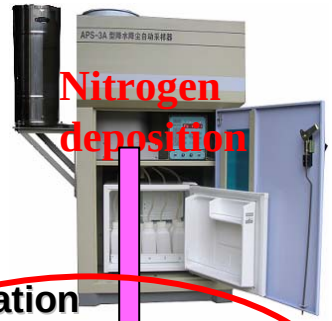
precipitation

photosynthesis

respiration

transpiration

N fixation



Nitrogen deposition

So respiration

litter

evaporation

N_2O

manure

Surface runoff

humification

SOM

immobilization

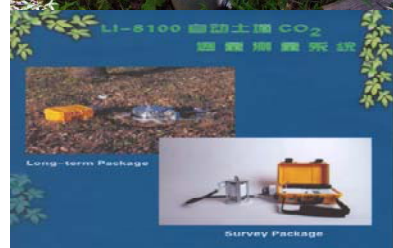
absorbtion

$(NH_4^+$ NO_2^- $NO_3^-)$

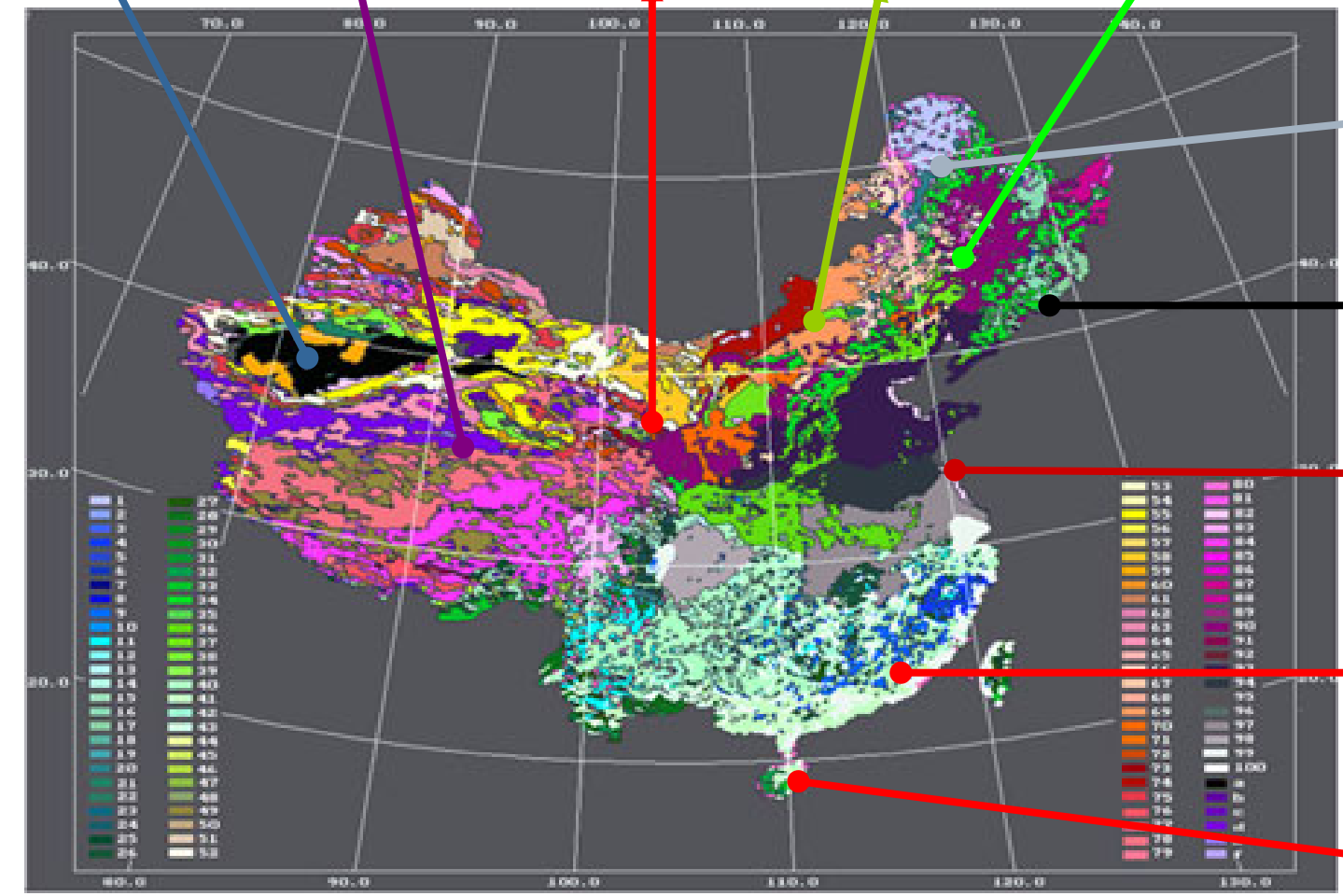
mineralization

nitrification

N leaching



5.3 Relationship between biological diversity and ecosystem function



Diverse ecosystems (Ma K.2006)

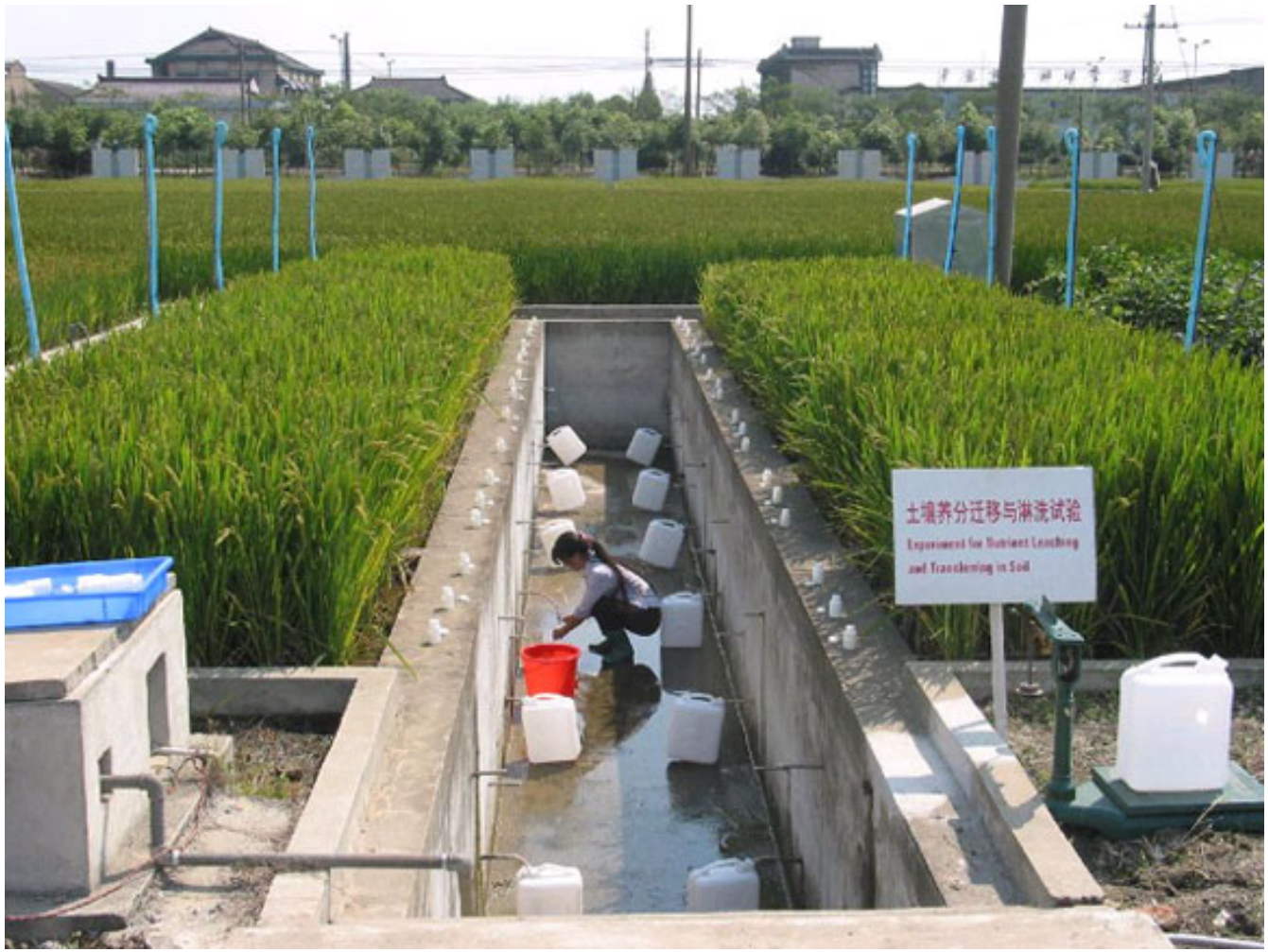
(4) Experimental study on ecological restoration and demonstration in the western China

8 demonstration regions of ecological restoration experiment in the western China

(5) Processes and control for agricultural non-point source pollution in the eastern China

- ✓ Monitoring N and P loss from cropland
- ✓ Process and mechanism of non-point source pollution
- ✓ Developing technology to control N and P loss from run-off
- ✓ Reasonable application of chemical and organic fertilizer
- ✓ Setting up the ecological engineering for reusing the nutrients

Monitoring Nitrogen loss by leaching (Lysimeter) in CERN station



(6) Mechanism and controlling technology of lakes eutrophication

Research contents:

- ✓ The key processes on transportation and transformation of pollutants
- ✓ Mechanism of endogenous nutrient load
- ✓ Response and feedback mechanism of ecosystem to lakes eutrophication
- ✓ Key driving factors of steady conversion and kinetics
- ✓ Technology of controlling major bioactive elements in lakes
- ✓ Principles and key techniques of lake ecosystem rehabilitation

THANK YOU !