Chinese Ecosystem Research Network (CERN): Achievements and Perspectives

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

- Consultation
  - Long-term monitoring
  - Scientific Research
  - Ecological application
  - Public Education

- Sci. & Tech.
- Society
- Agriculture
- Ecology
- Environment
- Living conditions
- International contribution
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

- Natural environmental changes
- Human activities

Changes in ecosystem pattern, processes and services and the underlying mechanisms

- Biotic communities composition, structure, biodiversity
- Ecosystem productivity, energy flow and materials and cycles
- Human-environment-ecosystem interactions
- Ecosystem management and acclimation to global changes
1.3 Research thought of CERN

**Scientific missions**
- Global Change Science
- International environmental convention
- Food production
- Natural resources management
- Environment protection
- Ecosystem ecology
- Ecosystem management
- Ecophysiology
- Biologic resource improvement

**Scale**
- Global
- Region
- landScape
- Ecosystem
- Individual

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

1. Missions and objectives of CERN
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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

(In 1988)

(In 2002)

(In 2007)
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 H₂O
2.3 Terrestrial Transects based on CERN

GCTE/IGBP Terrestrial Transects

- Kalahari Transect (KALA)
- Savanna on the Long-Term (SALT)
- North Australian Tropical Transect (NATT)
- Argentina Transect
- North East Chinese Transect (NECT)
- North American Mid-Latitude Transect (NAMER)
- Siberia Far East Transect (SIBE)
- Siberia West Transect
- Europe Transect
- Boreal Forest Transect Case Study (BFTCS)
- Alaskan Latitudinal Gradient (ALG)
- Amazon (LBA)
- Miombo Woodlands Transect
- SE Asian Transect
- North-South Transect of Eastern China (NSTE)
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 Haimei station

OTC at Inner Mongolia grassland station

FACE in Nanjing

OTC at Changbai Mo. forest station
2.5 Research platform for demonstration of ecosystem restoration in western China

Tarim River Basin

Heihe River Basin

Upper reach of Minpang River

HSDK

Loess Plateau
1. Missions and objectives of CERN
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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

- 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
Temporal and spatial pattern of radiation in China

Source: Synthesis research center, CERN
Temporal and spatial pattern of precipitation, accumulated temperature

Saturation deficit  
Accumulated temperature $>0,5,10,20\degree\text{C}$  
Mean wind speed

Mean annual precipitation  
Precipitation at 0,5,10,15 \degree\text{C}

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
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

Source: Synthesis research center, CERN
Spatial pattern of SOC and SIC storage in China

- SOC pool: $85.05 \pm 25.34$ Pg (1m)
  Mean SOC density: $10.57 \pm 3.15$ kg m$^{-2}$

- The SIC storage in China is $53.3 \pm 6.3$ Pg C
  (taking measured soil depth into account)
  Mean SIC density: $4.29 \pm 0.36$ kg C m$^{-3}$

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

- NEP had no 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

- 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

Forest’s NEP in China based on InTEC model:

1901-1949: \(-21.0 \pm 7.8\) Tg C yr\(^{-1}\),
1950-1987: \(-122.3 \pm 25.3\) Tg C yr\(^{-1}\),
1988-2001: \(176.7 \pm 44.8\) 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

Spatial pattern:
✓ negative relationship between Rs and latitude;
✓ positive relationship between Rs and annual precipitation

Source: Sub-center of atmosphere, CERN
Temperature and precipitation are the key factors controlling the carbon budget in terrestrial ecosystem in China.

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 continuum (SPAC)
✓ Polluted chemical effects of fertilizer and pesticide on environment and biologic rehabilitation
Fertility evolution of Black Soil and Paddy Soil

- 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 cycle in cropland in the North China Plain (kg N/ha)
Source: Luancheng site(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.
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
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

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
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

- 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
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 massive 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.

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 eutrophication of lakes and ecological rehabilitation

Controlling techniques of algae

- 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
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
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

Data Sharing System
- DELL 服务器 (CERN 网站系统)
- SUN V880 — DNS 服务器和邮件服务器
- 南京万全服务器 (网络服务器 — 数据库共享平台服务器)
- 空间服务器 (多台PC服务器)

Fusion System
- 联想PC 服务器 (全国尺度生物量数据)

Saving & Processing System
- 动态遥感数据库
- CERN 数据目录数据库 (SUN5500 Oracle 9)
- 数据空间数据库 (DELL 4000)
- ChinaFlux 数据库 (HP PROLIANT)
- 影像数据系统 (SGI图形工作站)

Input & Output System
- 输入设备
- 扫描仪
- 数字化仪
- 输入设备
- 绘图仪
- 彩色激光打印机

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
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Monitoring and Observation
Integrated multiple-scale and multi-technique measurement for research on ecosystem coupling cycle of C, H₂O and N.

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

Data management system of stations

Data collecting at stations and database system

Database system of sub-center

Data-sharing system of synthesis research center
Developing an integrated data-model fusion system of synchronous observation at cross-scale mechanism simulation

Multi-scale observation

Quantitative remote sensing

Landscape and regional ecosystem

Soil-plant-atmosphere system

Biological ecophysiological response

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.
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 & H₂O cycles

Photosynthesis

Respiration

Transpiration

Nitrogen deposition

Precipitation

Evaporation

Surface runoff

Litter

SOM

Humification

Absorption

Mineralization

Nitrification

Immobilization

N leaching

\(\text{NH}_4^+\) \(\rightarrow\) \(\text{NO}_2^-\) \(\rightarrow\) \(\text{NO}_3^-\)
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

Tarim River Basin

Hunshandake

Loess Plateau

Three-Gorges Reservoir

Upper reach of Minjiang River

Southwest Karst

Sources of three Rivers
(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
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!