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Chinese forest ecosystem research network: A platform for observing and studying sustainable forestry

Xiang Niu [1], Bing Wang [1, 2]* and Wen J. Wei [3]

[1] *Institute of Forest Ecology and Environmental Protection, Chinese Academy of Forestry, Beijing 100091, China.* [2] *Chinese Forest Ecosystem Research Network Center, Chinese Academy of Forestry, Beijing 100091,China.* [3] *Liaoning Academy of Forestry, Shenyang 110032, China. *e-mail: wangbingcfern@hotmail.com.*

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Abstract

Long-term research network is a power tool for studying the structure and functions dynamics of forest ecosystems at regional, national and global scale. In particular, it is essential to construct such a nationwide network in terms of implementing scientific research and the result-based implication in policy making. Over the last two decades, a great progress has been achieved in the establishment of the Chinese Forest Ecosystem Research Network (CFERN), with some distinct features relative to other nation-scale networks in the world. Currently, as the largest forest ecosystem research network of a single ecosystem type, CFERN consists of more than 70 stations, covering 49 forest types across the country, which is a platform for observing and studying sustainable forestry. In the arrangement of CFERN stations, crucial geographical, climatic, biological and human factors, such as temperature, moisture, landscape topography, Chinese ecological function zoning, biodiversity hotspots and critical areas of forests, were integrated at the national level. Among CFERN stations, two national-level transects, the North-South Transect of Eastern China (NSTEC) (heat-based) and West-East Transect of Southern China (WETSC) (moisture-based), were set up, respectively. To efficiently run the CFERN, a series of general guidelines have been developed for station infrastructure construction, biological and environmental monitor, data management and application for local stations. Utilizing the data of CFERN, scientific research results have been achieved and some were used for national- and international-level policy making. All these information of CFERN was systematically introduced in this paper, with great help to scientists, managers, policy makers and the public, who are concerned with the characteristics and functions of China's forest ecosystems at the national and international scales, especially this network was regarded as a platform which plays a role in communicate with experts in other countries.

Key words: Long-term, ecological research, spatial distribution pattern, guideline.

Introduction

Ecosystems and natural resources have been an integral part of the national and global infrastructure for science research and public service, and these properties have guideline for decision makers and managers [1]. Key cognitive of that few ecosystems are free of extensive human influence [2]. Although many studies have examined human-nature interactions [3], the complexity of coupled systems has not been well understood [4-5]. With the fast socioeconomic development, the strong negative effects on the ecological environment emerged, including environmental deterioration and natural resources destroyed. These serious consequences resulted from insufficient understanding on complexity coupled of natural system and human. Understanding and mitigating the consequences of global environmental changes will require an integrated global effort towards comprehensive long-term data collection, synthesis, and action [6]. The Long-term Ecological Research (LTER) is proposed in 1980 as a groundbreaking collaborative effort to investigate ecological processes in the United States over broad spatial and long temporal scales [7], and also has promoted synthesis and comparative research across sites and ecosystems [8-10].

Addressing global climate change has become an increasingly important issue influencing ecosystem management around the globe [11]. The lack of progress is largely due to the separation of field observation and ecological issues, and transformation from small scale to large scale. Although some scientists have realized the importance of studying long-term phenomena in ecology, major advancement in long-term ecological research has not yet been made in many parts of the world [12]. The shortage of comprehensive and reliable data from Asian regions is a serious impediment to understanding and mitigating the impacts of climate and environmental change [13-15]. An increasing number of interdisciplinary programs have been integrating ecological and social sciences to study the interactions between human and natural systems [16]. Meanwhile, network theory has proven to be a fruitful area of research for examining the interactions between the components of a system [17]. Forest ecosystem long-term research is become more and more attention in evolving social issues and science questions calling for sustained and interdisciplinary studies at contemporary.

As the third largest country in the world, China occupies approximately 6.5% of the global land area and stretches about 5500 km from north to south and about 5000 km from east to west. Across the country, there are a variety of topographies, climates, soils and anthropogenic disturbances, resulting in a great diversity of forest ecosystems in terms of composition, structure and function. In order to exemplify these spatially and temporally extensive and multifaceted changes to ecology, long-term research is essential for ecologist and relevant major's scientists. As declared by the Food and Agriculture Organization of the United Nations (FAO) in March 2010, China is one of the five most forest-rich countries in the world, and its large tree-planting program accounts for most of the recent gains in forest area [18]. Chinese Forest Ecosystem Research Network (CFERN) is a platform for scientists to understand ecological environments influenced by human activity and the responses of global changes. Meanwhile, it can support a series of observation data as cornerstone for ecological research and policy-making. For instance, the largest areas of forests not only provide timber but also supply ecosystem services for human, and several studies showed the high value of forest ecological services [19-22]. To quantify the value of forest ecosystem service accurately, it needs to know the ecological processes depends on CFERN, such as forest structure and functions, human and natural system, always some phenomenon cannot be investigated by means of disparate studies conducted at individual sites or in short periods of observation.

In this article we describe the missions and its history of CFERN, highlight the characteristics and development concept of CFERN as a platform for research. We pay particular attention to the CFERN's spatial distributed pattern and its planned strategy to 2020. We introduced the two main transects to addressing scientific issues across the broad temporal and spatial gradients, which are the North–South Transect of Eastern China (NSTEC) and the West-East Transect of Southern China (WETSC). Also, we elucidate the criterion systems should be followed from station establishment, field observation and research, data management to data applications. To do so, network study must be reinforced with spatial scales of different ecological space that is of interest to resource conservation and addresses where the problems are rooted and the changes at the scales of time and space, the complexity of the natural system challenges facing humanity. The useful of CFERN can be regarded as tools for government managers and policy-makers to make decisions, and also can be shared among scientists and members of the public in different countries.

Missions of CFERN

CFERN is a continental-scale research platform for discovering and understanding the fundamental ecological principles that govern the structure and function of forest ecosystems and their responses to environmental variables. With the aim of confronting a series of serious environmental issues, the three main missions of CFERN are as follows: (a) to study the responses of ecosystems and their components to natural and human-induced changes, such as climate change, across a range of spatial and temporal scales by acquiring long-term observation data from advanced facilities and instruments, (b) to provide database to decision makers, that will assist with the design of a comprehensive and sustainable management plan for the environment and to help popularize science among the public widely and (c) to enable educators to better understand ecological issues based on CFERN data, information, and forecasts.

A Brief History of CFERN

The establishment of research network has long been a matter of interest to ecologists [23]. A wide variety of ecological research network exists in the world, and these types of networks differ greatly in a number of respects, including forest, grassland, agriculture, wetland and multi-type ecological network. As a forest network of the largest number in single ecosystem type in the world, CFERN has experienced considerable changes over its development, the history can be briefed as follows. In fact, ecologist dedicated to the ecological research in the late 1950s. At that time, biogeographic methodology of the former Soviet Union was adopted and the first research site was established in Sichuan Province. Subsequently, an initial phase of specific site-scale and short-term observation and research were started. In the 1970s, long-term observation and research at forest ecosystem station was initiated along with the adoption of ecosystem theory and monitoring methods refer to Europe and the United States, but the network research was not started. As the increasing of forest ecosystem stations, the network of observation and research has been enlarged since 1992, and CFERN was established official at the same time, only 11 forest ecosystem stations included of the network. Until 2000, there are 15 forest stations exist belong to CFERN. Which were located in different vegetation regions (Table 1).

Over the past several decades years, as a major component of the Global Terrestrial Observing System (GTOS), the International Long-Term Ecological Research network (ILTER), the Environmental Change Network (ECN) and the AsiaFlux regional research network, CFERN has played an important role in research both domestically and abroad, which can be considered as an efficient platform for all scientists pursuing relevant ecological research. Currently, there are 70 stations of the CFERN (Fig. 1), which is the largest network with the quantity and forest types in single ecosystem types. Extensive observational data on ecosystem features such as hydrological, pedological, atmospheric and biological elements is acquired through CFERN's advanced facilities and instruments. In addition, ecological research of CFERN has undergone significant changes such as from individual sites to a national network, and the scales from short-term to long-term.

Characteristics and Development Concept of CFERN Platform

In a review of ecological research networks from around the globe, CFERN was needed to understand ecological systems and how they respond to human activities. Compared with other ecological network at home and abroad, CFERN showed differ with other networks in aspects of characteristics and development concepts (Fig. 2), which can be briefed as follows.

Multi-sites joint: Researches based on one single station and between stations are not synergy, and it is difficult to judge its accuracy and make comparison of the field data in one station in the ecological region. As a result, there are more stations gradually established in one ecological region as the development of CFERN, and compared and summarized the results between stations, formed the transects and watershed research, so as to better predicting the responses of ecosystems to global changes.

Multi-systems combination: CFERN not only focus on the forest vegetations, but also concerns on the hydrological, pedological, atmospheric, biological elements and human social systems. From the external environment to the internal structure, it is a coupled system with complex relationships. Increasing human demands for ecosystems products and services drive the alteration of most ecosystems of the world, either directly through on-station land

Table 1. Stations of CFERN and their distribution in the 9 vegetation regions of China*.

Vegetation Region	Established Stations	Planned Stations
I. Northeastern temperate mixed coniferous and broadleaf forest (Northeastern Region)	1 Heilongjiang Mohe; 2 Inner Mongolia Greater Higgnan Mountains; 3 Heilongjiang Nenjiangyuan; 4 Heilongjiang Lesser Khingan Range; 5 LS-Heilongjiang Liangshui; 6 Liaoning Binglashan; 7 Jilin Songjiangyuan; 8 Heilongjiang Mudanjiang; 10 Heilongjiang Maoershan	9, 11, 12
II. Northern China warm temperate deciduous broadleaf and *Pinus tabulaeformis* forest (Northern Region)	13 Liaoning Baishila; 14 Liaoning Liaodongbandao; 15 Beijing Yanshan; 16 Shouduquan; 17 Hebei xiaowutaishan; 19 Henan Yuzhou; 20 Shanxi Taiyueshan; 21 Shanxi Taihangshan; 22 Henan Huanghe xiaolangdi; 23 Shanxi Jixian; 24 Shandong Kunyushan; 25 Shandong Taishan; 26 Shandong Qingdao; 27 Shandong Huanghesanjiaozhou; 28 Henan Huanghuaihaipingyuan; 30 Ningxia Liupanshan; 31 Gansu Xinglongshan; 32 Gansu Xiaolongshan	18, 29, 33
III. Central southeastern subtropical broadleaf evergreen forest and *P. massoniana*, *Cunninghamia lanceolat* and *bamboo grove* forest (Central Southeastern Region)	34 Shanxi Qinling; 36 Hubei Shennongjia; 37 Hubei Zigui; 38 Henan Baotianman; 39 Henan Jigongshan; 40 Jiangsu Changjiangsanjiaozhou; 41 Anhui Dabieshan; 42 Anhui Huangshan; 43 Zhejiang Tianmushan 45 Chongqing Jinyunshan; 46 Chongqing Wulingshan; 47 Hunan Huitong; 48 Guangxi Lijiangyuan; 49 Guizhou Karst; 50 Jiangxi Dagangshan; 51 Zhejiang Qianjiangyuan; 52 Zhejiang Fengyangshan; 53 Fujian Wuyishan; 55 Guangdong Yanhai; 56 Guangdong Dongjiangyuan; 57 Guangdong Zhusanjiao; 58 Guangdong Nanling; 59 Guangxi Dayaoshan	35, 44, 54
IV. Yunnan-Guizhou plateau of subtropical broadleaf evergreen forest and *P. yunnanensis* forest (Yunnan-Guizhou Plateau Region)	61 Yunnan Dianzhonggaoyuan; 62 Yunnan Yuxi; 63 Yunnan Gaoligongshan	60, 64, 65
V. Southern tropical monsoon rain forest and rain forest (Southern Tropical Region)	66 Guangdong Zhanjiang; 69 Guangxi Youyiguan; 70 Yunnan Puer; 71 Hainan Wenchang; 72 Hainan Jianfengling	67, 68
VI. Southwestern high mountains and gorges coniferous forest (Southwestern High Mountains Region)	75 Sichuan Wolong; 76 Sichuan Emeishan; 78 Xizang Linzhi	73, 74, 77, 79
VII. Eastern Inner Mongolia forest-steppe and steppe region(Eastern Inner Mongolia Region)	80 Hebei Saihanba; 81 Inner Mongolia Saihanwula; 83 Inner Mongolia Daqingshan; 85 Inner Mongolia Erdos; 86 Ningxia Helanshan	82, 84, 87
VIII. Inner Mongolia-Xinjiang desert, semi-desert and mountain needleleaf forest (Inner Mongolia-Xinjiang Region)	90 Gansu Qilianshan; 93 Xinjiang Tianshan; 94 XinjiangAertaishan; 96 Xinjiang Talimuhe Huyanglin	88, 89, 91, 92, 95, 97
IX. Qinghai-Tibet Plateau steppe meadow and alpine desert region (Qinghai-Tibet Plateau Region)		98, 99

* Adopted from references (52-53). The stations underlined were established before 2000.

use by human system and indirectly through altered climate, altered atmospheric chemistry, altered watershed conditions. Therefore, it is critical for advancing this line of research especially the natural system and human system.

Multi-scales fitting: Scientists realized that the studies of temporal and spatial scales were meaningfully. In terms of temporal scale, abundant data were acquired in different years, which is the basis on study of influences of global changes on ecosystem and responses of ecosystem to global changes in time series. More and more studies focus on long-term rather than short-term. There were some differences between long-term and short-term research. A key difference is that long-term research provide insight to the causes of the changes in the slope of responses, the causes of the inflection points, and the magnitude of the long-term change, whereas the short-term focused only on the initial trajectories [24]. Based on CFERN, the spatial scales from individual, population, community, ecosystem to landscape were considered in the ecological process study. At the same time, the methodology of spatial instead of temporal were adopted in scientific research.

Multi-targets fusion: Normally, a station is not limited in a single study, but several research targets together. According to the CFERN, we are not only address the relevant scientific issues in regional forestry, but also offer the basic data for the national needs. It considering the multiple scientific issues such as climate changes, land use, ability of carbon fixed, net primary productivity, and interaction between hydrological, pedological, atmospheric, biological elements and human activities. That is to say, research conducted at CFERN stations have many advantages in terms of supported programs because of the long-term research in CFERN stations. Also, long-term research can provide pretreatment and reference-system data, as well as the basis for identifying ecological surprises, such as climatic events [25, 26].

CFERN provided more systematic data for forest ecological research by using muti-site joints. It supplied more abundant information with multi-systems combination, and offered scientific methods for conversion of forest stand scale into regional scale through multi-scales fitting.

The Spatial Distributed Pattern of CFERN and Planned Strategy to 2020

The spatial distributed pattern of CFERN is fundamental and guarantee for distributed measurement methodology in evaluation and offered data derived from different regions. CFERN is based on a stratified and multi-tiered design that combines limited coverage of the whole of China with more intense deployment of infrastructure in carefully selected representative areas, on

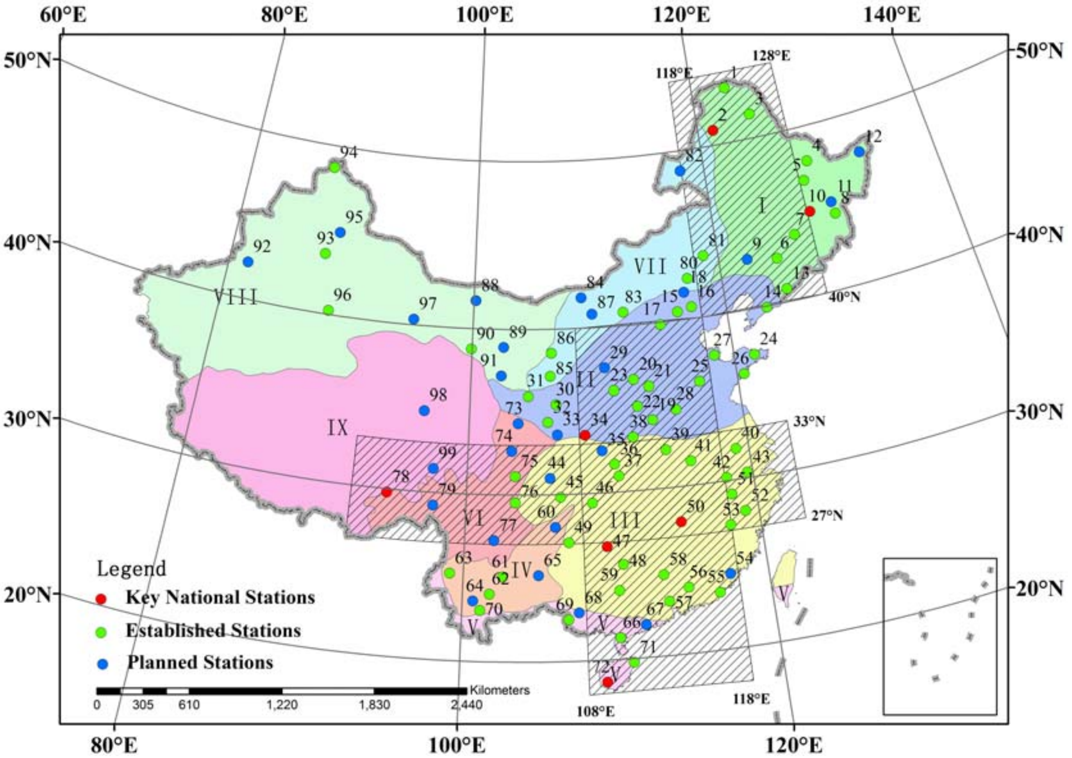

Figure 1. Distribution of Chinese Forest Ecosystem Research Network. Red dots indicate the key national stations, green dots the established stations and blue dots the stations planned for establishment by 2020. The NSTEC and WETSC are indicated by the hatched areas. The stations' name and their vegetation regions were showed in Table 1.

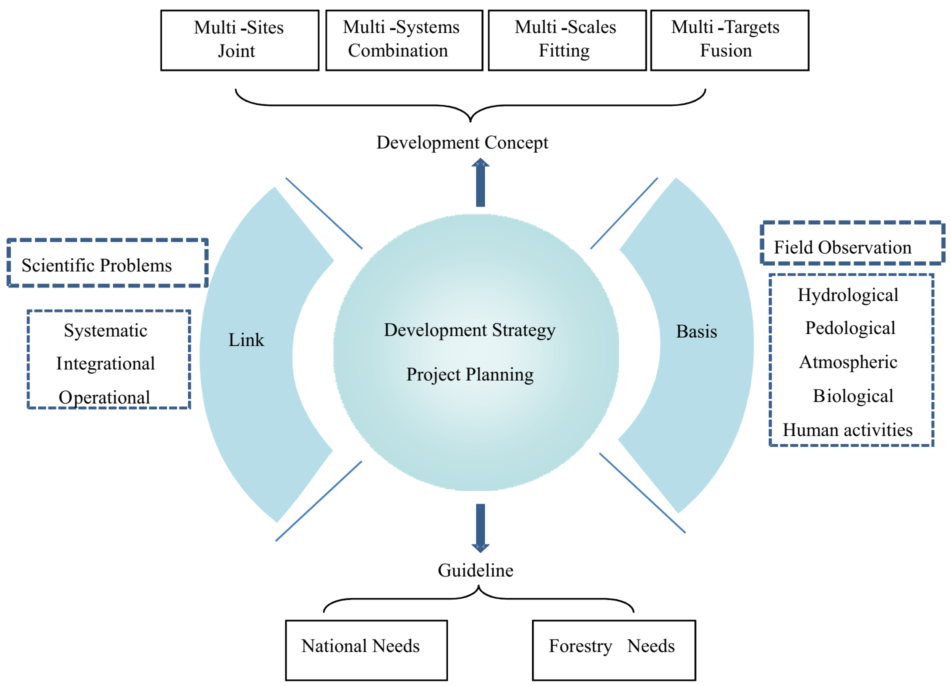

Figure 2. The Characteristic and Development Concept of CFERN.

gradients critical for understanding particular drivers of and responses to changes, along with other stations of special interest [27, 28].

On macro level, the distribution of vegetation in China is regional difference, which main reflect three aspects, such as from south to north along longitude, from east to west along latitude and from low to high along vertical space. For this reason, typical sampling layout was put forward, and the spatial distributed pattern of CFERN was formed. Several critical factors have been considered in determining station distribution. Some of these factors were selected following the distribution of typical sample design concept used by the National Ecological Observatory Network (NEON) [28] and INDOFLUX [29], including temperature, moisture and landscape topography indicators, which were adopted in the Eco-geological Region System in China [30]. Vegetation types were categorized into 9 vegetation regions and 48 vegetation subregions according to the Chinese forest distribution characteristics [31]. Also, Chinese ecological function zoning [32] and biodiversity hotspots and critical areas were regarded as the significant indicators [33].

Statistical methods such as multi-level analysis and principal component analysis were used to help optimize the placement of CFERN stations based on the indicator standards. GIS and RS were served as approaches used to analyze the superposition of multiple layers. Scientific issues such as forest and the environment, the value of forest ecosystem services and human activities, and the response of forest ecosystem to climate change, and policy issues such as government investment intensity and attitude, which were considered comprehensively, ultimately, there need 99 stations of CFERN at least by the year 2020 [34] (Fig. 1, Table 1). The CFERN contains representatives of 49 forest cover types and 31 provincial administrative regions in China. Each station represents a distinct eco-region of vegetation, landforms, climate, and ecosystem performance. The greatest station number of CFERN is 70 at present (Table 1). From the present to 2020, 29 additional stations will be established in the next step, with a distribution as shown in Fig. 1.

Transects of CFERN

Global climate change and global environmental change are real concerns [35]. Transect research is an important and effective approach to better understanding the mechanisms of vegetation changes under climatic change, the spatial and temporal dynamics of multiple drivers and complex responses and ecosystem structure, functions and processes along gradients of water, heat and altitude. Research at transects involves a diverse portfolio of basic and applied studies with short and long-term planning horizons. At present, CFERN has a well-designed and well-developed network distributed throughout the different climate zones in China. Based on long-term research, two transects, the North–South Transect of Eastern China (NSTEC) and the West–East Transect of Southern China (WETSC) are existed (Fig. 1), which are typical of forest types in terms of different water and heat condition.

The North-South Transect of Eastern China (NSTEC)

The NSTEC, which covers one of the politically, economically and culturally most important regions of China, has a temperature-driven gradient that extends over seven climatic zones from the cold temperate east continental monsoon climatic zone in the north to the equatorial monsoon climatic zone in the south. This transect is located between 118°E and 128°E north of Beijing (40°N) and between 108°E and 118°E south of Beijing. The NSTEC was designated by the IGBP as one of 15 international transects in 1999. One research objective of the NSTEC is to study the interaction between global change and agricultural ecosystems (farmland, forest and grass) at local, landscape and regional scales. The straight-line length of the NSTEC from north to south exceeds 3700 km, and the width is 10 degrees of longitude. This transect is unique because it includes a continuous belt of vegetation over a heat gradient [36]. Some of the research that makes use of the NSTEC concerns temporal variation in addition to spatial variation. Thirty-four of the CFERN forest stations are included in the NSTEC transect (Table 2). These range from the Jianfengling station, Hainan Province, in the tropical zone, to the Greater Higgnan Mountains station, Inner Mongolia Autonomous Region, in the cold temperate zone. Light, temperature and water resources vary along the transect, with an overall diminishing trend from south to north. Much of the uniqueness of the NSTEC can be attributed to the presence of the Qinghai-Xizang (Tibet) Plateau, the highest mountain region in the world, because the exchange of moisture and energy is inhibited between the two sides of the plateau.

The West–East Transect of Southern China (WETSC)

The WETSC has been formed gradually on the basis of transect theories, especially the advanced foreign theories concerning long-term ecosystem research. The WETSC lies between 33°N and 27°N, and 30°N is considered its center. At this latitude, unlike in other countries, there are almost no deserts in China. Warm and moist air from the Indian Ocean passes through the Himalayas, enters Yunnan province and moves eastward along the Yangtze River. At the same time, warm and moist air from the Pacific Ocean flows into China from southeastern coastal areas. These two strands of warm and moist air converge in the central southern region of China, bringing plenty of rainfall and maintaining the "oasis" at this latitude. The vegetation distributed along the Yangtze River serves as a significant corridor for ecological and environmental protection and as an important basis of sustainable social and economic development.

This transect, which has also been called the Yangtze River transect, reflects changes in water, heat and especially altitude. Temperature zones in the transect range from the warm temperate zone to the subtropical zone and the plateau temperate zone, and the moisture zones range from the humid zone to the sub-humid zone. The WETSC covers altitude categories from 0 m at sea level up through low, middle, sub-high and high altitudes to extreme high altitudes higher than 6000 m.

Sixteen stations of CFERN were established to promote the formation of the WETSC, from Wuyishan station in Fujian Province, to Linzhi station of Tibet, and the ecological conditions present at each station are listed in Table 3. The Linzhi station, located at the top of the Yarlung Zangbo canyon area, is presently the only forest station in the center of the Qinghai-Tibet plateau. This high-altitude station has already yielded highly important research results and played an important role in the international ecological monitoring network. Warm temperate deciduous broadleaf forest, northern subtropical broadleaf evergreen and deciduous forest and mid-subtropical broadleaf evergreen forest comprise the major forest types covered by the WETSC. Researching the relationships between climate change, environmental change and forests driven by temperature, moisture and altitude is the major goal underlying the WETSC.

Guidelines of CFERN

It is need to a series of guidelines of CFERN in light of standardization management. As a national scale network, the criterion systems of CFERN was motivated by the need to establish excellent station and compare studies in different vegetation region and administrative region, these in order to enable a deeper understanding of the ways in which key drivers altered forest ecosystem structure and function. As a national network, criterion system is the data guarantee of addressing ecological issues. Long-term ecosystem research, as has widely been carried out internationally, is a major approach to study ecosystem structure and functions and an important means of acquiring data on the interaction between global change and terrestrial ecosystems [37]. Some of the CFERN field monitoring specifications and data management methods were drawn up according to relevant knowledge in foreign countries. For instance, technical notes and database design refer to the standard protocols published by the UK environmental change network (ECN). These criterions, which specify station construction, data collection methods and data management protocols for all stations, can be viewed online as PDF files at http://www.Chinabzw.com/.

The criterion systems of CFERN can be grouped into four categories [38-47]. First, the establishment of station was concerned,

Table 2. Stations of CFERN in the NSTEC *.

Forest Station	Longitude	Latitude	Days With Temperature ≥10 ºC	Accumulated Temperature (ºC)	Annual Aridity Index	Soil Type (s)	Landform Type (s)	Altitude	Area Vegetation Type
1	122°44′	52°51′	<100	<1600	<1	S1	Mountains	MA	Greater Higgnan Mountains *Larix gmelinii* forest
2	121°30′	50°50′							
3	125°16′	50°42′							
10	128°00′	44°58′	100~170	1600~3200(3400)	<1	S2, S3, S4, S5	Plains	LA MA	Sanjiang plain grass meadow and scattered forest
7	126°12′	43°36′	100~170	1600~3200(3400)	<1	S1, S3, S5, S6	Mountains and hills	LA MA	Changbai mountain *Pinus koraiensis* and broadleaf mixed forest area
6	124°30′	42°30′							
13	124°50′	40°53′	170-220	3200(3400)-4500(4800)	<1	S7, S8, S9, S10	Hills and mountains	LA	Liaodong Penninsula mountains and hills *Pinus densiflora*, *Pinus tabulaeformis* and *Quercus* forest
14	122°58′	39°58′							
81	118°36′	44°13′	100~170	1600~3200(3400)	1.5-4.0	S1, S11	Mountains	MA	Hulun Buir, southeastern Inner Mongolia forest-steppe
34	110°42′	33°32′	220-240	4500(4800)-5100(5300)	<1	S3, S7, S8, S12, S13	Mountains, hills and basin	SHA	South slope of Qingling Dabashan mountains deciduous broadleaf evergreen mixed forest
36	110°25′	31°45′							
37	110°96′	30°82′							
28	115°00′	34°24′	170-220	3200(3400)-4500(4800)	1.00-1.49	S7, S9	Plains	LA	Huabei plain scattered deciduous broadleaf and agricultural protection forest
19	113°47′	34°16′	170-220	3200(3400)-4500(4800)	1.00-1.49	S7, S8	Mountains and hills	MA SHA	Shanxi and Hebei Province mountains loess plateau deciduous broadleaf, *Pinus tabulaeformis, Pinus bungeana* and *Platycladus orentalis* forest
20	112°32′	36°05′							
21	112°23′	37°38′							
22	110°42′	35°54′							
23	110°65′	36°12′							
25	117°13′	36°18′	170-220	3200(3400)-4500(4800)	1.00-1.49	S7, S14	Hills and mountains	LA	Shandong mountains and hills deciduous broadleaf, *Pinus tabulaeformis*, *Pinus densiflora* and *Platycladus orentalis* forest
38	111°55′	33°28′	220-240	4500(4800)-5100(5300)	<1	S7, S10, S12, S15, S16	Mountains, hills and plains	LA MA	Changjiang-Huaihe plain hills deciduous broadleaf evergreen and *Pinus massoniana* forest
39	114°03′	31°49′							
41	115°35′	31°15′							
50	114°40′	27°40′	240-285	5100(5300)-6400(6500)	<1	S15, S17	Mountains and hills	LA MA	Southeastern hills and low mountains broadleaf evergreen, *Pinus massoniana*, *Pinus taiwanensis*, *Phyllostachys pubescens* and *Cunninghamia lanceolat* forest
53	117°24′	27°44′							
47	109°45′	26°50′	240-285	5100(5300)-6400(6500)	<1	S15, S18	Hills and mountains	MA	Middle hills montane broadleaf evergreen, *Pinus massoniana*, *Cunninghamia lanceolat* and *Phyllostachys pubescens* forest
48	110°27'	25°53'							
46	108°44′	29°28′							
58	112°42′	42°42′	285-365	6400(6500)-8000	<1	S15, S18, S19	Mountains and plains	LA	Southern slope of Nanling and Fujian coastal broadleaf evergreen, *Pinus massoniana* and *Cunninghamia lanceolat* forest
56	114°22′	24°06′							
57	113°30′	22°54′							
55	116°69′	23°39′							
66	110°21'	21°16′	365	8000-9000	<1	S9, S20	Plains and hills	LA	Guangdong coastal plain hills and mountains monsoon broadleaf evergreen and *Pinus massoniana* forest
71	109°44′	19°45′	365	8000-9000	<1	S20, S21, S17	Terrace, hills, mountains and plains	LA	Hainan island (including South China sea islands) plain mountains tropical monsoon rain forest and rain forest
72	108°53′	18°37′							

* Names of the forest stations are given in Table 1. Total days with temperatures ≥10ºC describe temperature zones as follows: cold temperature zone (<100), mid temperature zone (100~170), warm temperature zone (170–220), north subtropical zone (220–240), mid-subtropical zone (240–285), southern subtropical zone (285–364) and tropical margin zone (365). The annual aridity index describes the following aridity zones: <1, 1.00-1.49, 1.5-4.0, respectively, stand for humid zone (<1), sub-humid zone (1.00–1.49) and subarid zone (1.5-4.0). Soil types are brown coniferous forest soil (S1), black soil (S2), meadow soil (S3), bog soil (S4), planosol (S5), dark brown forest soil (S6), brown soil (S7), cinnamon soil (S8), alluvial soil (S9), saline soil (S10), gray brown soil (S11), yellow brown soil (S12), yellow cinnamon soil (S13), eluvial cinnamon soil (S14), red soil (S15), paddy soil (S16), latosol (S17), yellow soil (S18), lateritic red soil (S19), coastal sandy soil (S20), sedimentary sandy soil (S21). Altitude ranges are as follows: low altitude (LA, <1000 m), middle altitude (MA, 1000–2000 m), sub-high altitude (SHA, 2000–4000 m) and high altitude (HA, 4000–6000 m). Categorization criteria were adopted from references (30, 52).

Table 3. Stations of CFERN in the WETSC *.

Forest Station	Longitude	Latitude	Days With Temperature ≥10 ºC	Accumulated Temperature (ºC)	Annual Aridity Index	Soil Type	Landform Type	Altitude	Area Vegetation Type
50	114°40′	27°40′	240-285	5100(5300)-6400(6500)	<1	S15, S22	Mountains and hilly	LA MA	Southeastern hills and low mountains broadleaf evergreen, *Pinus massoniana, Pinus taiwanensis, Phyllostachys pubescens* and *Cunninghamia lanceolat* forest
51	118°19′	29°11′							
52	119°10′	27°52′							
53	117°24′	27°44′							
76	103°21’	29°34’	50-180		<1	S6, S7, S18	Mountains and canyon	SHA	Daduhe,Yalong Jiang, Jinsha Jiang *Picea asperata* and *Abies fabri* forest
78	94°35’	29°46’	50-180		1.00-1.49	S1, S3, S18	Mountains and canyon	SHA HA	Southeastern Tibet *Picea asperata* and *Abies fabri* forest
39	114°03′	31°49′	220-240	4500(4800)-5100(5300)	<1	S7, S10, S12, S15, S16	Mountains, hilly and plains	LA MA	Changjiang-Huaihe plain hills deciduous broadleaf evergreen and *Pinus massoniana* forest
40	118°22′	31°14′							
41	115°35′	30°15′							
42	118°03′	30°06′							
43	119°25′	30°22′							
45	107°38′	30°10′	240-285	5100(5300)-6400(6500)	<1	S7, S18	Mountains	LA MA	Sichuan basin broadleaf evergreen, *Pinus massoniana*, *Cupressus funebris* and *Sinocalamus affinis* forest
75	120°36′	29°56′	50-180	5100(5300)-6400(6500)	<1 1.00-1.49	S1, S3, S7, S12, S18, S23	Mountains and canyon	SHA HA EHA	Min Jiang *Abies fabri* forest
46	108°44′	29°28′	240-285	5100(5300)-6400(6500)	<1	S15, S18	Hilly and mountains	MA	Middle hills montane broadleaf evergreen, *Pinus massoniana, Cunninghamia lanceolat* and *Phyllostachys pubescens* forest
36	110°25′	31°45′	220-240	4500(4800)-5100(5300)	<1	S3, S7, S8, S12, S13	Mountains, hilly and basin	SHA	Southern slope of Qingling Dabashan mountains deciduous broadleaf evergreen mixed forest
37	110°96′	30°82′							

* Names of the forest stations are given in Table 1. Temperature zones, aridity zones, soil types and altitudes are as described for Table 2. In addition, 50–180 days with temperatures ≥10ºC represents the plateau temperature zone, S23 indicates alpine frost desert soil and EHA indicates extreme high altitude (>6000 m). Categorization criteria were adopted from references (30, 52).

which mainly showed as the location of station and specifies the essential requirements for a comprehensive experimental building, meteorological observation facilities, hydrological observation facilities, biological research facilities, soil observation facilities, forest health and sustainable development observation facilities, water and soil resources observation facilities and data management facilities, and the specifications for digital observation and data collection equipment, digital transmission equipment, data processing and analysis equipment, and digital forest station infrastructure. Second, the field of observation and methodology be used in the stations. The former mainly specifies 94 observation indicators relevant to the conventional hydrological, pedological, atmospheric and biological elements of the ecosystem should be observed. The latter does not consider single ecological factors separately but aims to address 28 key scientific problems divided into the five categories of hydrological, pedological, atmospheric, biological and other hot issues, and the purpose, contents and methods of observation as well as data processing all were included. Third, specification for data management was designed to address the data obtained from the stations and avoid resources wasting. Fourth, the data application is significant to network. Data acquisition is meaningless if the data have no application. Forest ecological benefits evaluation is the ultimate data application, which contained six distinct ecosystem services: water conservation, soil conservation, carbon sequestration and oxygen release, nutrients accumulation, atmosphere environmental purification and biodiversity conservation.

The establishment of is an important strategy in long-term ecological research. The benefits of such guideline can be summarized as follows: (a) they help ensure comparability with long-term ecosystem research undertaken elsewhere in the world and enhance international communication regarding ecological field research, (b) they minimize the scientific observation data ‘island effect’, which leads to wastage of resources and incapability of sharing data and (c) they provide benefits for sustainable research. The criterion system served more scientific and comparable database through applying uniform methods, instrument and equipment.

In order to provide a comprehensive overview of criterion systems of CFERN, the management center of CFERN organized a three-day working-group meeting with participants from of a subset of CFERN stations in May 2010.

Future Research Agenda

Because of their multiyear nature, CFERN is increasingly serving as platform for ecological studies and go well beyond the goals originally envisioned. A major contemporary challenge facing ecologists is to better understand environments influenced by human acticity [48, 49]. It is timely to reflect on existing stations’ capabilities and lessons learned as a basis for planning future establishment and research, and their accompanying research agendas. Long-term research often have proved invaluable to both science and society because they have consistently produced new, important, and often unexpected findings [50]. Up to now, numerous installations were used in experiment and observations, a mass of data were acquired through the various means. Data management and shared become a major challenge to all ecological research. Under this backgroud, the competent departments of CFERN should take measures to strengthen the data management and integrated research, so as to served CFERN as a platform for primary, secondary, postsecondary, and continuing education programs, and collegers achieve their dissertations. Above all, the next step is really realize the comprehensive platform of observation and studying sustainable forestry, and further communicate with other relevant network of other countries.

Conclusions

CFERN can be considered as a significant platform for international forestry research communication. Long-term forest ecosystem research network is an essential tool for studying both human and nature system, such as ecological benefits and policy decision making, particularly in the context of global change [51]. It is important to exchange the ideas behind and experiences of constructing forest research stations between scientists in different countries. Compared with other national forest ecosystem research stations, CFERN stations have some distinct features, such as the largest national-scale network for long-term field research on a single ecosystem type in the world. It covers all the heat based regions ranged from tropical zone to cold temperate zone, and all the moisture base regions ranged from humid region to arid region. NEON covers 20 biological climate zones, and in each zone set up one core station and about two relocation stations, which shows the typical sampling layout idea, and collect ecological information on climate and atmosphere, soil, rivers, and all kinds of microorganism. The INDOFLUX in Asia, they mainly consider the different climate, vegetation and land use type elements et al for their site layout, and it involves land stations, ocean stations and coast stations, is a multidisciplinary environment monitoring network [52]. CFERN uses foreign network layout ideas for reference, the factors such as, temperature, moisture, landscape topography, Chinese geographical zoning, Chinese ecological function zoning were integrated at the national level, and become the typical network for monitoring hydrological, pedological, atmospheric and biological elements in forest currently. Under the framework of CFERN, Chinese forest ecosystem research stations have been systematically established within the nine vegetation regions and forty-eight vegetation areas recognized in China. Routine observation protocols have been standardized for all stations to ensure the ecological parameters collected in different regions in order to better evaluate the ecological benefits. As globalization intensifies, there are more interactions among even geographically distant systems and across scales [53]. Thus, it is critical to build an international cooperation platform for interdisciplinary research spanning local, regional, national, and global levels to delve into human and nature system. In terms of CFERN, which plays an increasingly important role in long-term ecological observation, research and application in China, in Asia and globally.

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