Study on Sustainable Development of Grassland Ecosystem in Fujian Mountainous Areas

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China Environmental Science Press

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Preface

Sustainable development is one of the questions that human are facing in the 21st century. China is the biggest developing country in the world, its situation of population resources and environment is much more severe. On February 15, 1994, the State Council of China passed the "21st Century Agenda of China", which set up the strategic goal that China would establish economical system, social system and maintain to the relevant resources and environment basis for sustainable development.

Fujian, one of the provinces where put into practice of the open and reform policy early in China, is located in south-east part of China's coastal area, which is populous, but the area of its land is much smaller. The contradictory between the increase of population and decrease of farmland has been puzzling the government of Fujian Province for a very long period. How to deal with the problem has been becoming the topic that the society concern mostly. Under the circumstances, Fujian provincial "211 Key Subject" of resources and environment and Research Center of Natural Resources, Fujian Teacher's University, both were lead by Professor Zhu Hejian, arose at the historic moment. The academic group took the problem faced in the development of society and economy as their study field, and Professor Zhu Hejian has also supervised some doctoral candidates who are engaged in this study. Under the hard working, both teacher and students, we have got great achievements in Fujian agricultural development, mountain resources development, geographical information system (GIS) fields, especially in the field of mountain grassland sustainable development, we have carried out fruitful work.

In the past years, both academic organizations and government stress the conservation and utilization mountain forest, but has less attention been given to the development and ecological benefit of plentiful mountain grassland resources. In accordance with the situation, under the support of Fujian Provincial Science and Technology Department, with Professor Zhu Hejian's supervision, we have been carrying out the study on grassland ecosystem in Fujian mountainous areas, hosted key scientific and technological project "Study on the ecological benefit of garden and green manure crop interplanting" and program of Fujian provincial natural science fund "Study on nutrient cycle within grassland ecosystem in Fujian mountain red soil area". With the cooperation of Office of Soil and Water Conservation, Experimental Station of Soil and Water Conservation of Jianou County, Fujian Province, through 3 years stationary inspection, by the methodology of field inspection and laboratory analysis, studied the stability aspects of mountain grassland ecosystem in Fujian Province, analyzed the potential productivity and limiting factors of its sustainable development, biomass of mountain grassland ecosystem and its ecological function, the role of mountain grassland resources in the development of mountain social and economical system, ect., which has supplied theoretical basis and decision making for sustainable development of society and economy in mountainous areas.

Professor Zhu Hejian threw a lot of his energy in overall design of this program, laboratory experiment, data analysis and wrote Chapter 2. After the first subscript was finished, Professor Zhu Hejian also spent much of his valuable time to revise it and gave some suggestions for further revision. Therefore, this book is the testimony of Professor Zhu Hejian's strict requirement in academic study and

his meticulous scholarship.

The study on Fujian mountain grassland ecosystem is much weaker, therefore, the fields and methodology that this study referred are much more deficient. This book intends to present the results of mountain grassland ecosystem, Fujian Province, in the past years to readers, and ask experts in this field give your precious suggestions to improve the study.

At last, give thanks to Mr. Hong Ming, Deng Hanming, Wu Liangmin and Wang Jiaming, Office of Soil and Water Conservation, Experimental Station of Soil and Water Conservation of Jianou County, Fujian Province, Ms. Tan Binghua, Research Center of Natural Resources, Fujian Teacher's University, who have done a lot of hard work in this study.

Zhu Lianqi

May 1, 2003, in Henan University

目　录

Introduction

Global Change and Mountain Areas

Mountainous areas take mountains as their main part, they also contain hills, plateaus and basins[1-3], which cover 75% of all global land areas* and are one of the most principal bodies of geographical system, provide goods and services to more than half of humanity. Accordingly, they received particular attention in the United Nations system under the current situation of global change[49].

Mountain ecosystem is a complex that consists of mountainous soil, creature, water and climate, which is a comparatively prosperous part in tremendous complicated earth surface ecosystem. Meanwhile it's also a relatively independent sub-system in global physical geographical ecosystem. Due to its comparatively protruding geographical position, mountainous areas ecosystem has a rapid material and energy exchange with its circumstances, but it has a much lower capacity of self-cycle and is very sensitive to the disturbance of surroundings owing to its evidently undulating landform, steep slope, thin soil layer, in case the mechanism of material and energy cycle is harmed, the change of mountainous areas ecosystem structure will occur at once, for example, soil erosion and deterioration of ecosystem caused by irrational agricultural resources exploitation will lead to deterioration of ecosystem in mountainous areas, etc., for these reasons, mountainous areas ecosystem has obvious characteristics of fragile. Owing to great disparity of relief, tremendous ecosystem entropy, mountainous areas ecosystem is highly unstable, avalanche and mud-rock flow occur frequently, these abrupt events lead to qualitative change of regional ecosystem, therefore, mountainous areas ecosystem possesses the characteristics of sudden change. Mountainous areas ecosystem has rich land, creature, water and mineral resources, its combination patterns not only varies in horizon, but also varies in vertical. Mountainous areas ecosystem has complicated structure and distinct variation, which supply material and energy basis for variety of mountainous agricultural production.

It has a long history for human being to exploit and use agricultural resources of mountainous areas. Before 3500 BC, agriculture and poultry began in Andes mountainous areas, southern Ecuador[4]. It was recorded in Shi, Daya, Gongliu that in China's Zhou Dynasty (1100-221BC), the Chinese people had known different cultivation styles in different topographical positions[4]. Studies on mountainous areas can be dated back to 300 BC, a Grace scientist charted mountainous areas' topographical map and surveyed the height of mountains by trigonometry correctly. In 1495, An Italy bishop studied vertical variety of vegetation in Aetna volcano and ignited the study on mountainous area vertical variety. During the first half of 19th Century, it was the period of extensive scientific investigation in mountainous areas, German scientists, Alexander von Humboldt and some other researchers, did their researches in mountainous vertical variety and that of mountainous climate in the Andes, south America. After then, Alexander von

* According to China Encyclopaedia, World Geography edited by professor Li Chunfen, world plain areas account for 25% of all earth's surface, therefore, mountainous areas account for another 75% of it.

Humboldt's study methods on mountainous areas were popularly used in that on the Alps and Carpathians in Europe by Walunbo. After half century's acknowledge accumulation, in the latter half of 19th century, the European mountain scientists began their intensive studies on the history of mountainous evolution, causes of mountainous formation, their structures and characteristics of mountainous integrated physical geography, Edward Hughes's Earth's Mortography, Heim Albert's Formation Mechanism of Mountains were typical works in this field. After then, with the establishment of geomorphology, ecology, landscape science and integrated physical geography and other theoretical systems, the study on mountainous area ecosystem was strengthened increasingly. The study on mountainous areas ecosystem in Europe began in Alps, some researchers studied it systematically in mid-19th century, for example, Edward Hughes studied Alps fold structure, Ruppell Edward researched the features of soil erosion in Alps valley, Albrecht Penck studied glaciating in Alps mountainous areas intensively[1]. The European researchers in mountain study field had accumulated rich experience and established systematic theory and method in this field on the basis of study on Alps mountainous areas.

In China's Warring States Period, China's mountains and rivers were described in details in Shan Hai Jing (Theory on mountain and sea), and in "Agriculture, Chapter of Guanzi", vertical distributions of mountainous vegetation had been recorded as well, Guan Zhong also pointed out that mountainous vegetation changed with that of the mountain height and had the difference between the different slope directions, which is the earliest book to introduce the knowledge of mountainous vertical zones. Shen Kuo (1031-1075), a famous scientist in Song Dynasty (960-1279), inferred that Taihang Mountain (in Central China) was ancient sea shore areas on the basis of extensive distribution of clam shell fossil and cobble, he also entered mountainous areas to study the affects of landform and climate to the growth of plants on the basis of intensive on-the-spot inspections, and got the results that "if plain blossomed in March, the high mountain would blossom in the end of April", and "these were caused by different landform", who is the first scientist to explain mountain historical evolution and mountainous phonology. Xu Xiake, China's pioneer of mountain study, famous traveler in Ming Dynasty (1368-1644) wrote his famous book Xu Xiake travelling notes, in which mountains, especially limestone in southern China, were recorded, which is also the first book in limestone mountain study field. In early Qing Dynasty (1644-1911), Sun Lan, a very famous geographer in Chinese history, raised the theory that climate human activity, internal and external forces are the elements of landform evolution. Sun's mountain study method was similar to that of modern physical geography study. Sun Lan thought that mountain study was not recording, but explaining. He advocated that geography study should focus on the causes of the formations of mountain and river, what caused mountains have so many branches and why river could flow continuously,[4] who supplied a superficial method, but it has significance to guide modern mountain study.

In the past years, global change has become one of the hotspots in science research. Global Change and Terrestrial Ecosystems' (GCTE) operational definition of "global change" encompasses far more than predicted climate change. It includes change in atmospheric composition, such as increases in the concentration of CO_2 and other greenhouse gases, which have direct impacts on vegetation with or without climate change. It also includes change in land-use, as driven by demographic, economic, technological, and social pressures. The most challenging feature of global change research, however, is that these driving

forces are not independent but are strongly interactive.

Global change is a reality, its effects will be felt much differently at the regional level. Mountain areas may experience the impacts of the rapidly changing global environment more strongly than others. Meanwhile, mountains, with their sharp altitudinal gradients, often intensify and transmit environmental impacts to lowlands. These same altitudinal gradients result in distributions of species that may change markedly during global change and may be sensitive indicators of subsequent impacts to lowlands. Water yield is affected by the biological community covering the watershed.

Three international global environmental change organizations, i.e., the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP), and the Global Terrestrial Observing System (GTOS), have been involved in and endorsed Global change and Mountain regions study. This Initiative spans a range of activities, monitoring, detection of change, fundamental process research and modelling, and policy and management applications-which are essential components of studying global environmental change.

The strong altitudinal gradients in mountain regions provide unique and sometimes the best opportunities to detect and analyze global change processes and phenomena because: 1) meteorological, hydrological, cryospheric and ecological conditions change strongly over relatively short distances; thus biodiversity tends to be high, and characteristic sequences of ecosystems and cryospheric systems are found along mountain slopes. The boundaries between these systems experience shifts due to environmental change and thus may be used as indicators of such changes. 2) the higher parts of many mountain ranges are not affected by direct human activities. These areas include many national parks and other protected environments. They may serve as locations where the environmental impacts of climate change alone, including changes in atmospheric chemistry, can be studied directly. 3) mountain regions are distributed all over the globe, from the Equator almost to the poles and from oceanic to highly continental climates. This global distribution allows us to perform comparative regional studies and to analyze the regional differentiation of environmental change processes as characterized above.

After entering 21st century, with the rapid population growth and technique progress, mountainous agricultural resources exploitation become more and more extensive, soil erosion and ecosystem deterioration become more and more serious in mountainous areas. Ecological problems in mountainous area are attracting more and more attentions of people around the world. Therefore, International Federation of Geography (IFG) set up Mountainous Ecological Committee in 1968. United Nations Education, Science and Culture Organization (UNESCO) put the topic of "The affects of human activity on mountains" as the sixth topic in "Man and Biosphere" (MAB) study plan in 1972. In December, 1974, German Foundation of International Development (GFID) held international mountainous ecological and environmental development conference in Munich, and issued Munich Declaration to be vigilant for the tendency of mountainous areas ecosystem deterioration. In 1975, United Nations Education, Science and Culture Organization held third "Man and Mountainous Environment Conference" in Katmandu, capital of Nepal. United Nations University (UNU) put the program of "Utilization and Governance of Renewable Resources" in the study plan of "Study on Interplay between Highland and Lowland" in 1976, strengthened the studies on mountainous areas ecosystem and its function. After then, international comprehensive study on mountainous areas ecosystem attracted more and more attentions, "Montology"

was put forward in that time. International Mountain Society was established in Colorado, USA, in 1980, and the major journal of "Mountain Research and Development" began to publish in May same year. This society held a conference on stability and unstability of mountainous areas ecosystem in Bernz, Switzerland, in September, 1981, which focused on the study of exploitation, utilization and preservation of mountainous natural resources, therefore, the causes of unstability in mountainous areas ecosystem were analyzed, indexes of stability and unstability in mountainous areas ecosystem were defined, the method for evaluating mountainous areas ecosystem stability was drafted, to look for the road for sustainable development of ecosystem in mountainous areas. Recognizing the significance of mountain regions for global change research, the IGBP core projects BAHC and GCTE, together with START/SASCOM, organized a workshop in Kathmandu, Nepal (March/April 1996), which resulted in IGBP Report # 43: "Predicting Global Change Impacts on Mountain Hydrology and Ecology". Immediately after the workshop, the results were discussed in a special session at the first IGBP Congress (Bad Münstereifel, Germany, 18—22 April 1996), which was attended by members of the SSCs and representatives of the IGBP core projects BAHC, GCTE, LUCC, PAGES and GAIM and by the IGBP Secretariat, in particular the IGBP Executive Director. The session participants welcomed the results of the Kathmandu Workshop and representatives of LUCC and PAGES enthusiastically expressed an interest to participate in the further development of the initiative. Two important follow-up events, which complemented the results of the Kathmandu Workshop, were a LUCC Workshop on "Dynamics of Land Use/Land Cover Change in the Hindukush-Himalayas" in Kathmandu, Nepal (April 1997), and the "European Conference on Environmental and Societal Change in Mountain Regions" in Oxford, UK (December 1997). The reports from these meetings, together with IGBP Report # 43, served as the basis for developing a draft document for "Global Change and Mountain Regions" at a joint IGBP/IHDP (BAHC, GCTE, LUCC, PAGES) workshop in Pontresina, Switzerland (16—18 April 1998). Fifteen experts attended the workshop, sponsored mainly by the Swiss Academy of Natural Sciences (SANW). The participants of the Pontresina workshop emphasized the need for interdisciplinary environmental change research in mountain regions, involving both natural and social scientists. Thus, in addition to the IGBP and its core projects mentioned above, IHDP and its science projects IDGEC and GECHS, as well as START and its regional programmes were suggested to be invited to join the group of collaborators. Moreover, at a meeting of the BAHC SSC in April 1998 in Paris, the official representatives of WCRP/GEWEX, Rick Lawford, and of UNESCO/IHP, Mike Bonell, expressed the interest of their programmes to participate in the initiative and provided input to it.

During more than ten years after international Mountain Society's establishing mountain researches only concentrated in Alps, Europe, Rocky, North America, etc. In Europe, studies on mountainous disasters in Alps were strengthened according to its characteristics. Every country established its disasters database on the basis of extensive investigations in mountainous areas, forecasting disasters by disasters database and harnessing them by ecological and engineering methods[5]. Meanwhile, study on relation between high mountainous grassland ecosystem primary productivity and husbandry was carried out as well[28]. During 1960s and 1970s, montolists in South America did their researches in the field of mountainous areas ecosystem evolution on the basis of extensive investigations on present environmental situation in Andes, pointed out the direction of Andes mountainous areas ecosystem evolution[29-30], supplied scientific

foundations for the preservation and administration of fragile mountainous areas ecosystem[31-32]. In Andes agricultural ecosystem sustainable development study field, in accordance with its agricultural present situation, i. e. decentralized agricultural management, more inputting, but less producing, advocated intensive farming and modern cultivation[33], in the light of serious soil erosion and more and more rapid deterioration of mountainous areas ecosystem in Andes mountainous areas, exploitable degree of agricultural resources, methods of soil and water conservation in Andes mountainous areas were studied, so as to look for coordinate measurements of agricultural resources exploitation and mountainous areas ecosystem's long-stability[34-35]. Baied, C. A studied the affects of patrol husbandry on mountainous grassland ecosystem in north patagonia Plateau, Andes mountainous areas, put forward measures for maintaining the sustainable development of mountainous grassland ecosystem[36]. In Africa, Wolde Mariadm studied the principles of poultry vertical distribution in Ethiopia Plateau[43], Liniger H described the situation of land resources exploitation in northwest slope in Kenya mountainous areas, within his study, geographic information system (GIS) and method of simulation were used, and it was indicated that increasing forest coverage and reducing the area of cultivated land could improve water resources utilization and raise agricultural productivity.[44] In North America, Martz J. F researched the soil and water conservation function of grassland ecosystem in Canada mountainous areas[37]. Asia is the continent that has the most extensive mountainous areas in the world, especially Himalayas in south Asia and south-east Asia, where most of the world's famous high mountains are amassed, its study has focused more attentions of scientists around the world. Dobremrz J. F has studied environmental variety in Himalayas,[38] Griffin D M ect have done the studies of human activity's influence on forest ecosystem in Nepal mountainous areas, indicated the future developing direction of forest in south Asia[39-40]. Shigeru Shirasaka researched cropping system and techniques for agriculture sustainable development in Asian tropics high mountainous area[45].

In recent years, with global change and the rapid economical growth in mountainous areas, the relationships between population, resources and environment become more and more strained, especially irrational exploitation and utilization of agricultural resources in mountainous areas, soil erosion in those areas becomes more and more serious, mountainous areas ecosystem and environment have been increasingly deteriorated as well, which have been limited development of agricultural economy seriously and affected the surrounding environment. Therefore, the study on mountainous areas has focused on economy sustainable development in mountainous areas and its environment effects.

Burton S S studied the problem of mountain soil deterioration caused by transferring woodland into farmland in Nepal and measures for raising soil fertility and soil and water conservation.[46] Sarmiento L. researched ecological basis and tendency of mountainous agriculture sustainable development in Venezuela Andes mountainous areas,[47] Harden C P studied the relationships among land utilization, soil erosion and deposit in reservoir in some Ecuador reservoir basins.[48] Some Japanese researchers also intensively studied the deterioration causes of grassland ecosystem in Japan's mountainous areas and mountain management database, to supply information service for exploitation of mountain resources and protection of mountain ecosystem.

China is a mountainous country, its mountainous areas take account for 2/3 of all nation's area.[9-11] Although some pioneers have done a lot of investigations and researches in some mountainous

areas, but intensive inspection and studies only began after the establishment of People's Republic of China, in 1949.

During 1950s and 1960s, China Academy organized some scientific investigation teams and carried out scientific investigations and studies in mountainous areas all over the country. At first, they did some scientific investigations and studies in Tibet Plateau, its geological formation, soil characteristics, vegetation, water resources and the vegetation, filled in the gaps of China's studies in that field. Except Tibet Plateau, some main mountains, for example, mountainous areas in south Yunnan Province, Wuzhi in Hainan, Qinling in Shanxi, Changbai in North-east of China, Tianshan in Xinjiang Uygur autonomous region, Yunnan and Guizhou Plateau in south China, were inspected systematically and studied extensively, kept informed on China's mountain types, distribution and their ecosystem primary potential productivity, especially after 1978, under China central government's concern, China Academy's South China Mountainous Areas Complex Investigation Team and Loess Plateau Complex Investigation Team have studied the characteristics of natural resources, structures of mountainous areas ecosystem, present situations, direction of mountainous areas ecosystem development, and measures of coordination in South China Mountainous Areas and Loess Plateau intensively and meticulously, which have supplied the theoretical basis for healthy development of society and economy, rational resources exploitation and scientific administration in those mountainous areas, meanwhile, these achievements are also very important to sustainable development in China's whole mountainous areas.

In the end of 1980s, under professor Huang Bingwei's (academician of China Academy, honor director of Geography Institute in China Academy) propose, Academy of Guangdong Province carried out the studies of amelioration and utilization in south China's hillside fields, after many year's inspection and experiment in Wuhua, Deqing, Heshan, Zhuhai in that province, they have sought some agricultural models that is suitable in those areas, for example, tropic crop planting model, grassland husbandry agricultural model, "planting, poultry and breeding, processing and trading" comprehensive agricultural resources exploitation model in those mountainous areas[12], they have been playing positive roles in soil and water conservation, mountainous areas ecosystem preservation and afforesting barren hills in south China. In addition, China's geographers also studied some other fields, for examples, mountainous climate, natural resources, disaster, ecosystem, economy, population, which have promoted the development of studies on mountainous climatology, mountainous ecology and mountainous economy. China Academy has established and perfected some institutes for studying mountainous areas, set up some special laboratory and field positional inspection stations, after 1985, China's Geography Association and China's Natural Resources Association have established Mountain Committee and Mountain Major Committee individually, so as to promote the development of studies on mountainous areas. They successively did their researches in Tibet Plateau and Changbai Mountainous areas systematically, especially in Tibet Plateau study field, they have got a great deal of achievements in the study of Tibetan climatic condition, soil resources, some books, i.e., "Series Books of Complex Scientific Investigations in Tibet Plateau", "Books of Complex Scientific Investigations in Hengduan Mountainous areas" and "Reports on Changbai Mountainous areas" have been published. In the same time, some other books of China's mountainous areas study, "Tibet Physical Geography", "Mountain Climate", "Evolution of Tianshan Mountain", "Disasters in Mountainous areas", "Mountainous Economy", and "China's

Mountains" etc., have been publicized as well. With the West Development, the construction in mountain region has been becoming more and more urgent, which has great influence on local environment, the prominent projects are Qinghai-Xizang Highway and railway, Zhang Yili and his colleagues studied the effects of Qinghai-Xizang Highway and railway on landscape pattern change on the basis of digital land use maps of 1995, 2000 and road map of Resources and Environment Data Center of IGSNRR, CAS, in macro-scale, exerting ArcGIS 8.1 and landscape ecology methods, the results demonstrated that the highway has significant influence on landscape change and land use[60]. Yang Wude developed the models of spatial soil erosion and sloping surface erosion with a lot of data obtained from the technique of Fixed Soil Core Eu (europium) Tracer (FSCET) in south China red soil slope area, which can be used to foresee distribution and sloping surface soil erosion.[65] Zhou Lihua proposed countermeasures of agricultural development in Northwest China arid zone after studying the general situations of natural resources for agricultrual development, suggested to regulate agricultural structure and to develop diversified economy, to implement a strategy for famous brands and to develop the new, peculiar and rare products to promote the development of local economy.[66]

In response to the study of global change, China researchers have been carrying out the study of mountain regions environment change in recent years. Zhang Baiping studied the Bayanbulak region, deep in the East Tianshan Mountains, China, one of the few biodiversity hotspots in central Asia, which was listed in 1986 as a Chinese national swan nature reserve, and is also the largest grazing area in Xinjiang as well as a tourist attraction. The study indicated that in the last 25 years, the population of wild swans has decreased from about 20000 to 2000, and approximately half of the pastureland now suffers from overgrazing and degradation Concerning the local government's decision of building reservoir in the region, Zhang's study result revealed that If this is done, the ecology of this region would be greatly altered, and almost all wild-swan habitats would disappear. The present study identifies alpine grassland types and concludes that it is urgent to protect the breeding areas of wild swans and control grassland degradation and that any plan for reservoir construction should be rejected[50]. Fu Bojie, Chen Liding and Ma Keming researched land use changes' influence on variety of natural phenomena and ecological processes, including soil conditions, water runoff, soil erosion and biodiversity in Yangjuangou catchment in the Loess Plateau of China, where has typical loess hill and gully topography. Fu's study focused on the affects of land use changes on soil erosion, the distribution of soil nutrient and soil moisture, and land use type at three spatial scales within the catchment by aerial photography interpretation and field survey mapping. Three types of typical land use structure during 15 years in the loess hill slope were selected in order to study the effect of land use structure on the distribution of soil nutrients and soil moisture. By measuring the contents of the total N, total P, available N, available P, organic matter of soil and soil moisture in 0 ~ 70cm depth, the results of Fu's study show that the land use structure type of slope farm land - grassland - forest has high contents of soil nutrients and low antecedent soil moisture. This indicates that this land use structure has a better capacity for retaining soil nutrient and a high efficiency for soil conservation. The analysis of soil nutrient and soil moisture in different land use types showed that the content of soil nutrient are: forest > grassland > slope farm land, while the content of soil water are: forest < grassland < slope farm land. Liu Yansui took Qingling north slope of Shaanxi Province as an

example to study optimal allocation of land use in mountainous areas, and put forward the designs of optimal allocation models in mountainous land use, namely regional model in macrostructure, industry model in mid-scope and micro-management model[52]. Li Jiayong analyzed land use change within 14 years in Qianyanzhou Experimental Station in Jiangxi Province, and evaluated the variation of soil organic carbon storage in different land use system in that area, the experimental data proved that the integrated land development and utilization of land resources in Qianyanzhou Experimental Station resulted in a sharp increase in the organic carbon volume stored in vegetation and soil, which made more CO_2 convert into organic carbon, to practice integrated techniques of land use in red soil hilly areas of China, several land use patterns were coordinated[53]. Li Xiaojian assessed the effects of land use and land cover change in middle Yiluo area, and proposed a hybrid model that integrates ideas from both physically and the statistically-based model in terms of land use and land cover[54, 55]. With the help of ARC/INFO software, based on the information from forest resources distribution maps of Luoning County from 1983 to 1999, Ding Shengyan studied environment change in the middle reaches of Yiluo Basin, 6 indices were used to analyze spatial pattern dynamics of forest landscapes of typical region[56]. Du Jun studied change of temperature in Tibet Plateau from 1961 to 2000, researched the trendency of climate change in that region[63]. Liu Yunfen studied CO_2 emission flux by enclosed chamber technique in Haibei Frigid Meadow Ecological Station, Gongga Mountain Alpine Forest Ecological Station, and Lhasa Agroecological Station, the result indicated that there was a very good relationship between temperature and CO_2 emission in that area, and the temperature appears an important factor affecting soil CO_2 emission, so the global warming will likely increase soil CO_2 emission, which is of practical significance and important scientific value to probe into carbonic balance in different ecosystems and its environmental factors affecting it, and to reveal its influence on and response to the changes of global carbonic greenhouse.[61,62]

Fujian Province is located in China's south-east coastal zone, mountainous areas cover about 87.50% of the area, which is called "south-east mountainous country"[13] and has a more than 3000 years history of mountainous agricultural resources exploitation, some characteristics of the mountainous areas ecosystem in Fujian Province has been known by local residents. In recent years, with economic prosperity and scientific development, the study on mountainous areas ecosystem is becoming more and more extensive and intensive, in accordance with the present situation of more and more soil erosion in mountainous areas, under the leadership of provincial soil and water conservation office, provincial soil and water conservation association, during 1983—1985, soil erosion survey was carried out in this province. According to the survey data, soil erosion areas cover about 17.43% of all provincial area, mastered the characteristics of soil erosion in Fujian mountainous areas, distribution principles and its harms to mountainous areas ecosystem, analyzed the causes of soil erosion and put forth the measures for soil and water conservation, which have been playing important roles in soil and water conservation and improvement of agroecosystem in mountainous areas.* During 1983 to 1989, China Academy's South China Mountainous Areas Complex Investigation Team did complex investigations and systematic studies in east part of China's subtropics hills and mountainous areas, which includes western Anhui, southern

* Office of Fujian Soil and Water Conservation Committee, Fujian Soil and Water Conservation Experimental Station. Survery report of soil erosion in Fjuian province, 1986.

Henan, northern Hubei, north-east Guangxi, Ganjiang basin in Jiangxi, Southern Hunan, northern Fujian, northern and eastern Guangdong and south-east Guangxi, within that period, the present situations of land, climate, forest and water resources exploitation in Jianxi River basin, northern Fujian Province, were studied, on this basis, the Team pointed out the development tendency of mountainous areas ecosystem and the measures of sustainable development;[14] meanwhile, Fujian Province carried out soil survey in all provincial areas during 1979-1989, ascertained the situation of soil nutrients and soil limits of agricultural production, supplied scientific basis for rational land resources exploitation and giving full play to soil potential productivity.[15] Professor Zhu Hejian, director of natural research center in Fujian Teacher's University, has intensively studied on soil formation factors, soil formation processes, soil variation in spatial, exploitation, utilization, administration and conservation in Fujian mountainous areas, who has published a series books, for examples, "Paddy Soil" (Agriculture Press, 1984), "Studies on Soil and Land Resources in Fujian Province" (Agriculture Press, 1994), summarized some models for land resources exploitation in mountainous areas, for examples, land utilization model based on difference of temperature, model for conservative soil, saving manpower model and intensive farming model, pointed out that agricultural resources exploitation in mountainous areas the best way is comprehensive, it's that to say agricultural exploitation in mountainous areas should begin on the basis of exploiting hills and basins among the mountains, then spreading agriculture exploitation into hills, transferring basin and valley agriculture into mountainous relief agricultural exploitation, improving middle and low productive fields and carrying out intensive farming,[16] developing forestry industry both long-term and short-term, proposing "Golden Exploitation" (Takes advantages of the exceptionally superior climate and micro-environment and set up different plantations develop a variety of economic crops and traditional specialties and quality products so as to obtain more economic profit), "Yellow Exploitation" (Raising crop productivity), "Green Exploitation" (Make the green treasure base, the dense forest and thick grass play an important role in sustainable development), "Blue Exploitation" (Tap the potentialities of shallow sea and seashore), "Black Exploitation" (Fully utilize barren mountains and wasteland" and "Red Conservation" (Rationally utlize the red earth on mountainous and hilly areas), which have set up the theory foundation for agricultural resources exploitation in Fujian mountainous areas.[17] In 1997, professor Zhu Hejian published his book Sustainable Development and Land Utilization in Hong Kong Yearbook Press, pointed out his new ideas about land use and sustainable development in Fujian mountainous regions.[57] Chen Jianfei studied the regulation and methodology of correlation between different soil classification systems, correlation between soil genetic classification and Chinese Soil Taxonomy of main soil types in Fujian is demonstrated, and the draft of keys to soil taxonomical classification of Fujian Province is put forward based on research experiences and data accumulated, which could promote the reformation of regional soil classification, be in favor of academic exchange and introducing technology in the domain[58], Chen also studied the diagnostic features of several representative pedons in Wuyishan, Meihuashan and Gushan based on Chinese Soil Taxonomy and summarized the distribution models of main mountainous soils in Fujian province.[64]

Cai Jianmin[18], Yang Jiatan[19] analyzed quantity, distribution and quality characteristics of water resources. Gao Zhaowei[20] seriously studied the forestry resources in Fujian mountainous areas; Tang Xingxia[21] put proposals for rational resources exploitation in mountainous areas, supplied theory basis for