CHINESE GEOGRAPHICAL SCIENCE
Volume 14, Number 2, pp.142-147, 2004
Science Press, Beijing, China

ECOLOGICAL SECURITY EVALUATION OF SUSTAINABLE AGRICULTURAL DEVELOPMENT IN KARST MOUNTAINOUS AREA

—A Case Study of Du'an Yao Autonomous County in Guangxi

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ABSTRACT: Ecological security is the main task and applied field of present geography, resources and environment sciences and ecology. Ecological security evaluation will efficiently promote ecological security and environmental construction in regional land use. In this thesis, the authors put forward the index system of ecological security evaluation in karst mountainous area on three aspects, the pressure of resources and eco-environment, the quality of resources and eco-environment, and the ability of environmental protection and ecological improvement. Using the evaluation method with single index, based on the case study of Du'an Yao Autonomous County of Guangxi Zhuang Autonomous Region, the system of synthetic regionalization of ecological agricultural economy was formed, which includes three regions, south region with basic security and synthetic agricultural development, east region with critical security and agriculture, forestry, animal husbandry balanced development, mid-west and south region with ecological insecurity and compounded agriculture and forestry management. Meanwhile, for these regions, the countermeasures of sustainable agricultural development were pointed out, which provide the basis and example for ecological regulation and control of sustainable agricultural development in counties of karst mountainous area.
KEY WORDS: sustainable agricultural development; ecological security; karst mountainous area

CLC number: P901 Document code: A Article ID: 1002-0063(2004)02-0142-06

1 INTRODUCTION

Guangxi karst mountainous area is bounded by Yunnan Guizhou Plateau on the northwest and by the Guangxi Basin on the southeast. From macroscopic view, Guangxi karst mountainous area, with an area of 97.7×10^3 km^2 (41.0% of total area of Guangxi), constitutes the incline region of Yunnan Guizhou Plateau. And it possesses the unique geological and ecological characteristics: firstly, subterrane and other cracks crisscross, hydrologic dynamic condition is violent, surface water leaks seriously, and drought and flood occur alternately; secondly, land surface is rugged and tattered, and land is infertile for plants growing; thirdly, geological disasters are frequent, ecological system is very frail and sensitive, and the carrying capacity of environment is very low; fourthly, land-use intensity and over population growth are beyond the carrying capacity of environment, the poverty phenomenon is general, and the sustainable agricultural development faces with severe challenge (LIAO *et al.*, 2002).

As is known to all, the secure natural eco-environment is the foundation of sustainable agricultural development. The ecological security displays the situation that the internal structure of the system is stable and the health service function of the system tends to be positive. As the forward subject of the research on sustainable development, the internal and external research of ecological security mainly focuses on the microscopic study that involves ecological (environmental) hazard, security of genetic engineering and the influence of chemical material. However, there is still a gap in the research on ecological security and evaluation of sustainable development in less developed area. Ecological security is not only an aim of regional development but also a procedure. The ecological security evaluation for sustainable agricultural development in Du'an Yao Autonomous County in Guangxi Zhuang

Received date: 2003-12-15
Foundation item: Under the auspices of the National Natural Science Foundation of China (No.40161004)
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Autonomous Region, will supply the basis and the example for ecological regulation and control of sustainable agricultural development in karst mountainous area.

2 ECOLOGICAL SECURITY EVALUATION OF SUSTAINABLE AGRICULTURAL DEVELOPMENT

2.1 Study Area

Du'an Yao Autonomous County, lying in 23°47′–24°34′N, 107°49′–108°34′E, is situated at the east foot of Duyang Mountains that is on the incline region from Yunnan Guizhou Plateau to Guangxi Basin. Except the north and the west of the county with some middle and low hill landforms formed from clastic rock of Triassic System, most of the region are the typical karst landforms, of which the area of stone mountains is 3634km^2, accounting for 89% of total area. Du'an County is situated on the region of subtropical monsoon climate, its average annual temperature is between 18.2℃ and 21.7℃, and its average annual precipitation is between 1200mm and 1900mm, where surface water is short, groundwater is rich but buried deeply, water yield and water level are unstable, and soil erosion is serious. The total population in the county was 625×10^3 in 2001, among which agricultural population was 587×10^3, being 93.9% of total population, and its population density was 152.54 persons/km^2. With the prominent contradiction between man and land, it is the region with the prominent contradiction between resources, environment and social and economic development, where ecological environment is worse.

2.2 Index System and Weighing Methods

The evaluating research of regional ecological security not only follows the general laws of ecological system, but also considers the regional character. Meanwhile, it should be followed a series of laws, such as the scientific laws, multiple laws, dominant laws, laws of levels, dynamic laws and the laws of operation. The service function of ecosystem reflects the mutual relation between the eco-environment system and the need of human activities and society, which refers to the action that human society reforms eco-environment and the retroaction that eco-environment affects human society (LIAO and HAO, 1999). In view of the conception of system service of eco-environment, according to Analytic Hierarchy Process (AHP), the general level structure system of ecological security evaluation can be formed.

O. Objective level: in the research, the security index of regional eco-environment system or the insecurity index, as the objective level, is used to characterize the overall security situation of regional ecological system.

A. Standard level: the main factors, which restrict the regional ecological security, include the pressure of resources and eco-environment, the quality of resources and eco-environment and the response of human society.

B. Substandard level: it is used to characterize its importance to the standard level. In the standard level, the pressure of resources and eco-environment includes population pressure, land pressure, water resources pressure and the pressure of social and economic development. The quality of resources and eco-environment includes resources quality and environmental quality. The response of human society includes technological ability and investing ability.

C. Measure level: it is constituted by the index measured directly, which is the basic level of index system of ecological security evaluation. Through the specified calculating model, the index of ecological security can be obtained.

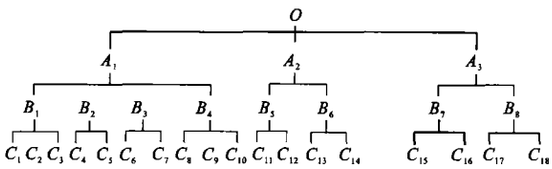
According to that, the index system of ecological security evaluation in karst mountainous area is formed from the pressure of resources and eco-environment, the quality of resources and eco-environment, as well as the ability of environmental protection and ecological improvement.

Through analyzing and selecting, the index system of evaluation is established as follows (HU and REN, 1998; WU, 2001; ZUO *et al*., 2002) (Fig. 1).

Each index has distinct contribution to ecological environment. To indicate each index how to influence the index of ecological security, it is very important and troublesome how to weigh the index of synthetic evaluation. In this thesis, we have combined the IAHP and the estimating method of expert's experience to define the weighing of different level index. According to the importance to the system, the level structure model has been structured. Meanwhile, the experts were asked to compare and judge the importance of each level index, and count the weighing value of each level index. After collecting all evaluating results of experts, we can obtain matrix of relative importance of all evaluating indexes, then, adopt the method of weighing to get the index (Table 1).

2.3 No-dimension of Index Data—Evaluation with Single Index

After defining the evaluation indexes, it is still difficult to evaluate the ecological security directly with them. Just because these indexes are not unified, it is diffi-



Notes: O—index system of ecological security evaluation
A_1—pressure of resources and eco-environment
A_2—quality of resources and eco-environment
A_3—response of human society
B_1—population pressure
B_2—land pressure
B_3—water resources pressure
B_4—pressure of social and economic development
B_5—resources quality
B_6—environmental quality
B_7—technological ability
B_8—investing ability
C_1—population growth percentage
C_2—urbanization percentage
C_3—population density
C_4—cultivated land percentage
C_5—cultivated land percentage of slope above 25°
C_6—water area percentage
C_7—efficiently irrigated area percentage
C_8—poor population percentage
C_9—average chemical fertilizer utilization of cultivated land
C_{10}—density of tractor-ploughing road
C_{11}—percentage of stable yields despite drought or flood
C_{12}—cultivated index percentage
C_{13}—soil erosion percentage
C_{14}—forest coverage
C_{15}—average income per farmer
C_{16}—investing intensity of ecological construction
C_{17}—grain per person
C_{18}—amount of agricultural machines per hundred farm household

Fig. 1 Level structure model of ecological security evaluation

cult to compare them. Only through quantifying them by several degrees from low value to high value, they will show the change of environmental conditions. Generally, the data of single index are mostly gotten from the statistics and the investigation reports. We can use the simple differential standard method to realize no-dimension.

$$P_i=\frac{x_i-x_{\min}}{x_{\max}-x_{\min}}\times 10 \quad (1)$$

where P_i is valuation of the ith index, x_i is actual valuation, $x_{\max}$ is the actual maximum, $x_{\min}$ is the actual minimum. And the larger P_i is, the safer index is.

If the conception and sense of environmental quality, in which one factor quantifies the degrees, is opposite with Formula (1), the standard quantifying formula of the factor is as follows.

$$P_i=10-\frac{x_i-x_{\min}}{x_{\max}-x_{\min}}\times 10 \quad (2)$$

In this formula, P_i is valuation of the ith index, x_i is actual valuation, $x_{\max}$ is the actual maximum, $x_{\min}$ is the actual minimum.

2.4 Process and Result of Ecological Security Evaluation

Using the degree of ecological security to indicate the ecological condition, the model of synthetic evaluation is as follows.

$$P_0=\sum W_i\times P_i \quad (3)$$

In the formula, P_0 is security index, W_i is the weight of the ith index, P_i is valuation of the ith index. The larger security index is, the higher ecological security degree is in the region. According to the original scientific achievement and the experts' opinions, now we use 4 degrees to define the degree of ecological security: A is security, $8.00\leqslant P_0<10.00$; B is basic security, $5.15\leqslant P_0<8.00$; C is critical security, $3.35\leqslant P_0<5.15$; D is insecurity, $0.00\leqslant P_0<3.35$. With the

Table 1 Weight of Evaluating Index System

Index	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
Weight	0.050	0.050	0.050	0.075	0.025	0.080	0.020	0.045	0.035	0.025	0.035	0.065	0.065	0.052	0.053
Index	C_{16}	C_{17}	C_{18}	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	A_1	A_2	A_3	
Weight	0.055	0.090	0.060	0.150	0.100	0.100	0.100	0.100	0.150	0.150	0.150	0.450	0.250	0.300	

town as the unit, we have synthetically evaluated the ecological security condition of sustainable agricultural development in Du'an County (Table 2).

Through synthetically evaluating the ecological security condition during 1990–1995 and 1996–1999 in Du'an County, we have gotten two definite conclusions: 1) The degree of ecological security is generally lower in the towns of Du'an. With the synthetic evaluation of ecological security during 1996–1999, among 22 towns, there was no town to reach the condition of

Table 2 Synthetic evaluation results and degrees of ecological security of Du'an County

Town	P_0		Degree	Town	P_0		Degree
	1990–1995	1996–1999			1990–1995	1996–1999	
Dengjiang	5.60	5.76	B	Bao'an	3.66	3.31	D
Gushan	2.70	2.51	D	Banling	5.04	4.26	C
Anyang	5.30	5.95	B	Yong'an	4.18	3.23	D
Disu	5.91	5.83	B	Sanzhiyang	2.69	2.62	D
Sannong	4.48	5.40	B	Longwan	3.72	3.22	D
Dongmiao	4.11	3.66	C	Jingsheng	3.62	3.10	D
Gaoling	4.50	5.18	B	Lalie	3.81	3.41	C
Wuzhu	3.24	3.18	D	Baiwang	5.86	5.83	B
Daxing	3.32	3.68	C	Jiagui	4.99	4.52	C
Xia'ao	3.88	3.36	C	Laren	4.81	5.04	C
Longfu	3.43	4.03	C	Jiudu	4.20	3.75	C

Note: original data from Du'an County Annals, Du'an Land Annals, Du'an Hydraulic Annals, and Investigation Form of Du'an Foresty

security, A degree. Only 6 towns reached the condition of basic security, 9 towns reached the condition of critical security, 7 towns belonged to insecurity. 2) The ecological security condition has been worsening overall Du'an County. Except such 6 towns as Dengjiang, Anyang, Sannong, Daxing, Longfu and Laren, the degrees of ecological security in other towns during 1996–1999 were obviously lower than those during 1990–1995, and now it is still going on the worse. The reason lies in the fact that population pressure on eco-environment is still increasing sharply, the poverty problem is still prominent, the cultural quality of agricultural labor is still lower, and the technological ability has not been strengthened obviously to protect and construct eco-environment, and that various natural calamities have frequently happened, especially the disasters of drought and flood have been being serious.

3 REGIONALIZATION OF ECOLOGICAL SECURITY AND SUSTAINABLE AGRICULTURAL DEVELOPMENT

The purpose of regionalization of ecological security and sustainable agricultural development is to provide the reference for the regional agricultural resources protection, eco-environmental construction and formulating the ways to be lifted out of poverty (YANG *et al.*, 2000). According to the index of ecological security during 1996–1999, 4 degrees of ecological security (Table 2), as well as the regional coalition principles, we group 22 towns to 3 regions of ecological security and sustainable agricultural development as Ⅰ, Ⅱ, Ⅲ, and region Ⅲ is divided into 2 sub-regions (Table 3). In each region, the countermeasures are suggested for their ecological security and sustainable agricultural development.

Table 3 System of synthetic regionalization in Du'an County

Region	Sub-region	Name	Town
Ⅰ	Ⅰ-1	South region with basic security and synthetic agricultural development	Dengjiang, Anyang, Disu, Sannong, Gaoling, Baiwang
Ⅱ	Ⅱ-1	East region with critical security and agriculture, forestry, animal husbandry balanced development	Banling, Laren, Jiudu, Lalie, Jiagui
Ⅲ		Mid-west and south region with ecological insecurity and compound agriculture and forestry management	
	Ⅲ-1	Mid-west and north sub-region of fuel forest in peaks and depression area, dryrice, cattle and goat, wild grape, local specialty	Dongmiao, Bao'an, Longfu, Xia'ao, Yong'an, Daxing, Sanzhiyang, Wuzhu
	Ⅲ-2	South sub-region of dryrice, goats and chicken, medicinal materials, shelter-forest	Gushan, Jingsheng, Longwan

3.1 Region Ⅰ

This region, with basic security and agricultural synthetic development, is situated in the region of peaks and hills in the southern county. The region is generally smoother, where hilly area occupies 60%, temperature is appropriate, and precipitation is abundant. All conditions are advantageous to develop planting industries. The developing level in the region is relatively higher, and its investing strength to manage eco-environment is relatively more strengthened, land use is more rational, and regional ecological security index is so higher to be situated in the state of basic security, so it tends to develop more safely. However, there are also some factors un-beneficial to ecological security: firstly, the cultivated land area has reduced down by 0.06%, and popula-

tion growth has increased by 4.7‰ per year, which cause the relation between man and land tending to be serious; secondly, soil erosion is tending to be critical, the rate of soil erosion increases by 2% per year; and thirdly, the rate of land use is still lower.

The countermeasures of sustainable agricultural development in this region is as follows: 1) Around the construction of grain base, focus on two crops a year; popularize advanced agricultural technology to rise yield per unit area and to improve quality. 2) Quicken development of livestock husbandry with pig breeding as major industry, strengthening construction of commodity pig production base. 3) Quickly enlarge the production scale of sweet bamboo and beans, improve economic benefit of land use. 4) Stress the production of traditional and advantageous fruits, such as banana, orange. Meanwhile, positively plant economic forests, such as mulberry, longan, orange, litchi, etc. 5) Strengthen protection of in the field, improve synthetic benefits of land use. 6) Energetically develop aquaculture, make full use of water resources. 7) Positively construct food processing industries as advantageous industry to increase the employment opportunity. 8) Quicken urbanization, strengthen agglomerative extent to weaken the population pressure to eco-environment.

3.2 Region Ⅱ

This region, with critical security and agriculture, forestry, animal husbandry balanced development, is situated in peaks valley in eastern counties. In the region, topography is complicated, and gentle land is less, and stone desert is widespread. Though the Diaojiang River flows through region Ⅱ, the distribution of water resources in the region is not balanced in the space. The conditions of climate and soil there are so suitable to develop forestry and agriculture, and its vegetation coverage reaches 29.2%, with bushes as the main. The management of goat breeding is not enough perfect, so stock rising has done harm to eco-environment at certain extent. However, poor population has been reduced, lessening 64.2% from 1995 to 1997. Generally, eco-environment in the region is in the condition of critical security, and tends to worse.

The countermeasures of sustainable agricultural development in the region are as follows: 1) Readjust tree species, implement forestry plan, protect and recover the forest conserving water, and energetically transform stone desert. 2) Make rational use of resources, develop timberland, keep a certain quantity of economic forest, urge forestry to develop in balance. 3) Develop livestock husbandry with goat and pig breeding as major industry, positively cultivate introduced herbage, and improve the way of land use and quality of herbage. 4) Stabilize the grain yield in valley area, and import new species with more economic benefit. 5) Improve fruit species, and develop fruit production. 6) Make full use of water resources of the Diaojiang River, develop water and electricity industry in mountainous area, and improve the irrigation condition for cultivated land. 7) Strictly manage the extraction of mineral resources, and improve the work condition. 8) Strengthen the construction of road, and develop traffic and communication to promote the commodity production of agriculture, livestock husbandry and forestry.

3.3 Region Ⅲ

This region, with ecological insecurity and agriculture and forestry copound management, is situated in the region of peaks and depression in the mid-western and southern counties. Its population density is so high (124 persons/km^2), the vegetation coverage is lower, stone desert is also widespread, and the quantity and quality of water and land resources are both low, so the economy of the region is in the poor and backward condition. In the region, because of weak consciousness of farmers' ecological protection, land development is generally in the condition of over-cultivated and lower level of ecological construction. The disasters of drought or flood frequently happens, so that the grain yield is lower and unsteady, eco-environment becomes worse, and ecology is in the insecurity condition. Meanwhile, this region is divided into two sub-regions.

Sub-region Ⅲ-1—mid-west and north sub-region of developing fuel forest in peaks and depression area, dryrice, cattle and goat, wild grape, and local specialty. The countermeasures of sustainable agricultural development are as follows: 1) Moderately lumber fuel forest, protect original shelter-forest, and carry out the measures of closing hillsides to facilitate forest for the stone mountains naked seriously. 2) Adjust the way of land use, thoroughly return cultivated land of slope over 25° to forest. 3) Energetically plant wild grape, and raise benefits of economic forest. 4) Increase fund investment to build water conservancy facilities, and protect limited water resources. 5) Develop methane source of energy, and make full use of waste residue and waste liquid. 6) Cultivate technical staff to raise

the crop yield. 7) Improve tractor-ploughing road, raise road density, keep the yield of advantageous local specialty, and widen market channel.

Sub-region Ⅲ-2—south sub-region of developing dryrice, goats and chicken, medicinal materials, and shelter-forest. Its countermeasures of sustainable agricultural development are as follows: 1) Transform mid and low yield field, and raise multiple crop index. 2) Control the growth of population, regulate the population distribution and raise the density of agglomerative population. 3) Increase the utilization of organic fertilizer, such as planting green manure, spreading manure, returning waste crop to the field, etc. 4) Develop family sideline with chicken and goat breeding as major industry. 5) Energetically build forest for water and soil conservation on waste cultivated land and hillsides fields. 6) Energetically develop medicine materials planting.

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