African Journal of Agricultural Research Vol. 7(17), pp. 2653-2663, 5 May, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.385
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

The relationship between agricultural intensification and sustainability in China

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Accepted 12 March, 2012

According to the principles of agricultural sustainability, combining with utilizing the methods of principal components analysis, we made full use of statistical data from 1949 to 1998, Yujiang County, Jiangxi province. At the same time, the assessing system included 28 formed. The results showed that agricultural sustainability rose increasingly with agricultural intensification growth. However, both of them kept the same pace. The production sustainability index has been increased from 0.0808 in 1949 to 0.1496 in 1998. The annual raising rate has reached 1.265% during 50 years in Yujiang County; the economic sustainability index leaped from 0.0166 in 1949 to 0.4093 in 1998. It is enlarged 24.65 times compared with that of 1949. The ecological sustainability index has augmented 0.125% yearly since 1949. In general, the sustainability index reached 0.7533 in 1998. When the agricultural intensification is raised 1 unit, the sustainability would be enhanced by rate of 0.0001.

Key words: Yujiang County, sustainability, agriculture, intensification.

INTRODUCTION

Many definitions about sustainable agriculture and sustainability have been put forward since 1987. A widely accepted definition for sustainable agriculture was the one adopted in 1988 by The American Society of Agronomy (1988), namely, the sustainable agriculture enhances environmental quality and the resource on which the development of agriculture depends, and provides for basic human food and fiber needs, and is economically viable, and enhances the quality of life for farmers and society as a whole. The term sustainability was first advanced in 1980 by the International Union for the Conservation of Nature and National Resources (Lele, 1991). While sustainability is a complex and wide-ranging concept and sustainability properties dimensions vary widely (Filson, 2004). Agricultural intensification can be technically defined as an increase in agricultural production per unit of inputs (which may be labour, land, time, fertilizer, seed, feed or cash). For practical purposes, intensification occurs when there is an increase in the total volume of agricultural production that results from a higher productivity of inputs, or agricultural production is maintained while certain inputs are decreased (FAO, 2004). They therefore employ relatively larger investments in land, labor, and capital than was traditionally the case when smaller, more mixed farming operations predominated (Filson, 2004).

Nearly 100% of farmers in China use improved varieties of rice, wheat and maize (Huang et al., 1999), together with subsequent investments in water controlling, intensification of chemical input use. According to the state statistical data, the fertilizer application reached 298 kg·hm^{-2} in 2004. Officially, the percentage of irrigated arable land has risen from 16% in 1950 to nearly 50% in 1990's (Conway, 1997). Since 1990s, it has been paid high attention to the sustainable development of intensive Chinese agriculture which follows the same definition of FAO, Earth Summit document. During the same period, some scientists have voiced concerns that the intensification of farming

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systems may not be sustainable because of systematic degradation of the resource base and environment (Pingal et al., 1994). Brown (Brown, 1995; Brown and Halweil, 1998) addressed “who will feed China?” and “China’s water shortage could shake world food security”. China is not only the world’s most populous country, but also its economy grows fast. China is faced with an extraordinary challenge (Brown, 2005). Could not the intensive China’s agriculture develop sustainably? Concerning reports have not been found, so the author according the principles of agricultural sustainability collected the data of Yujiang county, Jiangxi province, adopted the SPSS method to get the weight of index, obtained the value of agricultural sustainability since 1949 by comparing the sustainability every year.

At last it revealed the relationship between the intensification and sustainability of agriculture in china.

RESEARCH METHODS

General condition of research region

The researched area was Yujiang County, Jixiang province. Its sites are 116° 41' ~ 117° 09' E, 28° 04' ～ 28° 37' N. In 2008, the population was 335500, and the total area of arable land was 20400 ha. The total land area is 927 km^2, 78.2% of which is covered with the mountain area and only 21.8% of which is the plain. The average of sunshine duration is 1809 h per year. The mean annual temperature is 17.6°C. The number of frost-free season is 262 days. The average annual precipitation could reach 1700 mm. Moreover, the level of agricultural intensification was high, for instance, total machine power reached 2.94 kW/ha, and the rate of fertilizer application was 675.8 kg/ha. Therefore, these conditions would play a key role in intensive agricultural development.

The standardization of original data

There were diversities of dimensions and quantitative levels in the original data. For the sake of analysis, it was essential to standard original data. Therefore, both of the dimensions would be unified and the gap of quantitative levels of indexes could be eliminated. The formula of standardization for original data was as follows:

$$\frac{X_i - X_{\min}}{X_{man} - X_{\min}}$$

Where: X_i = original data on every index, X_{min} = the minimum datum of original data, X_{max} = the maximum datum of original data.

After the standardization of original data, the value of data would be between 0 and 1.

Selecting the method to confirm the evaluation indexes weight

The weight vectors were confirmed by the method of principal components analysis. The standardization data should be used and analysed with method of principal components analysis, the contribute rate (CR) and factor loading matrix (FLM) would be calculated. The accumulation of CR multiplying by FLM of main components could express the effects on total information by each index. This method was proposed by Wu and Chen (1996a). The formula was as:

$$WK_i = \frac{\sum_{j=1}^{n} CR(j) * FLM(ji)}{\sum_{i=1}^{n}\sum_{j=1}^{n} CR(j) * FLM(ji)}$$

Where: Wk = index weight; i = the serial number of index; j = main component; n = the number of index; CR = the contribute rate of main component; FLM = factor loading matrix.

According to the afore-mentioned formula, the weight per index would be easily confirmed.

Weight of evaluation indexes confirming

According to the aforementioned method, the weight of index would be decided, the results was showed in Table 2.

EVALUATION SYSTEMS

The data collection

The statistics data were furnished by statistics office of Yujiang county, Jiangxi province. A few data were gotten by forum with some offices of agriculture office, Forestry Office of Yujiang County.

Production sustainability

The production sustainability is that the produce could meet the need of economic growth and increasingly improve the living standard. It is affected by many factors such as industrial input including inorganic fertilizers, pesticides and mechanization of agriculture (Chi, 1990; Shen, 1996; Niu, 1997; Luo, 2001; Chen, 2003).

Economic sustainability

The economic sustainability involves both economic beneficial and efficiency aspects. The economic benefits are the primary content of agricultural production; they are the core of agricultural sustainability. The economic sustainability focuses on the aspects of increasing growth of economic benefits and efficiency (Niu, 1997; Luo, 2001; Chen, 2003; Ren, 1995).

Ecological sustainability

The ecological sustainability is defined as making full use of resources, protecting natural environment and improving the environmental quality. However, better environment is the crucial basis of production and economic sustainability. So the ecological sustainability means a responsibility for the environment - a stewardship of our natural resources (Luo, 2001; Wu and Chen, 1996b; Niu, 1997; Chen et al., 1993). Amongst production, economic, and ecological sustainability, they are integration, and they promote the intensive agriculture sustainable development. Therefore, production, economic and ecological sustainability play the same role of the development of intensive agriculture.

Table 1. The evaluation system of intensive agriculture in Yujiang County.

The first level of indexes	The second level of indexes	The third level of indexes
Production sustainability (PS)	Natural resources index (NRI)	Area of arable land per capita (AALPC) Area of paddy rice per capita (APRPC)
	Agricultural intensification index (AII)	Amount of fertilizer application per area (AFAPA) Agricultural intensification (AI)
	Production index (PI)	Commercial ratio of agricultural production (CRAP) Amount of grain per capita (AGPC) Amount of meat per capita (AMPC)
	Production efficiency index (PEI)	Yield of rice per area (YRPA) Yield of grain per area (YGPA) Commercial ratio of pig (CRP)
Economic sustainability (ES1)	Production benefit index (PBI)	Total value of agricultural (TVA) Value of plantation (VP) Value of livestock (VL) Value of forestry (VF) Value of aquaculture (VA)
	Economic efficiency of production index (EEPI)	Net Income per capita (NIPC) Output value per labor (OVPL) Output value per capita (OVPC) Productivity (P)
Ecological sustainability (ES2)	Resources utilization index (RUI)	Nitrogen balance index (NBI) Phosphorus balance index (PBIp) Potassium balance index (PBIk) Planting index (PI) Ratio of energy output to input (REOI) Rate of light utilization of grain (RLUG) Rate of light utilization of rice (RLUR)
	Agricultural calamity- resistance index (ACRI)	Irrigation rate of arable land (IRAL) Rate of calamity- resistance (RCR)

The evaluation index and systems

The evaluation system was established (Table 1). It is consistent with afore-mentioned principle of sustainability. The evaluation system would be divided into three levels (He and Bi, 1986; Hou, 1999). The first level included production, economic and ecological sustainability indexes. The second one was composed of different index groups that indicated three sustainabilities, namely, the production sustainability indexes were formed by natural resources index, agricultural intensification index, production index; economic sustainability indexes were formed by production efficiency index, production benefit index, and economic efficiency of production; the ecological sustainability indexes were constructed by index of resources utilization and agricultural calamity-resistance index. The third one included 28 index. The detail contents were showed in Table 1.

RESULTS AND ANALYSIS

The relationship between intensification and the production sustainability

Among the components of production sustainability index, the natural resources index has been heavily cut down with the population size increasingly growth. On the contrary, the agricultural intensification index has been zoomed with the rate of machine, electronic power, artificial fertilizer application per area of arable field growing; the agricultural production index has been enlarged with the crop yields rising (Figure 1). From 1949

Table 2. The weight of evaluation index of intensive agriculture in Yujiang County.

Index	Weight	Index	weight	Index	weight	Index	weight
AALPC	0.0386	YRPA	0.0361	VA	0.0400	PBIk	0.0340
APRPC	0.0367	YGPA	0.0368	NIPC	0.0403	PI	0.0315
AFAPA	0.0398	CRP	0.0393	OVPL	0.0404	REOI	0.0382
AI	0.0399	TVA	0.0395	OVPC	0.0242	RLUG	0.0288
CRAP	0.0388	VP	0.0371	P	0.0363	RLUR	0.0216
AGPC	0.0168	VL	0.0386	NBI	0.0361	IRAL	0.0395
AMPC	0.0350	VF	0.0396	PBIp	0.0368	RCR	0.0397

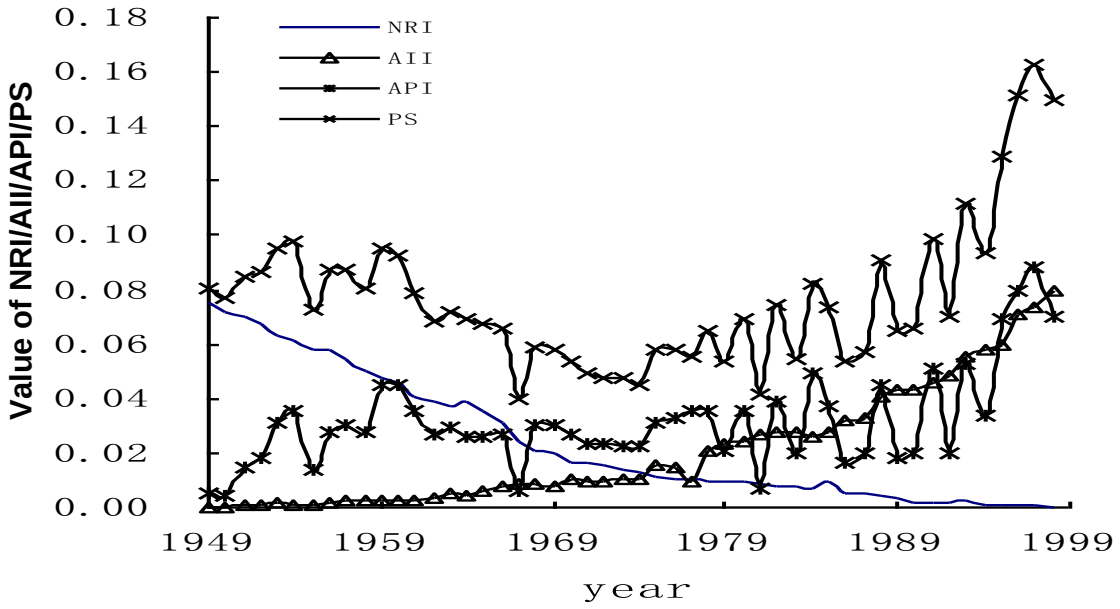

Figure 1. The relationship between PS and NRI, AII and PI in Yujiang County for 50 years.

to 1998, the NRI was gradually cut down by population size augment. The AALPC and APRPC reached the minimum in 1998. The natural resources index had been reduced at the rate of 0.1506% during 50 years in Yujiang County. The corresponding period, the AALPC and APRPC had been decreased by 67.53 and 68%, respectively. The former decreasing annual rate was 0.2592% and the latter was cut down by the rate of 0.2316% annually (Figure 2). In the same period, AII has been continuously grown; the annual increasing rate reached 0.1594% (Figure 2). AFAPA had outgrown from 1.3 kg·ha^{-1} in 1949 to 786.44 kg·ha^{-1} in 1998. As for the AI, it climbed about 38 times from 140.38 CNY in 1949 to 5327.03 in 1998 (Figure 3). Moreover, PI has been aggrandized, the rate of agricultural production index arrived at 0.1286% per year (Figure 1). Since CRAP was raised from 18.83% in 1949 to 42.30% in 1998; the AGPC reached 431 kg and AMPC was 81.8 kg in 1998, but the AGPC was only 238.7 kg in 1949, the AMPC was 15.23 kg in 1978 (Figure 4).

In general, the PS index has been increased as 85.15% from 0.0808 in 1949 to 0.1496 in 1998. The annual raising rate reached 1.265% for 50 years in Yujiang County.

The relationship between economic sustainability index and production efficiency, production benefit and economic efficiency of production index

The economic sustainability index was affected by production efficiency, production benefit and economic efficiency of production index. However, the production efficiency was affected by YRPA, YGPA and CRP. Both YRPA and YGPA increasingly grow with AI. In comparison with production efficiency of 1949, it enhanced almost 2 times and reached 0.1105 (Figure 5). Figure 5 indicated that the economic sustainability soared from 0.0166 in 1949 to 0.4093 in 1998. It enlarged 24.65 times comparing with that of 1949. The annually leaping rate

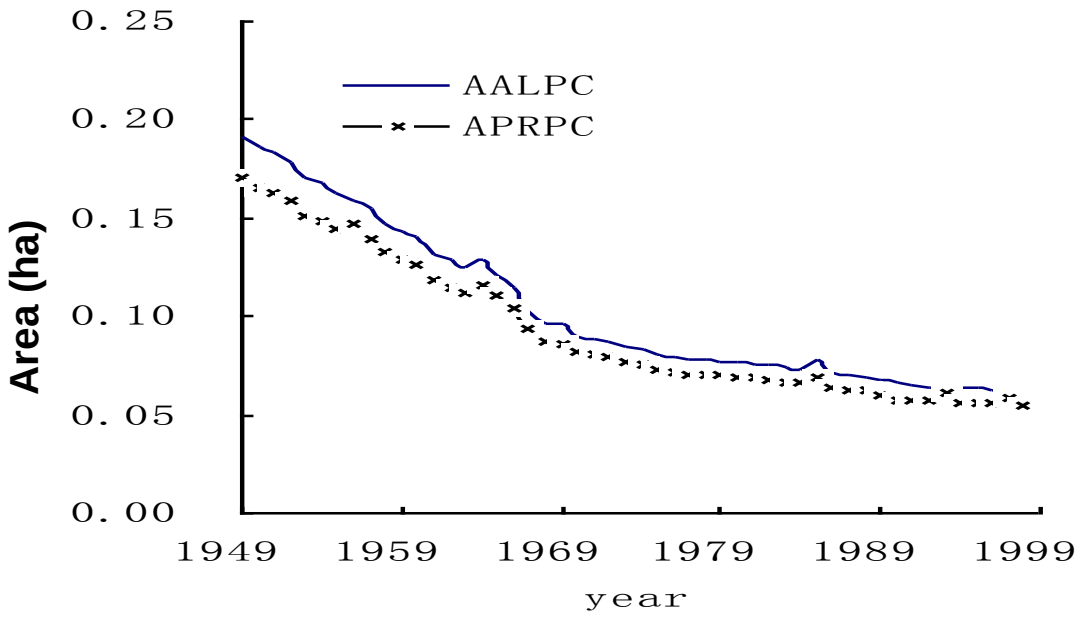

Figure 2. The variation of AALPC and APRPC during 50 years in Yujiang County.

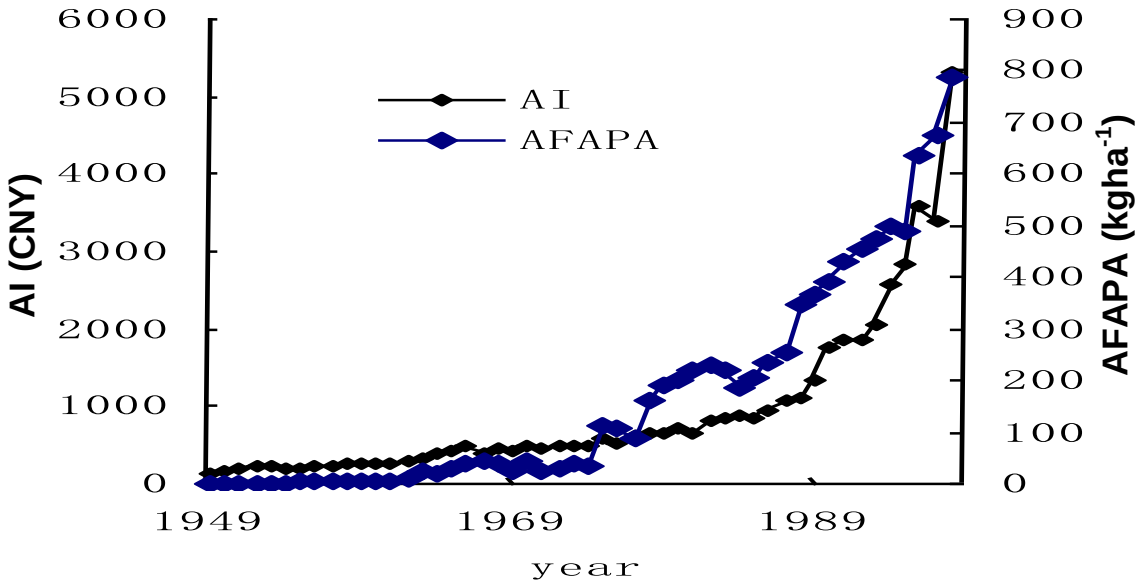

Figure 3. The variation of AI and AFAPA during 50 years in Yujiang County.

was 6.7596% as a result of net income increase. YRPA and YGPA increasingly rose. The former enlarged from 1275 kg·ha^{-1} in 1949 to 8048 kg·ha^{-1} in 1998; the latter leap more than 7 times (from 990 to 7667 kg·ha^{-1}). The commercial rate of pig rose from 74.26% in 1949 to 145.29% in 1998. It has been benefited from “Green Revolution”. Thereby production efficiency index increasingly rose at the annual rate of 0.188% (Figure 6). During the same term, the production benefit index enhanced in 1784 times. The increasing rate reached 16.51% annually. The TVA, VP, VL, VF, and VA outgrow were 52.38, 25.16, 75.97, 327.25 and 208.2 times for 50 years, respectively (Figure 7).

As to the economic efficiency of production index, it reached 0.1204 in 1998. The NIPC, OVPL, OVPC, and P raised to 2082, 5217.16 and 1986.81 CNY, and 1133 kg

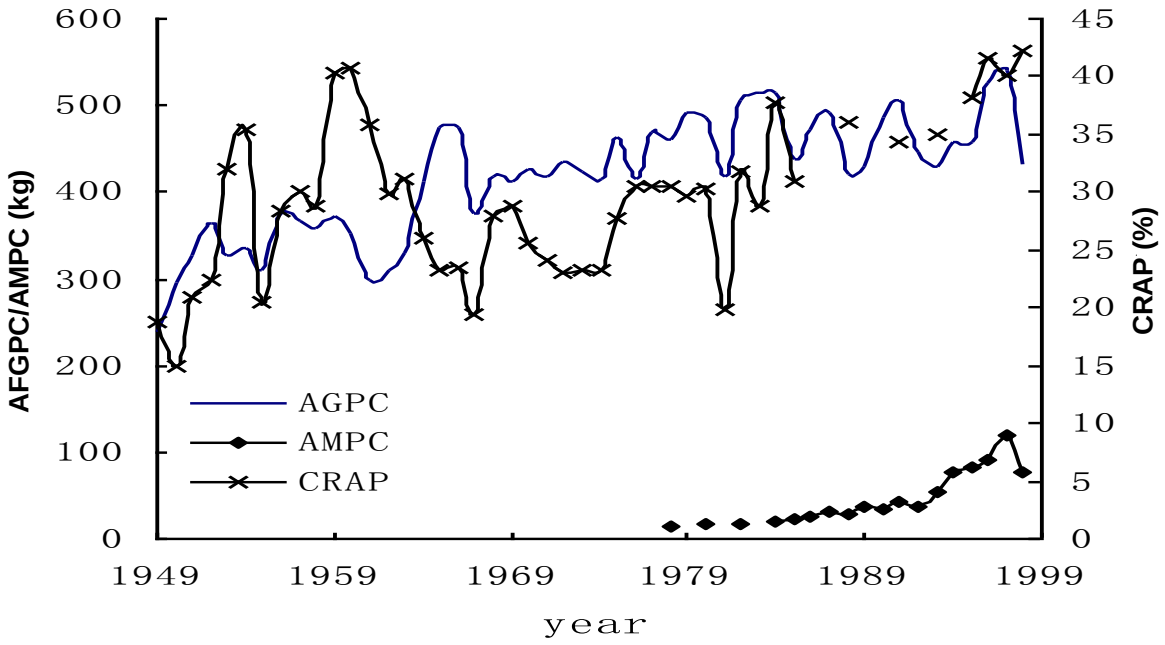

Figure 4. The variation of AGPC, AMPC and CRAP during 50 years in Yujiang County.

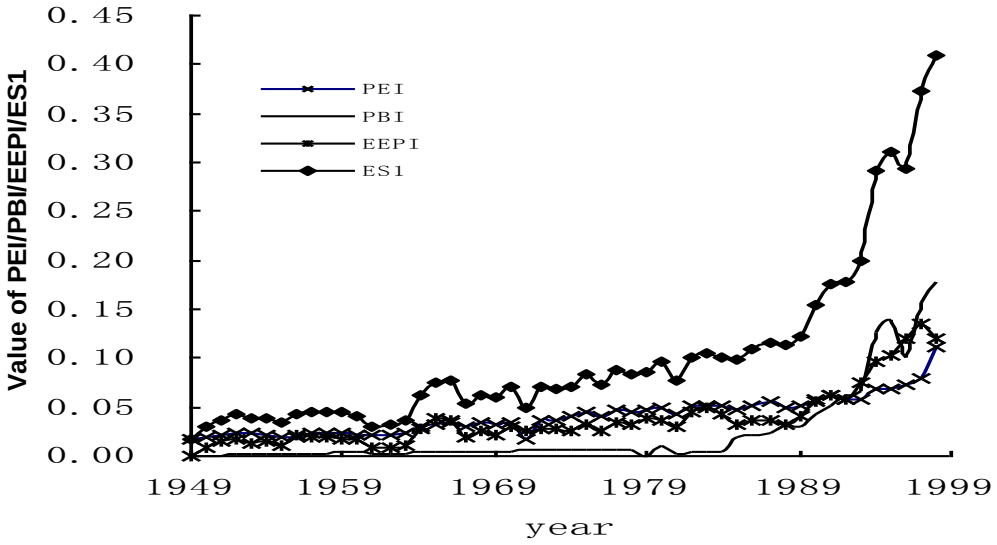

Figure 5. The variation of ES1, PEI, PBI and EEPI during 50 years in Yujiang County.

in 1998, respectively; compared with that of 1949, they raised about 56.3, 22.1, 17.7 and 1.5 times, respectively (Figure 8).

The relationship between ecological sustainability index and resources utilization and agricultural calamity- resistance index

The ecological sustainability index was affected by resources utilization and agricultural calamity- resistance index. The resources utilization index was determined by NBI, PBIP, PBIK, PI, REOI, LURFG and LURR. The NBI, PBIP, PBIK were defined that input of N and/or P and/or K to output of N and/or P and/or K in agriculture systems. But the calamity- resistance index rested with the IRAI and RCR. Therefore, the ecological sustainability index augmented 0.125% yearly since 1949 (from 0.1319 in 1949 to 0.1944 in 1998) (Figure 9). From 1949 to 1998, the resources utilization index increased from 0.0932 to

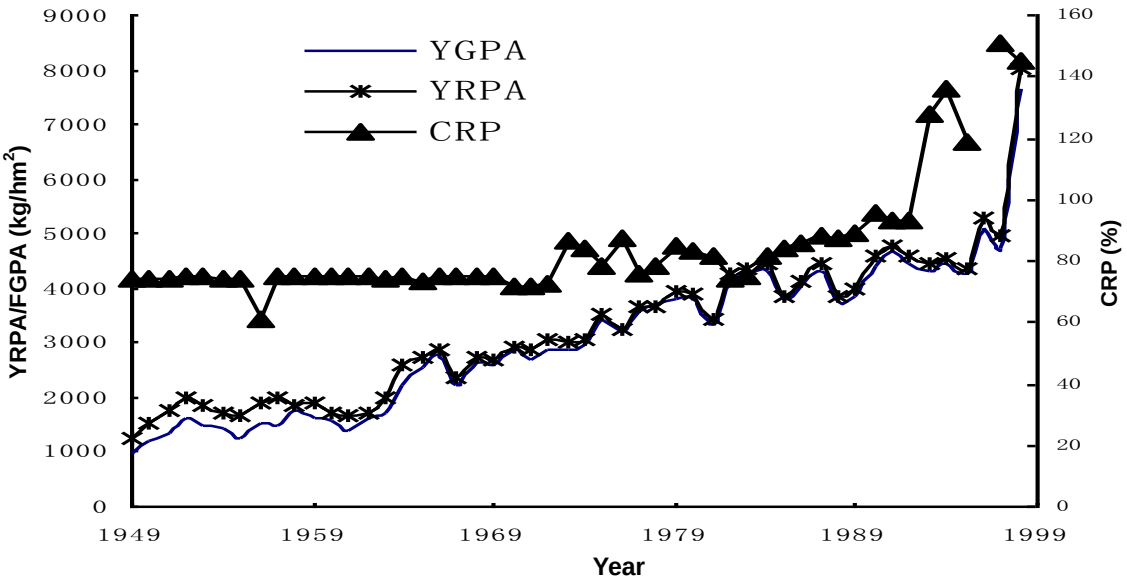

Figure 6. The variation of YRPA, YGPA and CRP during 50 years.

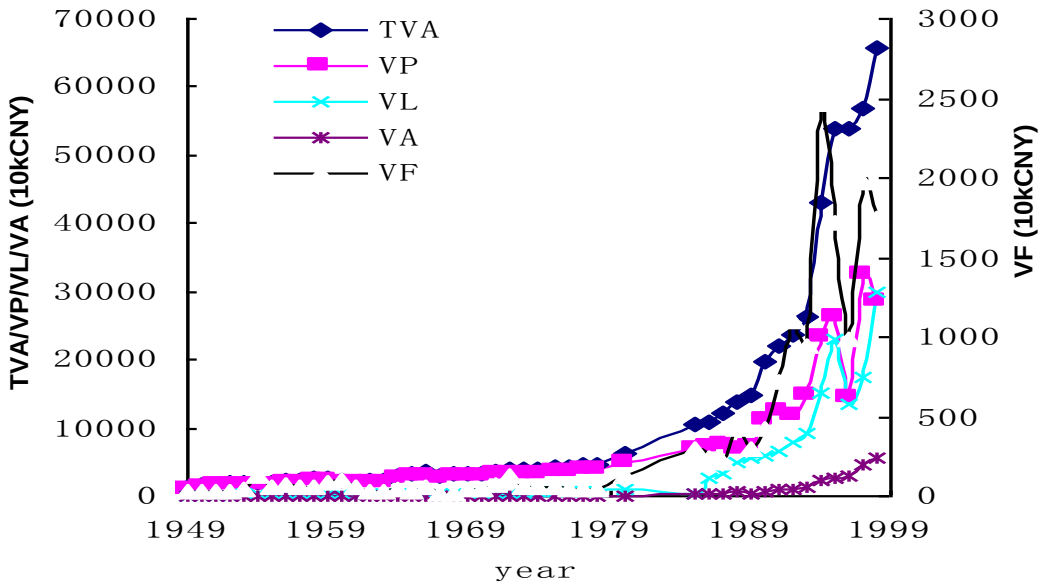

Figure 7. The variation of TVA, VP, VL, VF and VA during 50 years.

0.1217. The nitrogen nutrition turned from the state of shortage into the state of surplus with the chemical fertilizer application. The nitrogen balance was 1.16 in 1949 and 0.47 in 1998. However, as for the phosphorous balance and potassium balance, the conditions were on the contrary. The phosphorus was still plenitude; the phosphorous balance was 0.23 in 1949 and 0.15 in 1998. The potassium nutrition still changed from grievous shortage to slight surplus. It was shown by that potassium balance (3.35 in 1949 and 0.90 in 1998). The REOI still slightly decreased from 3.42 in 1949 to 2.89 in 1998 (Figure 10). As to the RLUG, RLUR rose from 0.0778 and 0.1003% in 1949 to 0.6029 and 0.6328% in 1998. The planting index enhanced 120.3 from 154.8% in 1949 to 275.1% in 1998 (Figure 11).

On the other hand, with the rate of arable land increasing (from 4.91% in 1949 to 92.13% in 1998), and rate of calamity-resistance decreasing (from 90.53% in 1949 to 81.91% in 1998), the calamity- resistance index grow to 0.034 (from 0.0387 in 1949 to 0.0727 in 1998)

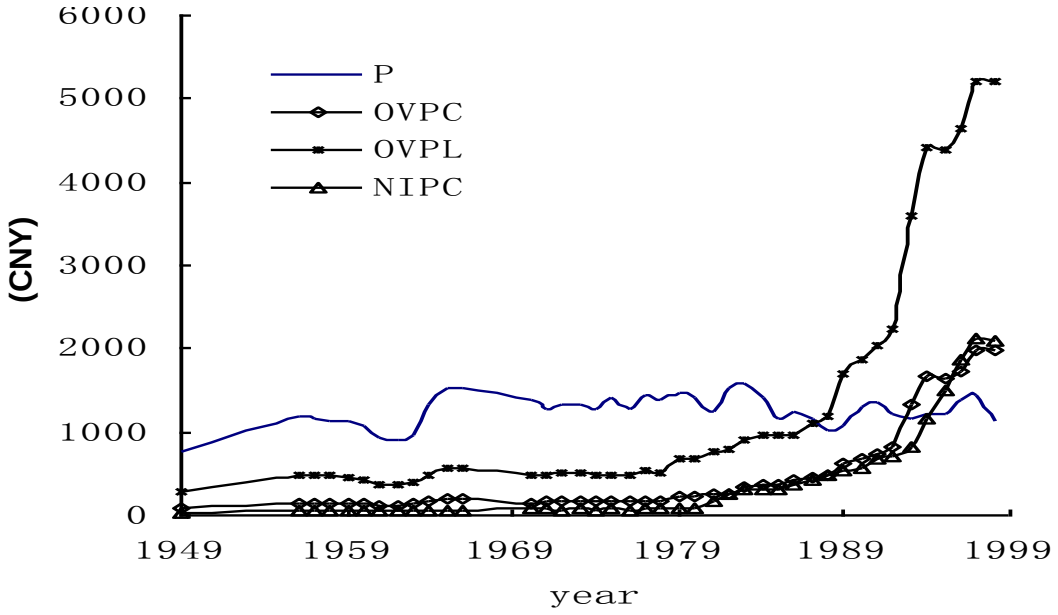

Figure 8. The variation of P (kg), OVPC, OVPL and NIPC (CNY) during 50 years.

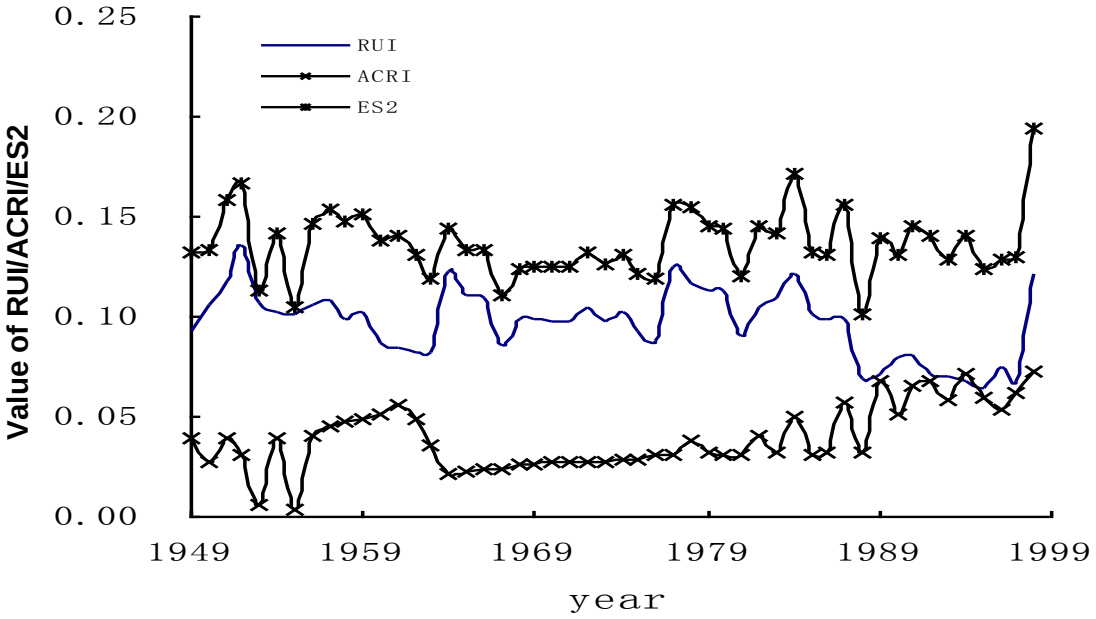

Figure 9. The variation of ES2, RUI and ACRI during 50 years in Yujiang County.

(Figure 12). Figure 12 showed that the RCR was the lowest during 1960 to 1980s. We thought that the population rapidly increased and needed much more lands to convert into farmlands; the agricultural intensification level was low, the agricultural machines were poor, thereby the agricultural production was threatened by drought and flood disasters, also the application of pesticide was little, the pest or disease might decrease the yield, even get nothing.

The variation of sustainability since 1949 in Yujiang County

Since 1949, the sustainability has been increasingly grown in Yujiang County. The sustainability was merely

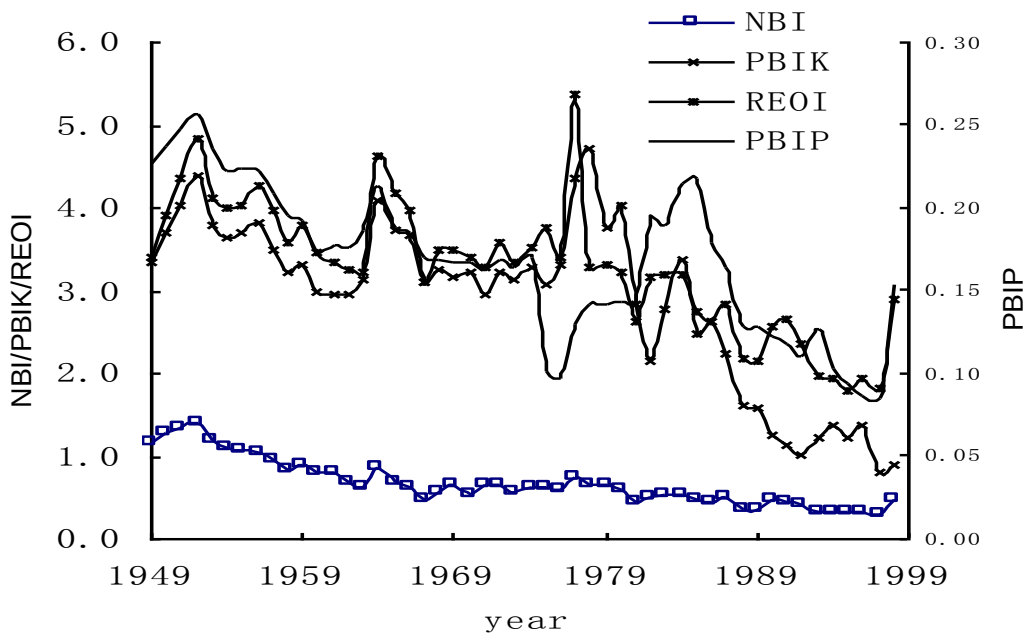

Figure 10. The variation of NBI, PBIP, PBIK and REOI during 50 years.

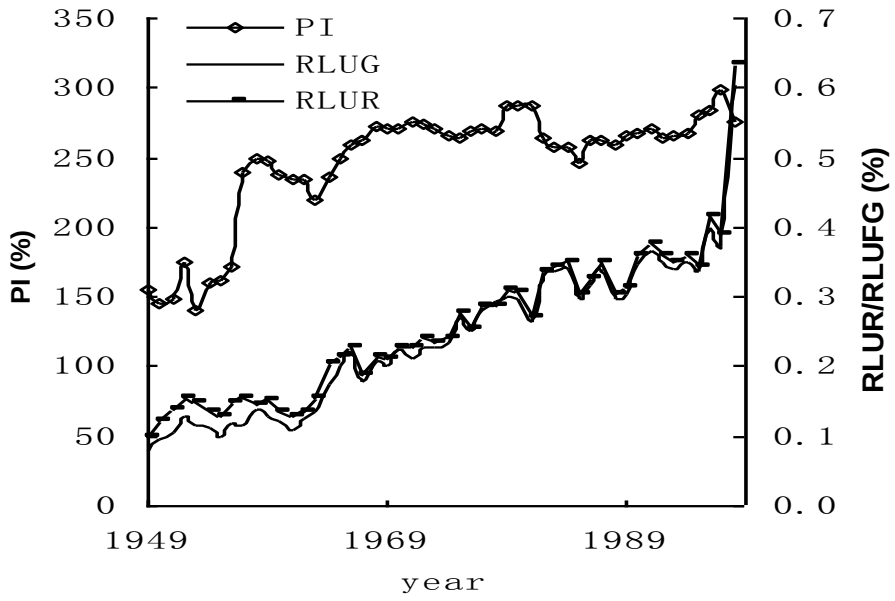

Figure 11. The variation of PI, RLUG and RLUR (%) during 50 years in Yujiang County.

0.2294 in 1949, but it was 0.7533 in 1998. It climbed 3.28 times (Figure 13).

The relationship between sustainability and agricultural intensification in Yujiang County

In order to study the relationship between sustainability and agricultural intensification in Yujiang County, the formula of sustainability (y) and agricultural intensification (x) was established:

$y = 0.0001x + 0.2184$, $R^2 = 0.9268$, $r = 0.9627^{**}$, $r_{0.01} = 0.328$, $r_{0.05} = 0.235$

According to the formula, it is obviously found that the

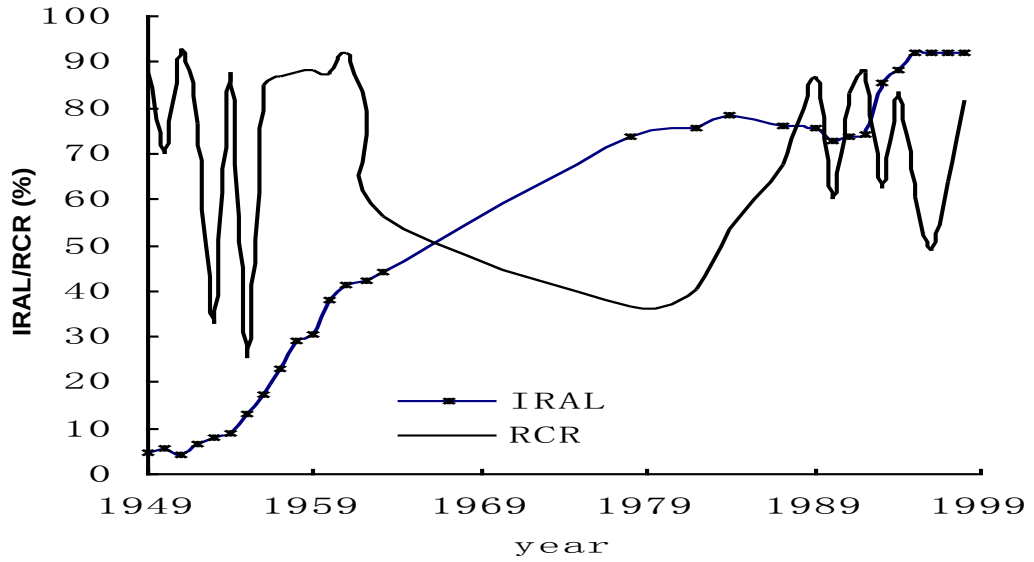

Figure 12. The variation of IRAL (%) and RCR (%) during 50 years in Yujiang County.

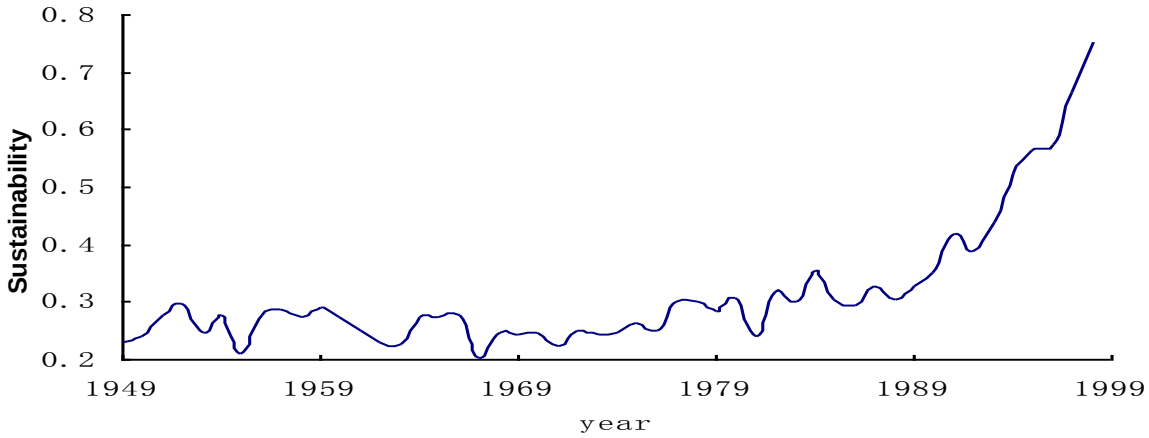

Figure 13. The variation of sustainability since 1949 in Yujiang County.

sustainability increased with agricultural intensification rising. Because they have linear relationship, and agricultural intensification raised 1 unit, the sustainability would be enhanced to 0.0001.

DISCUSSION

Agricultural sustainability has become an increasingly important issue in the latter half of the 20th Century, and in particular how this can be matched with intensification (Morse et al., 2002). Today, concerns about sustainability centre on the need to develop agricultural technologies and practices that do not have adverse effects on the environment, and lead to both improvements in food productivity and have side effects on environmental goods and services. Some report showed that they were inconsistent, even they were opposite. But the development of Yujiang County, Jiangxi province displayed that the production sustainability index has been increased from 0.0808 to 0.1496 in 50 years. Meanwhile, the annual raising rate has reached 1.265% and the sustainability index reached 0.7533 in 1998. When the agricultural intensification raised 1 unit, the sustainability would be enhanced by rate of 0.0001. So, we found the relationship between sustainability and agricultural intensification was linear one in Yujiang County. As a more sustainable agriculture seeks to make the best use of nature's goods and services, technologies and practices must be locally adapted and fitted to place (Pretty, 2007). At the same time, the chemical fertilizer was applied more and more, the soil fertility could not be

only improved but also increased.

The state of soil nitrogen turned from shortage to over plus, the state of potassium could be evident change. These advances were fuelled by modern plant breeding, improved agronomy and development of inorganic fertilizers and modern pesticides (Hazel and Wood, 2008). Therefore, in China, growing population, shrinking arable land demand more attention to improve sustainability and intensification of agricultural development.

CONCLUSION

The study concludes that agricultural sustainability can increase easily with agricultural intensification growing in the meantime in China. The relationship between sustainability and agricultural intensification was linear one; both theory and practice from the point of view, there may be intensive and sustainable synchronization; but there may be separate. Result of the separation of interaction is mutual restraint. If the two complement each other, they can continue to progress together.

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