CHINESE GEOGRAPHICAL SCIENCE
Volume 9, Number 4, pp. 358– 367, 1999
Science Press, Beijing, China

DEGRADATION OF NATURAL RESOURCES BY ENVIRONMENTAL POLLUTION①
——A Comparative Study Between Huizhou City and Zhaoqing City

Kuang Yaoqiu(匡耀求)　　Sun Dazhong(孙大中)

Guangzhou Institute of Geochemistry, the Chinese Academy of Sciences, Guangzhou 510640, *P. R. China*

(Received 27 May 1999)

ABSTRACT: Compared the total agricultural production (TAP) of the 5 counties in Huizhou City with that of the corresponding 5 counties in Zhaoqing City during the period from 1980 to 1996, it can be seen that the TAP growth rate of the 5 counties in Huizhou City had been a little higher than that of the 5 corresponding counties in Zhaoqing City before 1983, but has been becoming lower than the latter since 1984, and the agricultural production in Huizhou City has been gradually becoming lag behind that in Zhaoqing City since then. The TAP loss in Huizhou City kept above 3×10^8 yuan every year since 1986. Detailed investigation shows that the acid rain caused by the atmospheric pollution may be the main cause for the lower productivity of the land in Huizhou City. The atmospheric pollution arisen from rapid and extensive development of the economy in the Zhujiang(Pearl) River Delta Region has already greatly reduced the load capacity of the natural resources in Huizhou City and severely affected the sustainable development of the region.

KEY WORDS: environmental pollution, agricultural economic loss, degradation of natural resources, acid rain

1 INTRODUCTION

Both resource and environment are relative conceptions, which are relative to the systems they refer to. The environment of a certain area (or a certain business) is possibly the resources of the surrounding areas (or another business). The atmosphere, water bodies and soil on the ground are commonly the environment receiving wastes discharged from industry, and also at the same time the resource basis supporting agricultural development. Hence from a wider and longer point of view, the pollution to the environment is, to some extent, a kind of destruction to resources. It is now quite difficult to accurately calculate the economic loss of resource destruction or degradation caused by environmental pollution. This paper attempts to discuss the economic loss in agriculture due to degradation of natural resources caused by atmospheric pollution.

Since the reform and open policy was carried out in 1979, the economic growth in the Zhujiang River Delta Region has kept in a very high speed. The rapid development of industries has led to vast demand of energy and building materials, which stimulated the explosive development of power industry and cement manufacture. More and more coal-burning power plants and cement factories were put into production, which make the region a cluster of chimneys. The harmful gases like SO_2 and NO_X discharged from them caused severe pollution to the high sky of the whole region. Such acid materials in the high sky may sink to the ground in the form of acid rain under

① The work is a part of the "Study on Key Issues in the Sustainable Development of the Zhujiang River Delta Economic Zone" (Z97002), which is financially supported jointly by the Ministry of Science and Technology of the People's Republic of China and the Natural Science Foundation Committee of Guangdong Province.

the function of the weather system. The frequency and acidity of the acid rain in the Zhujiang River Delta Region are increasing year by year. The frequency of acid rain in the eastern and central parts of the region had been up to 70% since the end of the 1980s. The acid rain occupies almost 90% of the total precipitation, and the average annual pH value of the acid rain is as low as 4.2.

Attempt here is to discuss the economic loss due to degradation of natural resources caused by atmospheric pollution, through comparing the growth of the agricultural production value during the period from 1980 to 1996, of two typical districts, which are similar in natural geographical and agricultural conditions as well as social development level, but distinctive in acid rain frequency and acid rain buffering capacity.

2 COMPARISON OF AGRICULTURAL GROWTH BETWEEN ZHAOQING CITY AND HUIZHOU CITY

Zhaoqing City and Huizhou City are located in Guangdong Province, P. R. China. They are similar in many aspects, such as the geographical condition, agricultural condition, and social development level (Table 1 and 2). Therefore, their agricultural development should be comparable. Actually, the scale of agricultural development (agricultural population and total agricultural production) and the agricultural growth rate of the corresponding counties in the two cities were very close in 1980. As a whole, the 5 counties in Huizhou City were a little stronger in the total amount of agricultural resources and per capita agricultural resources and productive value than the corresponding 5 counties in Zhaoqing City in 1980. If it was not disturbed by some factors like environmental pollution, Huizhou City would be possible to keep its agricultural growth rate not less than that of Zhaoqing City.

Table 3 gives a comparison of the total agricultural productive value of the five counties (or areas) in Zhaoqing with the corresponding counties (or areas) in Huizhou from 1980 to 1996. It can be seen from Table 3 and Fig. 1 that the agricultural growth rates of the five counties in Huizhou were comparable with that of the corresponding counties in Zhaoqing, and the growth rates of Longmen, Huiyang and

Table 1 Natural geographic conditions of Zhaoqing and Huizhou

Items	The 5 counties (or area) in Huizhou	The 5 counties (or area) in Zhaoqing
Geographic situation	22°40′ – 24°00′ N, situated in the northeastern end of the Zhujaing River Delta Economic Zone	22°50′ – 24°00′ N, situated in the northwestern end of the Zhujiang River Delta Economic Zone
Climate	Oceanic monsoon climate, average annual precipitation 1600 – 2000 mm	Affected by oceanic monsoon climate, average annual precipitation 1660– 2000 mm
Landform	Hilly mountainous region with small basins along the Dongjiang River valley	Hilly mountainous region with small basins along the Xijiang River valley
Zonal soil	Dominated by lateritic red earth, pH value 4.5– 5.5	Dominated by lateritic red earth, pH value 4.5– 5.5
River	The main stream of the Dongjiang River runs through	The main stream of the Xijiang River runs through
Traffic	Guangzhou– Meizhou– Shantou railway, No. 205 and No. 324 national highways run cross and through	Sanshui– Maoming railway, No. 321 and No. 324 national highways run cross and through
Geology	Mesozoic faulting depression basins, clastic sedimentary rocks occur widely	Caledonian folding belt and Indosinian depression zone, carbonate rocks occur widely

Table 2 The agricultural conditions of the corresponding 5 county pairs in Zhaoqing and Huizhou

County or area	Total area of land (km^2)	Proportion of cultivated land (%)		Agricultural population (1980) (persons)	Per capita cultivated land area (ha)	Total agricultural production (10^4 yuan)	Per capita productive value (yuan)
		1980	1996				
Guangning in Zhaoqing	2471	7.23	6.63	401000	0.05	8428	210.17
Longmen in Huizhou	2295	8.89	7.63	309258	0.07	7172	231.91
Gaoyao in Zhaoqing	2192	17.46	14.34	547065	0.07	13881	253.74
Boluo in Huizhou	2870	20.16	16.18	543536	0.11	15836	291.35
Zhaoqing proper	688	20.83	13.99	144552	0.10	4559	315.39
Huizhou proper	419	18.79	7.06	62753	0.13	1624	258.79
Sihui in Zhaoqing	1258	20.87	15.60	287100	0.09	8270	288.05
Huiyang in Huizhou	2178	19.06	14.28	378027	0.11	10488	277.44
Fengkai in Zhaoqing	2723	7.95	7.55	317632	0.07	8567	269.71
Huidong in Huizhou	3396	10.78	9.73	398768	0.09	10041	251.80
5 counties in Zhaoqing	9332	12.69	10.46	1697349	0.07	43705	257.49
5 counties in Huizhou	11158	14.72	11.75	1692342	0.10	45161	266.86

County or area	Comprehensive comparison in social development
Guangning in Zhaoqing	Mountainous county, transporting facilities deficient
Longmen in Huizhou	Mountainous county, transporting facilities deficient
Gaoyao in Zhaoqing	Closely adjacent to Zhaoqing proper, having good transporting service
Boluo in Huizhou	Closely adjacent to Huizhou proper, having good transporting service
Zhaoqing proper	Administrative office of prefecture level is located
Huizhou proper	Administrative office of prefecture level is located
Sihui in Zhaoqing	Closely adjacent to Zhaoqing proper, having good transporting service
Huiyang in Huizhou	Closely adjacent to Huizhou proper, having good transporting service
Fengkai in Zhaoqing	Border county, bounded by Guangxi, with water and land transporting facilities to Wuzhou city. No. 321 national highway runs through the southern part of the county
Huidong in Huizhou	Coastal county, with water transporting facility to many coastal harbor cities including Hong Kong. No. 324 national highway runs through the southern part of the county

Source: 1980–1990 National Economic Statistics of the Counties or Areas in Guangdong Province and the Statistic Bureau of Guangdong Province, 1997.

Huidong were even higher than their corresponding counties in Zhaoqing, before 1983, but became obviously lower than the latter since 1984. Negative growth even occurred in Longmen county and Huizhou proper in some years. Since then, the agricultural economics in Huizhou grows slower and slower, and largely lagged behind by Zhaoqing.

The economic loss of agriculture in Huizhou is estimated in Table 3, assuming that the agricultural growth rate of the 5 counties in Huizhou be the same as that of their corresponding counties in Zhaoqing. It can be seen from Table 3 that there was no significant economic loss in Huizhou before 1983, but the loss became significant in 1984, which was amounted to more than 1×10^8 yuan (RMB), (in the price of 1980, the same for below), and increased year by year since then, up to more than 3×10^8 yuan in 1986, 4×10^8 yuan in 1990, 5×10^8 yuan in 1993, 6×10^8 yuan in 1995, and 7×10^8 yuan in 1996. The cumulative loss from 1984 to 1996 totaled to 58×10^8 yuan in the price of 1980, which is equivalent to 300×10^8 yuan in the price of 1996.

Why the agricultural economic growth in Huizhou had largely lagged behind Zhaoqing since 1984? What caused so much economic loss for the agriculture in Huizhou?

Table 3 Comparison of agricultural productive values in the corresponding 5 county pairs in Zhaoqing and Huizhou and estimation of economic loss in Huizhou

County name or item	Total agricultural productive value(10^4 yuan, in the price of 1980)										
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Guangning in Zhaoqing	8428	8619	9067	9106	11755	12709	14326	17983	19020	19205	20759
Longmen in Huizhou	7172	7747	9021	8645	8225	7598	7447	8030	8429	9633	9506
Loss of Longmen	0	– 412	– 1305	– 896	1778	3217	4744	7273	7757	6710	8159
Gaoyao in Zhaoqing	13881	15468	19465	20188	22861	26327	32690	37225	37546	37614	40208
Boluo in Huizhou	15836	16754	18370	17280	18752	20509	19845	21753	23115	25418	28439
Loss of Boluo	0	893	3836	5751	7329	9526	17449	20715	19719	17494	17432
Zhaoqing proper	4559	5204	6905	6650	7786	9334	10660	12065	12946	13477	14307
Huizhou proper	1624	1839	2042	1794	2141	2260	2268	2607	2654	2700	2835
Loss of Huizhou proper	0	15	418	575	633	1065	1529	1691	1958	2101	2261
Sihui in Zhaoqing	8270	8268	10435	10349	11756	13277	14880	16087	17191	17884	20507
Huiyang in Huizhou	10488	10701	12794	13163	13600	14692	14855	16130	16642	18188	19519
Loss of Huiyang	0	– 216	440	– 38	1309	2146	4016	4272	5160	4492	6488
Fengkai in Zhaoqing	8567	8307	9913	9419	10481	11692	14059	16579	17834	20225	21839
Huidong in Huizhou	10041	11296	11589	11249	11835	12686	13425	14242	15198	17578	19840
Loss of Huidong	0	– 1560	30	– 209	449	1018	3053	5190	5704	6127	5757
Total loss in Huizhou	0	– 1280	3418	5182	11498	16971	30791	39140	40297	36924	40097

County name or item	Total agricultural productive value (10^4 yuan, in the price of 1980)						Cumulated loss (10^4 yuan)		Cumulated loss of per unit cultivated land	
	1991	1992	1993	1994	1995	1996	Price in 1980	Price in 1996	Price in 1980	Price in 1996
Guangning in Zhaoqing	22186	24957	27362	28408	30616	32845				
Longmen in Huizhou	9731	11201	11560	12632	13746	14338				
Loss of Longmen	9149	10036	11725	11543	12307	13612	105396	518403	51642	254011
Gaoyao in Zhaoqing	45133	47101	54380	61796	69931	78448				
Boluo in Huizhou	30964	35318	36860	42464	46840	51809				
Loss of Boluo	20526	18417	25179	28035	32940	37688	282928	1362841	48910	235594
Urban Zhaoqing	15489	17176	17945	17809	18971	24839				
Urban Huizhou	3370	3704	3188	3011	3688	4289				
Loss of Huizhou proper	2148	2414	3205	3333	3070	4559	30973	186287	39333	236567
Sihui in Zhaoqing	21916	25077	28620	32145	37265	38303				
Huiyang in Huizhou	19105	21847	23845	26859	29200	30715				
Loss of Huiyang	8689	9955	12451	13907	18060	17861	108991	641554	26255	154547
Fengkai in Zhaoqing	24137	27105	26912	28676	31572	34816				
Huidong in Huizhou	20170	24399	27098	31163	34906	39189				
Loss of Huidong	8120	7370	4444	2446	2099	1617	51653	307579	14110	84020
Total loss in Huizhou	48632	48192	57003	59264	68475	75338	579942	3016664	35308	183663

Source: 1980– 1990 National Economic Statistics of the Counties or Areas in Guangdong Province and the Statistic Bureau of Guangdong Province, 1997.

3 FACTORS INFLUENCING THE AGRICULTURAL ECONOMIC GROWTH IN HUIZHOU

As is described above, the geographic and agricultural conditions and social development level are similar in the corresponding counties between Huizhou and Zhaoqing, and moreover, Huizhou have the advantages of being a coastal region and adjacent to Shenzhen Special Zone, the conditions for the agricultural economic development in the 5 counties in

Huizhou should be better than those in the corresponding counties in Zhaoqing. Therefore, the main factors influencing the agricultural economic growth in Huizhou should lie in the productivity of the local land. Then what have caused the reduction of the land productivity in Huizhou?

Some people noticed that the reduction of grain production in the Zhujiang River Delta Region was related to the reduction of the cultivated land resources (Wen and Hu, 1995). Is the reduction of the agricultural growth rate in Huizhou caused by the reduction of cultivated land resources due to over-exploitation? Through comparison of the variation curves of the cultivated land area of the corresponding counties in the two cities during the period from 1980 to 1996 (Fig. 2), it can be seen that the variation trends of annual cultivated land reduction rate of the corresponding counties in the two cities were almost the same. The reduction rate of cultivated land area was a little higher in Zhaoqing before 1987 and in Huizhou since 1992 and the total reduction rates have been nearly the same since 1995. The reason why the cultivated land reduction rate has been obviously higher in Huizhou proper than that in Zhaoqing proper since 1992 is that there was a great difference in the original total cultivated land area between the two cities' propers. In fact, there was no great difference in the total reduction of cultivated land area between the two propers, which were 4914.47 ha and 4707.6 ha respectively. The cultivated land reduction rate in Huidong County was always higher than that in its corresponding Fengkai County, but the agricultural economic loss in Huidong County was the least in Huizhou City, and the agricultural economic growth rate in Huidong County almost caught up with Fengkai County in 1996 (Fig. 1).

Obviously, the differences in the agricultural growth rates between the counties in Huizhou and counties in Zhaoqing are of little relation with their differences in cultivated land area reduction. Besides, the total cultivated land area in the 5 counties in Huizhou is much more than those in the correspond ing 5 counties in Zhaoqing (Table 2), hence the

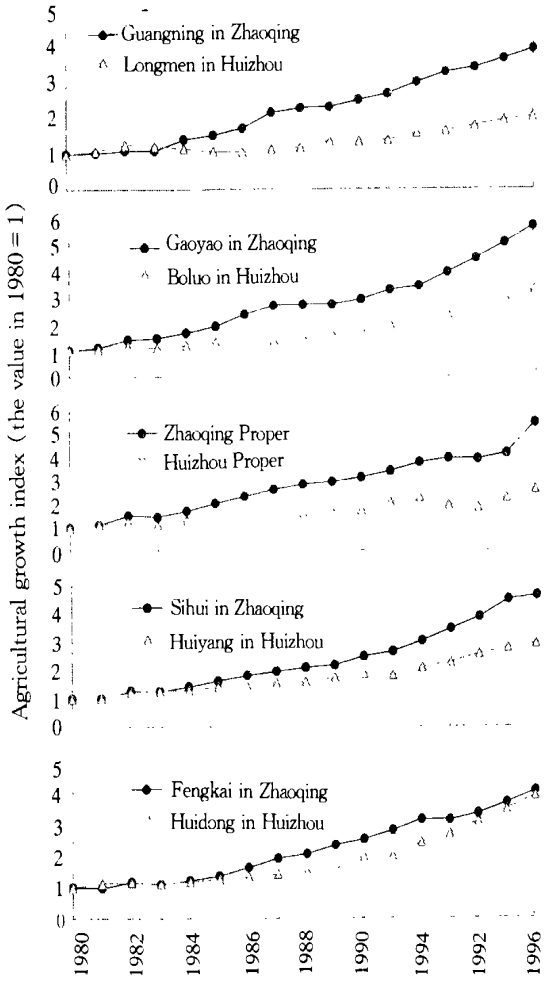

Fig. 1 Comparison of APV growth in Zhaoqing and Huizhou

potential of agricultural production increase with the development of agricultural sciences and technology should be much more in Huizhou than in Zhaoqing. Moreover, the agricultural products in Huizhou should be sold easier and more expensive, because it is close to Shenzhen and Hong Kong. Why the agricultural growth rate in Huizhou becomes much lower than that in Zhaoqing since 1984?

Huizhou is a coastal region. Is it because that Huizhou suffered more from typhoon disaster? If so, the loss of the coastal counties (Huidong and Huiyang) near the sea in the east should be more than that of the inner counties (Longmen and Boluo) far from the sea in the west. Actually, the loss of the inner counties in the west is much more than that of the coastal counties in the east. The coastal county,

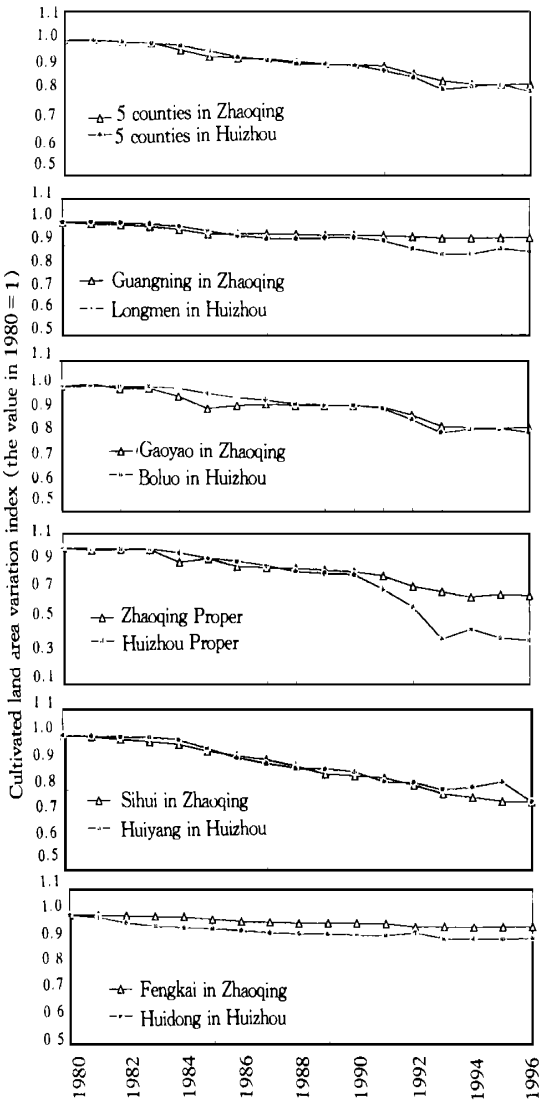

Fig. 2 Curves of cultivated land area variation of the corresponding 5 county pairs in Huizhou and Zhaoqing

Huidong suffered the least loss, its agricultural growth rate being the highest in Huizhou, which almost kept the same growth rate as Fengkai County in Zhaoqing, the county to be referred to control plot. Therefore, such distribution pattern of agricultural loss is impossible to be caused by typhoon disasters.

It can be seen from Table 4 that the frequency of acid rain was much higher, and the acidity was much stronger, in Huizhou than in Zhaoqing in the late period of the 1980s. The frequency of acid rain in Zhaoqing is less than 30%, but high as 50% in Guangzhou (close to Huizhou). Comparing Table 3 and Table 4, we can see that the difference in agricultural growth rate between Huizhou and Zhaoqing is becoming larger with the increase of SO_2 discharge by coal-burning power plants in the eastern Zhujiang River Delta Region and Hongkong, and the frequency as well as the acidity of the acid rain in the region.

An aero-survey carried out by the Chinese Academy of Environmental Sciences in 1988 shows that there was a high SO_2 zone 300 m over a line along Shajiao- Donguan- Zengcheng, in which the molecular volume of SO_2 reaches 45×10^{-9} - 100×10^{-9}, and higher in the afternoon than in the morning. The coal-burning power plant in Shajiao was no doubt one of the important SO_2 contributor. The SO_2 and fine particle isograms of Pearl River Delta Region mapped according to aero-survey in several times indicated that the pollutants discharged from Shajiao Power Plant in Dongguan and Qingshan Power Plant in

Table 4 The situation of acid rain in Zhaoqing and Guangzhou (close to Huizhou) and discharge of SO_2 in the eastern Zhujiang River Delta Region

Region		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Zhaoqing	(1)*	37.5	45.0	7.7	29.2	28.6	16.1			68.2	62.9	80.0			67.7	49.5
	(2)*	5.64	4.89	6.37	5.49	5.37	5.23		4.74	4.77	4.66	4.57	4.67		4.43	4.25
Guangzhou	(1)	48.0	46.1	37.8	44.1	48.3	52.0	57.4	64.5	60.4	71.6	76.4	69.6	69.3	70.4	76.0
	(2)	5.14	4.93	5.19	5.34	5.36	4.73	4.39	4.34	4.20	4.38	4.24	4.61	4.62	4.45	4.39
(3)* (10^4 t/a)						10.3	13.4	15.4	17.1	16.7	20.0	21.7	23.0	23.4	21.4	23.0

* (1) Frequency of acid rain(%); (2) Average pH value of precipitation; (3) SO_2 discharge in the eastern Zhujiang River Delta Region (including Shenzhen, Dongguan, Huizhou and Guangzhou).

Due to no monitoring data of acid rain in Huizhou before 1996, the data of Guangzhou is presented here for comparison. The monitoring station in Conghua County of Guangzhou City is close to Longmen and Boluo Counties, the main acid rain areas in Huizhou City. The situation of acid rain in Conghua may inflect the situation of acid rain in Boluo and Longmen of Huizhou City. Data were collected from the Environmental Protection Bureau of Guangdong Province.

Hong Kong can be transported northward to the high sky over Dongguan and Zengcheng in summer, which have an important influence on the region east of the Zhujiang River mouth (Huang *et al.*, 1993). The water vapor in the atmosphere over the Zhujiang River Delta is mainly transported by the air flow from southeast (partial to south), and the vapor is mainly from the South China Sea. The northward low level ai flow from South China Sea passing through the Estuary of the Zhujiang River to Guangzhou will be stopped by Maofeng Mount (534 m above sea level) and separated into two lines. The west line flows from Guangzhou passing through Huadu northward along the valley of the Beijiang River, while the east line passes through Dongguan and Zengcheng along the valley of the Dongjiang River northeastward. The east line of air flow can transport the atmospheric pollutants from south side to the sky over Huizhou City (especially over Longmen and Boluo counties in western Huizhou). Such warm and wet air flow with pollutants will sink to the ground of Huizhou in the form of acid rain when encountering the cool air flow from north.

Huizhou is situated in the eastern Zhujiang River Delta, to the direct north of Dongguan, Shenzhen and Hong Kong, which are the most industrialized areas in China. It also suffers from the atmospheric pollution caused by such industrialized areas. Therefore, Huizhou suffers much more atmospheric pollution than Zhaoqing. The productive increase contributed by the progress of agricultural sciences and technology in Huizhou in the past decade might have been largely offset by the reduction of land productivity caused by environmental pollution.

It can be seen from Fig. 3 and Table 4 that the annual agricultural economic loss in Huizhou is in close connection with the electric energy production and SO_2 discharge of the coal-burning power plants in the eastern Zhujiang River Delta Region, especially of those in Shenzhen, Dongguan and Huizhou. There is a sudden increase of agricultural economic loss in Huizhou during the period from 1985 to 1988, showing no relation with the power production in the above cities, but corresponding to the peak period of coal-burning power plant development in Hongkong. During that period, a generating set of 60×10^4 kW was putting into production and increased more than 2×10^4 ton of SO_2 discharge to the sky every year.

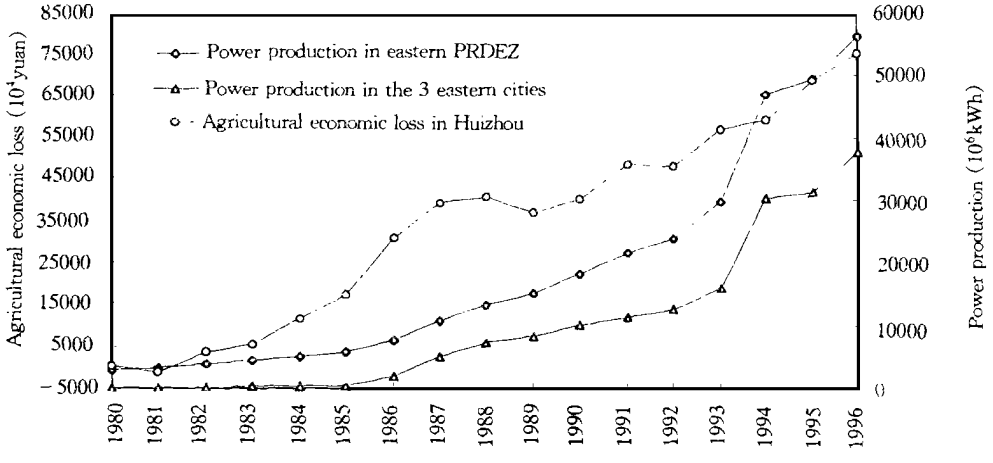

Fig. 3 The agricultural economic loss in Huizhou via the electric energy production of the power plants in eastern PRDEZ

The total SO_2 discharge in eastern Zhujiang River Delta Region was roughly under control since 1993. The discharge to the low sky reduced largely, but there was no reduction on the discharge to the

high sky by the large-scale coal-burning power plants, so the increasing trend of agricultural economic loss in Huizhou had not changed.

Due to the difference in their geologic and geochemical background, the sensitivity of the agro-ecological environment to acid rain in different areas is different. The most sensitive area is the granite and sandstone distributing area where the neutralization capacity of the rock and soil is the poorest, and the acid rain buffer capacity of the local agro-ecological environment is rather poor. The least sensitive area is the carbonate rock distributing area, where acid rain can be neutralized by the rock and soil, and the acid rain buffer capacity of the local agro-ecological environment is quite strong. The stratigraphic lithology and acid rain buffer capacity of the rock outcropped in the referred counties or areas in Huizhou and Zhaoqing are described in Table 5. Zhaoqing is situated in the Caledonian folding belt and Indosinian depression zone, where carbonate rocks occur widely and the acid rain buffer capacity is relatively strong; while Huizhou is situated in the Mesozoic fault depression basin, where carbonate rocks occur much less, and the acid rain buffer capacity is relative poor.

Table 5 The stratigraphic lithology and its acid rain buffer ability in the corresponding 5 county pairs in Zhaoqing and Huizhou

County (area)	Stratigraphic lithology of the rocks outcropped	Acid rain buffer capacity	Agricultural growth index	
			1990	1996
Guangning of Zhaoqing	Dominated by Sinian metamorphic rocks and Mesozoic Granites, with some Cambrian sandstone and shale in the northwestern part.	Rather poor	2.46	3.90
Longmen of Huizhou	Late Paleozoic sedimentary basin and Mesozoic faulting depression basin, with occurrence of granites in northern, western, southern sides, carbonate and calcareous shale occur widely.	Relatively strong	1.33	2.00
Gaoyao of Zhaoqing	Paleozoic and Mesozoic sedimentary basin, Paleozoic carbonate and Cretaceous calcareous mudstone and siltstone occur extensively.	Quite strong	2.90	5.65
Boluo of Huizhou	Sinian metamorphic rocks occur in the southwestern part, Mesozoic and Neozoic faulting basin in the northeastern part.	Medium	1.80	3.27
Zhaoqing proper	Dominated by Devonian and Carbonaceous carbonates, covered with thick Quaternary alluvial sediments.	Quite strong	3.14	5.45
Huizhou proper	Jurassic and Cretaceous sedimentary rocks, with some Quaternary alluvial terrace sediments.	Medium	1.75	2.64
Sihui of Zhaoqing	Sinian metamorphic rocks in the western part, granites in the center, and Paleozoic carbonate in the eastern part.	Medium	2.48	4.63
Huiyang of Huizhou	Dominated by Jurassic volcanic and sedimentary rocks, with Paleozoic sedimentary rocks in the northern part and Devonian–Carbonaceous sediments and Cretaceous faulting depression deposits in east end of its southern part.	Relatively strong	1.86	2.93
Fengkai of Zhaoqing	Dominated by Cambrian shallowly metamorphosed sandstone and shale, with Paleozoic and Mesozoic granites in the eastern part.	Medium	2.55	4.06
Huidong of Huizhou	Dominated by Jurassic volcanic rocks, some granites and Paleozoic sedimentary rocks as well as some Cretaceous sedimentary rocks occur in northern and southern parts	Medium	1.98	3.90

* The agricultural growth index here refers to the relative agricultural productive value of the year as compared with the value in 1980 (taking the latter as 1).

In Zhaoqing City, the agricultural growth rate is the highest (the total agricultural productive value in 1996 was 5.5 times that in 1980) in Gaoyao County and Zhaoqing proper where the acid rain buffer capacity of the land is very strong; the lowest (the total agricultural productive value in 1996 was 3.9 time that in 1980) in Guangning County where the acid rain buffer capacity is very poor. It can be inferred that

the acid rain buffer capacity of the land is an important factor influencing the agricultural production while the acid rain frequency bears little influence on it. The influence of acid rain on agricultural production is not yet important in Zhaoqing City.

In Huizhou City, the agricultural growth rate is the lowest in Longmen County where the acid rain buffer capacity of the land is relatively strong, and the highest in Huidong County where the acid rain buffer capacity is relatively poor. The agricultural growth rate is gradually increasing from Longmen County in the west end to Huidong County in the east end. The agricultural productive value in 1996 was 2 times that in 1980 in Longmen County and 3.9 times in Huidong County. The cumulated economic loss per unit area of cultivated land is gradually reducing from west to east (Fig. 4). This may be caused by the change of acid rain frequency. Due to rare pollutant discharge from east, the acid rain frequency is much lower in the east than in the west of Huizhou City. It can be concluded that the influence of the acid rain buffer capacity of the land on the agricultural growth is not significant in Huizhou, where the agricultural growth rate is closely related to the acid rain frequency.

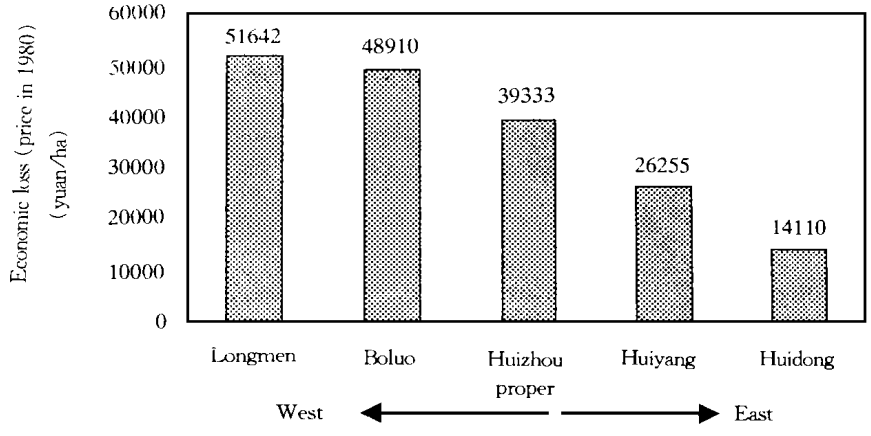

Fig. 4 Cumulated economic loss per unit area of cultivated land of the counties in Huizhou

4 CONCLUSION

To be summed up from above, the acid rain is the main factor influencing the agricultural growth in Huizhou. Was it not influenced by environmental pollution like acid rain, the agricultural production in Huizhou would be completely possible to keep the growth rate as high as that in Zhaoqing, even higher. Even if in the same growth rate, the economic loss every year on agricultural production in Huizhou caused by environmental pollution is more than 3×10^8 yuan (RMB, in the price of 1980) since 1986, which almost occupies 50% of total agricultural production value in Huizhou City. This means that almost half of the land "lost" invisibly. So it is said that the loss and pain caused by ecological crisis and environmental disasters to life of the people and to the development of the region is not inferior to the foreign military invasion, even more than the latter sometimes.

The atmospheric pollution arisen from rapid and extensive development of the economy in the Zhujiang River Delta Region has already degraded the productivity of the cultivated land resources in the region. It has greatly reduced the population load capacity of the natural resources of the region. Huizhou is the richest in per capital land area in the Zhujiang River Delta Region. Natural resource is an important support for its sustainable development. The degradation of land resources and agro-ecological environment by pollu-

tion like acid rain had severely affected the sustainable development in Huizhou (Kuang and Sun, 1998). The desulphurization and denitrification facilities for the coal-burning power plants must be installed as soon as possible. The trans-boundary pollution control and its compensation as well as the inter-regional allocation of the capacity of the atmospheric environment among the Zhujiang River Delta Economic Zone, Hong Kong and Macao must be placed on the agenda soon.

REFERENCES

The Statistic Bureau of Guangdong Province, 1997. *The Statistical Yearbook of Guangdong Province* (1996). Beijing: China Statistic Publishing House, 1–574. (in Chinese)

Wen Yanmao, Hu Guoguang, 1995. Analysis on the reduction of grain production and cultivated land resources in the Pearl River Delta Region. *Pearl River Delta Economy*, (1): 22–24. (in Chinese)

Huang Xinmin, Liu Youhong, Lu Zengrong *et al.*, 1993. Multiple isochronal monitoring of Guangzhou atmospheric environmental capacity and quality control in its monitoring. In: National Environmental Protection Bureau of People's Republic of China (ed.). *Study on Environmental Background Value and Environmental capacity*. Beijing: Science Press. 257–265. (in Chinese)

Kuang Yaoqiu, Sun Dazhong, 1998. Preliminary evaluation on the sustainable development in the Pearl River Delta Economic Zone. *China Population, Resources and Environment*, 8 (Special Issue): 31–34. (in Chinese)