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A comparative case study of cultivated land changes in Fujian and Taiwan

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Abstract

In this study we chose Fujian and Taiwan for a comparative case study of cultivated land changes. Separated by a short strait, these two regions are similar in biophysical and cultural characteristics but differ in the level of economic development. Taiwan is ahead of Fujian by 15 to 20 years in economic development. We compared quantitative and qualitative changes of cultivated land in these two regions, and analyzed the proximate causes and the driving forces for cultivated land changes over time. The study showed a time lag, similar to that of economic development, in the dynamic (i.e., greater rates of change) period of cultivated land changes and the ranking of major driving forces. The results suggest that similar land-use changes can occur in different regions as the regions pass through comparable stages of economic development at different times.

Keywords: Cultivated land; Land-use change; Driving forces; Fujian; Taiwan

Introduction

Several international study groups on land-use/land-cover change (LUCC), including the International Geographical Union (IGU), the International Geosphere–Biosphere Programme (IGBP), and the International Human Dimensions Programme (IHDP), have advocated in recent years the importance of comparative case studies. According to these groups, comparative case studies can greatly improve our understanding of the major human causes of LUCC in different geographic and historical contexts. For example, Geist and Lambin (2002) compared 152 local case studies from Asia, Africa, and Latin America in search for a general understanding of the proximate causes and underlying driving forces of tropical deforestation. Instead of finding a general theory, they concluded that tropical forest decline is determined by different combinations of factors in varying geographic and historical contexts. Geist and Lambin (2002) highlight the challenge of finding any general theories for LUCC and, at the same time, the importance of comparative case studies. But there are both conceptual and practical difficulties in comparing LUCC in different regions. The conceptual difficulty lies in the coordination of time, space, and human driving forces in different regions. And the practical difficulty lies in data availability and reliability and, for comparative analysis, data compatibility.

Most LUCC researchers recognize economic development as perhaps the most basic driving force for land-use changes (e.g., Heilig, 1997). In this study, we linked economic development to a comparative case study by assuming that similar land-use changes can occur in different regions as the regions pass through comparable stages of economic development at different times. To test the feasibility of our assumption, we chose to analyze and compare changes of cultivated land in Taiwan and Fujian.

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Separated by a short strait, Taiwan and Fujian are similar in biophysical characteristics as well as demographic and cultural characteristics. But the two regions differ in the political system and the level of economic development. Since adopting the open-door policy in 1978, China has developed an export-oriented economy, similar to her neighbors such as Taiwan and South Korea (World Bank, 1993; Liou, 1999). Thus the difference in the political system, except for land management policies, is not really a major factor in this comparative study. Economic development is different: Taiwan has prospered since the 1960s, whereas Fujian began its economic development only after China's open-door policy in 1978. There is a time lag of 15–20 years. We are therefore interested in finding whether this time lag is repeated in cultivated land changes of the two regions. Cultivated land, also called farmland, refers to land under temporary and permanent crops; in both Taiwan and Fujian, cultivated land can generally be classified into paddy field and upland field. As a land use, cultivated land may increase in the initial stage of economic development but invariably decreases as increased population, urbanization, industrialization, road construction, and nonstaple food production demand more space. In other words, change (i.e., decline) of cultivated land is closely related to the overall pattern of economic development and is thus a good indicator for testing our assumption.

This paper is organized into the following sections. Section 2 describes Fujian and Taiwan in terms of their physical environment, cultural and demographic characteristics, economic development, and land management policies. Section 3 compares quantitative and qualitative measures of cultivated land changes in the two regions. Section 4 explains the proximate causes and explores the driving forces for cultivated land changes in Fujian and Taiwan. Section 5 discusses the results and concludes the paper.

Study areas

Physical environment

Fujian has a total area of 121,400 km^2. About 75% of the land area in Fujian is covered by mountainous terrain, 15% is classified as hilly lands, and only 10% is lowlands, which are limited to the coastal area and small alluvial valleys (Edmonds, 1996). Lying almost directly across the Taiwan Strait from Fujian is Taiwan. With a total land area of 36,000 km^2, Taiwan is less than one-third of Fujian in size (Fig. 1). About 47% of the land area in Taiwan is classified as highlands (above 1000 m), 27% slopelands (100–1000 m), and 26% lowlands (below 100 m). Only lowlands, which are mainly on the alluvial plains of the west coast, are suitable for agricultural use. The land surface is very steep, with nearly 50% of the island having slopes above 40%. Both Fujian and Taiwan are limited in land areas suitable for cultivation. In terms of climate,

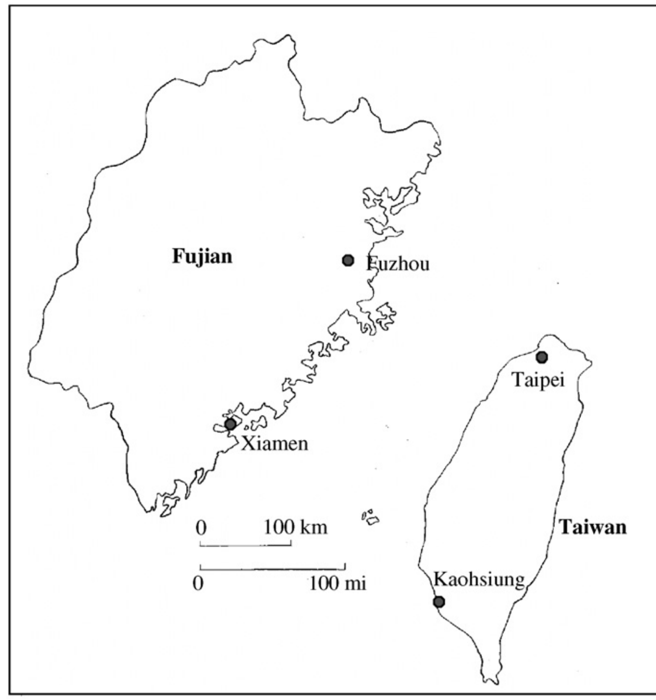

Fig. 1. Taiwan and Fujian across the Taiwan Strait.

Fujian has a subtropical monsoon climate and Taiwan a subtropical and tropical monsoon climate. Warm temperature and ample precipitation bring double or triple agricultural harvests annually to both regions.

Cultural and demographic characteristics

Fujian and Taiwan have similar cultural and demographic characteristics. Northern Chinese culture spread to Fujian with three major southward migrations of *han* people in history. Fujianese culture, a localized *han* ethnic culture, extended to Taiwan and gradually became the main component of Taiwanese culture (Liu, 2002). About 80% of people in Taiwan are descendants of immigrants from Fujian.

Economic development

Taiwan's economic development began in the 1960s when the Taiwan government adopted an export orientation policy to promote labor-intensive industries (Lin, 1973; Ho, 1978; Ranis, 1979; Kuo, 1983). The first export processing zone was established in Kaohsiung in 1966, followed by two more in 1969. A shift from labor-intensive to capital- and technology-intensive industries in Taiwan's economy took place in the 1970s and 1980s (Kuo, 1983; Gold, 1986). In 1973 the Taiwan government selected petrochemical, basic metal, and shipbuilding industries for major construction projects in the public sector. Later the government promoted computers, telecommunication, and precision instrument and machinery for industrial upgrade. In 1980 the first science-based industrial park was established in Hsinchu (Li, 1995). The shift toward knowledge-based, high-tech industries continued into the 1990s (Chen and Lee, 2004). Taiwan has become a leading producer of semiconductors, computers and computer peripherals, and telecommunication equipment in the world.

In 1978 China began an open-door policy for economic "modernization" along the coastal areas. Fujian has been an important part of this coastal strategy. The open-door policy encouraged the development of small-scale, labor-intensive township and village enterprises (TVEs) as well as the growth of foreign-invested and private enterprises in the industrial, transportation, and construction sectors (Lin, 1992; Yabuki, 1995; Chen, 1998; Otsuka et al., 1998; Oi, 1999; Yeung, 2005). The Xiamen Special Economic Zone (SEZ) was established in 1979, followed by the Fuzhou Mawei Economic and Technical Development Zone (ETDZ) in 1985 and the Fuqing Bay Investment District in 1992 (Fan, 1995; Yeung and Chu, 2000). With substantial foreign investment from Taiwan, Hong Kong, and overseas Chinese in Southeast Asia, Xiamen and Fuzhou have become important growth centers in South China and Fujian one of the five "emerging tigers" in China's coastal provinces (Weng, 1994; Ash and Qi, 1996; Liou, 1999; Howell, 2000).

The average growth of GDP in Fujian was 13.9% between 1978 and 1998, making it China's fastest growing province (Golley, 2002). Fujian's per capita GDP relative to national average was 0.72 in 1978 and 1.63 in 2002. In 2002 Fujian's per capita GDP was USD 1630. (As a comparison, Taiwan's per capita GDP in 2002 was USD 12,600.) Leathers and furs, wood products, paper and products, plastic products, and clothing dominated Fujian's manufacturing sector from the mid-1980s to the mid-1990s (Golley, 2002). According to Chen (1998), light industry products accounted for 68% of export commodities in 1995, while heavy industry products and agricultural products accounted for 20% and 12%, respectively. In recent years, the Fujian government has targeted petrochemicals, machinery and electronics, building materials, forest products, and fisheries as five leading industries to promote (Maruya, 2000). This process of industrial upgrade and structural change is in many ways similar to Taiwan's experience during the 1970s, with a time lag of 15 to 20 years.

Rural land management policies

China's constitution stipulates that land in rural areas is collectively owned by rural residents. Since 1978, the Chinese government has made a number of changes to the rural land system and land development processes (Kirkby and Zhao, 1999; Cartier, 2001; Zhai and Huang, 2002; de Brauw et al., 2004; Lin and Ho, 2005). The introduction of the household production responsibility system in 1978, followed by the replacement of the commune system by a township and village system in 1983, decentralized the decision-making process in agricultural production and allowed farmers to engage in a variety of nonagricultural activities. Starting in 1983, the TVEs grew rapidly and became an important source of China's economic growth (Eng, 1997; Johnson and Woon, 1997; Kirkby and Zhao, 1999; Fan et al., 2003). At the same time, these nonagricultural activities, along with urban expansion, resulted in a severe loss of cultivated land during the years 1984–1986 (Ash and Edmonds, 1998; Lin and Ho, 2005).

To slow down the loss of cultivated land, China enacted the Land Management Law and created the Land Administration Bureau in 1986. The new law decelerated the shrinkage of arable land for several years, but the process of conversion began to accelerate again after 1990, primarily because of the relatively higher incomes to be derived from nonagricultural activities (Kirkby and Zhao, 1999; Lin and Ho, 2005). The promulgation of the "Regulation for the Protection of Basic Farmland" in 1994 prohibited the removal of "basic farmland" from cultivation. This was followed by a one-year moratorium on arable land conversion in 1997, which was later extended to 1999. In 1998, China revised the Land Management Law by requiring each province to designate at least 80% of its cultivated land as "basic farmland," which must be preserved. But the new law is still subject to local manipulation and internal contradictions (Cartier, 2001; Lin and Ho, 2005).

Taiwan's rural land management policies began with a series of land reform programs in 1949–1953. The "37.5% Rent Reduction Act" set the farm rental rate at 37.5% of the annual yield of the main crop; the "Sale of Public Lands Act" sold off a large area of public lands; and the "Land to the Tiller Act" allowed each landlord to keep only 3 chia (1 chia = 0.97 hectares) of medium-grade paddy field or 6 chia of dry land (Ho, 1978). Although these land reform programs significantly raised the level of land ownership among farmers, they also resulted in a large number of small holders.

Problems with labor-intensive small-scale farming operations began to appear during the 1960s as Taiwan's export-oriented industries provided job opportunities outside of agriculture (Thorbecke, 1992). Farm income per capita deteriorated compared to nonfarm income, and mechanization for improving agricultural productivity was hampered by the small average size of a family farm (Clark, 1989; Thorbecke, 1992). In 1973, Taiwan enacted the "Agricultural Development Act," which eventually became the body of laws governing Taiwan's rural land management. To promote agricultural mechanization in the 1970s, the Act pushed for increasing the "operational" farm size through joint operations and cooperative farming without affecting the ownership pattern. Starting in the late 1980s, a number of policy changes for liberalization of agriculture have been introduced to the Agricultural Development Act. The concept that agricultural land is owned by tillers and reserved for agricultural use has been gradually redefined to allow agricultural land to be traded in the free land market and to be converted for nonagricultural uses. In 1995, the Taiwan government implemented the "Agricultural Land Release Act," allowing over 300,000 hectares (ha) of secondary agricultural land to be converted for nonagricultural use.

Measures of cultivated land changes

Quantitative measures

Fig. 2 shows the decline of Fujian's cultivated land since 1975. The pattern resembles the national trend for the period 1978–1995: a steep decrease in 1984–1986, a slower decrease in 1987–1990, and another steep decline in 1991–1995. After 1996 and the change of method for compiling agricultural statistics, Fig. 2 shows a rapid rate of decrease. In quantitative terms, the average annual rate of decrease from 1996 to 2001 was 17,696 ha, considerably higher than 5488 ha from 1980 to 1989 and 5755 ha from 1990 to 1995. Fujian's cultivated land totaled 1.17 Mha (million hectares) in 2001 (Fujian Province Statistics Bureau, 2002).

Taiwan's cultivated land totaled 848,743 ha in 2001 (Council of Agriculture, 2002). Fig. 2 shows gradual and steady decreases of cultivated land mainly after 1977. The average annual rate of decrease was 2140 ha from 1978 to 1989 and 3822 ha from 1990 to 2001. Although the rate of decrease did increase over time in Taiwan, the rate was slower than that of Fujian, especially in recent years.

Fig. 3 shows changes of cultivated land per capita. It declined from 0.06 to 0.03 ha between 1975 and 2000 in Fujian and from 0.06 to 0.04 ha in Taiwan during the same period. Although the two regions have similar changes of cultivated land per capita, they differ in terms of cultivated land per farm labor (Fig. 3). In Fujian cultivated land per farm labor dropped from 0.07 to 0.05 ha between 1975 and 2000, whereas in Taiwan it actually increased slightly from 0.16 to 0.23 ha during the same period. This difference can be attributed to a greater absorption rate of farm labor in other economic sectors in Taiwan as well as a series of aforementioned land reform policies.

Qualitative measures

Qualitative changes of cultivated land are equally as important as quantitative changes. To measure cultivated land productivity, we adopted the *cultivated land standard index* (CLSI), an index proposed by Zheng and Feng

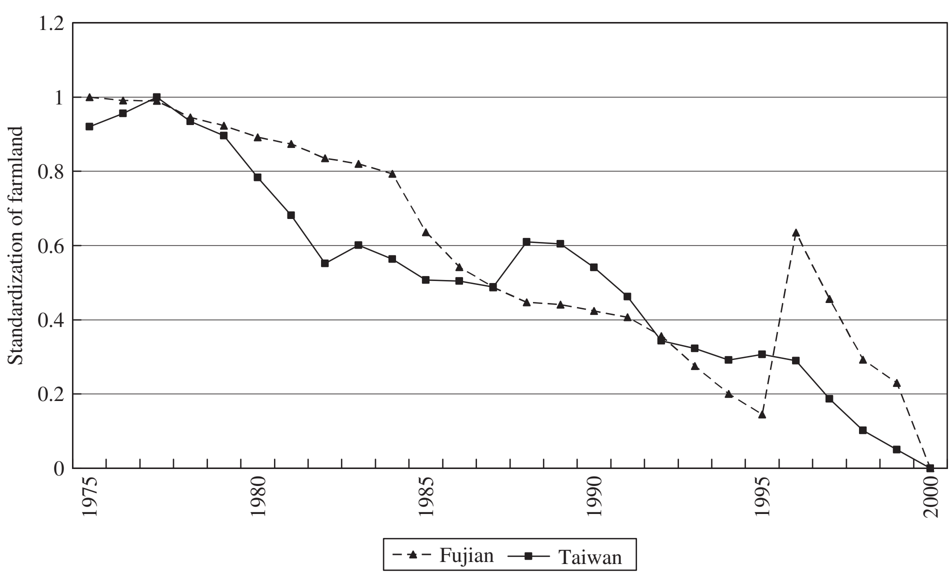

Fig. 2. Farmland in Fujian and Taiwan, 1975–2000. For the purpose of comparison between the two regions, areas of cultivated land have been standardized to the scale of 0.0–1.0.

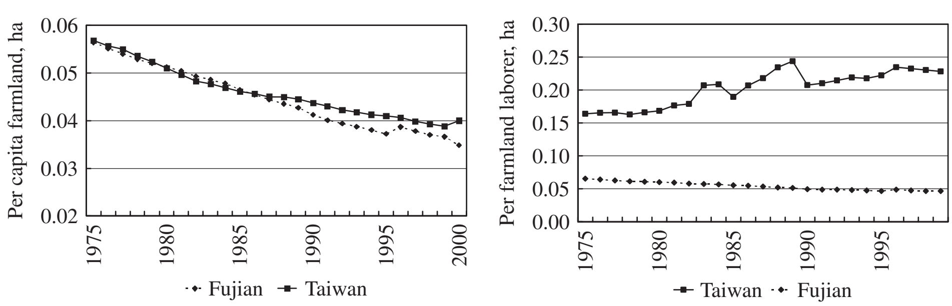

Fig. 3. Comparison between Fujian and Taiwan in area of farmland per capita (left) and per farm laborer (right).

(2003). CLSI is defined as the ratio of the local average cultivated land productivity to the regional average cultivated land productivity. Another index, *standard cultivated land* (SCL), can be calculated by multiplying actual cultivated land by CLSI. For our study, we selected rice, a major crop in both Fujian and Taiwan, to calculate CLSI and SCL.

The following illustrates how to derive the change of SCL between 1978 and 2001 for Fuzhou County in Fujian. First, the CLSI can be calculated by dividing the average rice production in Fuzhou by the average rice production in Fujian, with both numbers weighted by their respective multiple cropping indices:

$$\begin{aligned}\mathrm{CLSI}_{\mathrm{Fuzhou}} &= (422\,\mathrm{kg/ha} \times 2.56)/(356\,\mathrm{kg/ha} \times 2.09) \\ &= 1.45.\end{aligned}$$

Then the change of SCL can be calculated by multiplying 1.45 by the change of cultivated land:

$$\Delta\mathrm{SCL}_{\mathrm{Fuzhou}} = 1.45 \times (-5758\,\mathrm{ha}) = -8349\,\mathrm{ha}.$$

In the case of Fuzhou, the loss of SCL is higher than the actual loss of cultivated land because of the county's higher productivity relative to other counties in Fujian.

Figs. 4 and 5 plot the local CLSI against the change of cultivated land by county for the past 23 years in Fujian and Taiwan, respectively. Fig. 4 shows that the heavy losses of cultivated land in Fujian have taken place mainly in more productive counties (i.e., higher CLSIs). In contrast, Fig. 5 shows that losses of cultivated land in Taiwan have occurred in average productive counties (i.e., mid-range CLSIs) and, at the same time, increases of cultivated land have occurred at both ends of the CLSIs. Thus the distribution of cultivated land changes has been more balanced relative to agricultural productivity in Taiwan than in Fujian.

Table 1 shows aggregated data by actual area and standard area and by decrease and increase. Because of the steady losses of cultivated land in both regions, the ratio of net decrease of cultivated land to net increase of cultivated land is negative in every case. (−8.02:1 means that the net

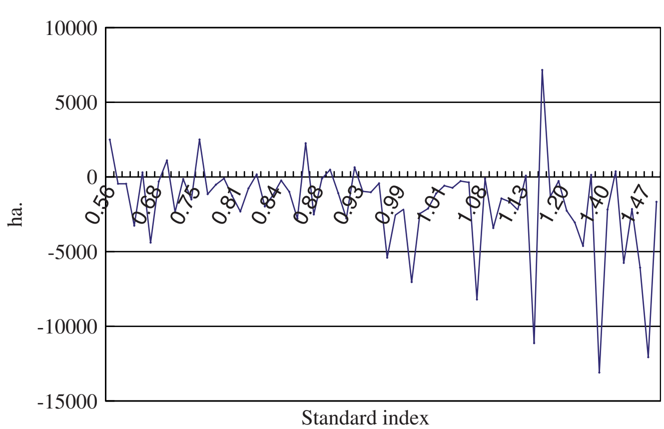

Fig. 4. Cultivated land change against cultivated land standard index (CLSI) by county in Fujian, 1978–2001.

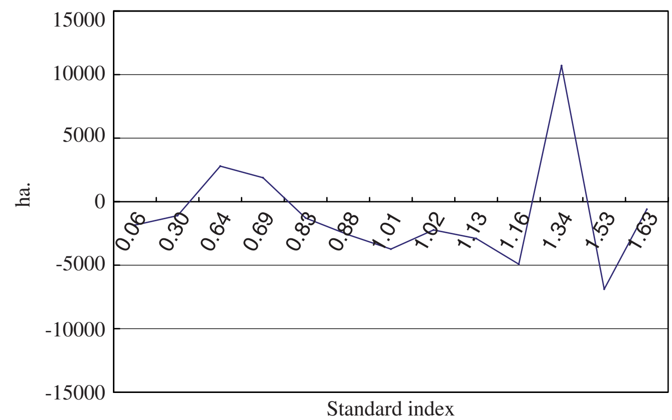

Fig. 5. Cultivated land change against cultivated land standard index (CLSI) by county in Taiwan, 1977–2000.

Table 1
Comparison of standard area change and actual area change of cultivated land in Fujian and Taiwan

Region	Cultivated land	Net decrease of cultivated land: net increase of cultivated land
Fujian (1978–2001)	Actual area	−8.02:1
	Standard area	−9.70:1
Taiwan (1977–2000)	Actual area	−5.22:1
	Standard area	−3.56:1

decrease of cultivated land is eight times larger than the net increase of cultivated land.) But the more interesting information can be derived from Table 1 by comparing between actual area and standard area. In Fujian, a decrease of each ha of actual cultivated land equals a decrease of 1.21 ha of SCL (9.70/8.02). In other words, newly cultivated land is less productive than the cultivated land lost. The pattern is reversed in Taiwan: a decrease of each ha of actual cultivated land equals a decrease of 0.68 ha of SCL (3.56/5.22). In Fujian, as in other coastal provinces of China, land management policies have not achieved their intended goals of protecting cultivated land (Ho and Lin, 2004; Lin and Ho, 2005). In contrast, farm income enhancement programs in the 1970s and 1980s have indirectly protected productive agricultural land in Taiwan (Chen, 2002).

Causes for cultivated-land changes

Proximate causes

This section examines proximate causes that directly impact cultivated land in Taiwan and Fujian. Table 2 shows quantitative changes of cultivated land by land-use type in Taiwan from 1978 to 2000. Reclamation from forest and slope lands, riverside, and tidal land account for the largest percentage (49.54) of the increase in cultivated land. On the other hand, built-up areas have the largest percentage (29.85) of the decrease in cultivated land, followed by forestation and fallow (24.90).

Table 3 shows quantitative changes of cultivated land by land-use type in Fujian from 1983 to 2001. Like Taiwan, reclamation account for the largest percentage (64.13) of the increase in cultivated land. But the percentages of tidal land reclamation (30.14) and land renovation (27.87) are much higher in Fujian than in Taiwan. Built-up areas also have the largest percentage (46.95) of the decrease in cultivated land; this percentage is considerably higher than in Taiwan.

When examined by sub-period, Tables 2 and 3 clearly show that the more dynamic (i.e., greater rates of change) sub-period is from 1978 to 1989 in Taiwan and from 1991 to 2001 in Fujian. In Fujian, the increase of cultivated land is 130% higher between 1991 and 2001 than between 1980 and 1990. Likewise, the decrease of cultivated land is 58% higher in the second sub-period than the first.

Grey relation analysis

We used grey relation analysis (GRA) as an exploratory tool to rank the explanatory variables for cultivated land changes in Fujian and Taiwan. The mathematics of GRA is derived from grey theory originally developed by Deng (1985a, b). Often used as an alternative to statistical correlation analysis, GRA does not require assumptions about the statistical distribution of data and can be used with a relatively small amount of data (Chang and Lin, 1999). GRA is therefore ideal for our study considering the problem of data availability. Since the early 1980s, GRA has been applied to various fields including analysis of carbon dioxide emissions, performance of airports, and the form design of mobile phones (Chang and Lin, 1999; Feng and Wang, 2000; Hsu and Chen, 2003; Lai et al., 2004; Wang et al., 2004; Wu et al., 2004; Chang et al., 2005).

Table 2
Quantitative change of cultivated land in Taiwan from 1978 to 2000

Year	Increase (ha)	Prcent increase of cultivated land from					
		Forest and slope lands reclamation	Improving irrigation	Tidal land reclamation	Riverside reclamation	Land renovation	Others
1978–2000	251722.74	32.49	2.98	3.19	13.86	6.69	40.79
1978–1989	161439.20	36.83	3.65	3.70	13.67	4.43	37.73
1990–2000	90283.59	24.74	1.80	2.28	14.20	10.72	47.22
Year	**Decrease (ha)**	**Percent decrease of cultivated land to**					
		Built-up	Aquaculture	Forestation and uncultivated	Loss to disaster	Re-division and measure correction	Others
1978–2000	327700.85	29.85	8.72	24.90	3.07	19.95	13.51
1978–1989	194503.28	24.35	9.63	29.94	2.99	20.61	12.47
1990–2000	133197.57	37.87	7.39	17.54	3.20	18.98	15.03

Data source: Taiwan Agricultural Yearbook, 1978–2000.

Table 3
Quantitative change of cultivated land in Fujian from 1983 to 2001

Year	Increase (ha)	Percent increase of cultivated land from			
		Reclamation	Tidal land reclamation	Land renovation	Agricultural restructuring
1980–2001	44149.15	33.99	30.14	27.87	8.00
1980–1990	13317.4	36.91	33.06	27.66	2.36
1991–2001	30831.75	32.68	28.82	27.97	10.53

Year	Decrease (ha)	Percent decrease of cultivated land to		
		Built-up	Agricultural restructuring	Loss to disaster
1980–2001	157888.79	46.95	40.21	12.83
1980–1990	61139.33	55.06	44.94	0.00
1991–2001	96749.46	41.83	37.22	20.95

Data source: Fujian Statistical Yearbook, 1983–2001.

Input variables for GRA are typically organized into categories. For this study, we adopted the following six categories used by Wei and Chen (2004) in their study of nonagricultural use of cultivated land in Fujian: population and urbanization, economic level, primary industry, secondary industry, tertiary industry, and export orientation. We then selected 22 factors in Fujian and 21 factors in Taiwan from available government publications to represent the six categories.

GRA starts with a series of the reference factor and the series of the compared factors. Usually, each series is normalized by dividing respective data of the original series by their averages. Let the transformed reference series be $x_0 = \{x_0(1),\ x_0(2),\ldots,x_0(n)\}$, and the compared series be $x_i = \{x_i(1),\ x_i(2),\ldots,x_i(n)\}$, $i = 1$ to m, where n represents points in a time series and m the number of compared factors. The relational coefficient $\xi_{01}(k)$ between the reference series $x_0(t)$ and the compared series $x_i(t)$ at time k can be calculated by the following equation:

$$\xi_{01}(k) = \frac{\min_i \min_k \left|x_0(k) - x_i(k)\right| + \delta \max_i \max_k \left|x_0(k) - x_i(k)\right|}{\left|x_0(k) - x_j(k)\right| + \delta \max_i \max_k \left|x_0(k) - x_i(k)\right|}, \tag{1}$$

where $|x_0(k)-x_i(k)|$ denotes the absolute difference between the two sequences, $\min_i \min_k |x_0(k)-x_i(k)|$ and $\max_i$-$\max_k |x_0(k) x_i(k)|$ are the minimum distance and the maximum distance for all time points in all compared sequences, which form a comparison environment, and δ is a distinguishing coefficient, which is used to adjust the range of the comparison environment and to control the level of differences of the relational coefficients. δ can range from 0 to 1 but is usually set at 0.5.

If we assume that every point in a series is equally important, then the series or 'line' relational grade can be obtained by averaging relational coefficients at all time points:

$$r_{0i} = \frac{1}{n}\sum_{k=1}^{n} \xi(k). \tag{2}$$

If the relational grade from compared series i is greater than j, it means that compared series i has a higher degree of correlation with the reference series than j. Therefore, by ordering the relational grades calculated from GRA, we can find the importance ranks of the compared factors.

We ran GRA for each region by sampling data in three sub-periods: 1980–1990, 1991–2001, and 1980–2001 in Fujian; and 1973–1989, 1990–1998, and 1973–1998 in Taiwan. Tables 4 and 5 show the ordered relational grades by factor in Fujian and Taiwan, respectively.

Table 4
Relational grades of change of cultivated land in Fujian with a distinguishing coefficient of 0.5

	Factors		1980–1990		1991–2001		1980–2001	
			Relational grade	Order[a]	Relational grade	Order[a]	Relational grade	Order[a]
Population and urbanization	Total population	X_1	0.947	1	0.928	1	0.901	1
	Urban population	X_2	0.785	9.5	0.729	4	0.721	17
	Per capita floor space of residential buildings in urban area	X_3	0.877	2	0.800	2.5	0.803	2
	Per capita floor space of residential buildings in rural area	X_4	0.831	3	0.796	2.5	0.763	3
	Per capita net income in urban area	X_5	0.803	4	0.619	10	0.729	8.5
	Per capita net income in rural area	X_6	0.762	16	0.622	10	0.719	17
Economic level	GDP	X_7	0.770	13.5	0.587	15	0.730	8.5
	Per capita GDP	X_8	0.779	9.5	0.591	15	0.728	8.5
	Total investment in fixed assets	X_9	0.755	19	0.563	20.5	0.727	8.5
	Total expenditure	X_{10}	0.790	5.5	0.632	6.5	0.726	8.5
Primary industry	Primary industry	X_{11}	0.773	13.5	0.611	12.5	0.720	17
	Gross output value of farming	X_{12}	0.787	5.5	0.626	6.5	0.724	17
	Gross output value of forestry	X_{13}	0.752	19	0.630	6.5	0.711	21.5
	Gross output value of animal husbandry	X_{14}	0.757	16	0.617	10	0.714	21.5
	Gross output value of fishery	X_{15}	0.741	21	0.569	18	0.726	8.5
Secondary industry	Secondary industry	X_{16}	0.781	9.5	0.575	18	0.734	8.5
	Total investment in capital construction	X_{17}	0.780	9.5	0.567	18	0.731	8.5
	Gross output value of construction enterprises	X_{18}	0.760	16	0.562	20.5	0.731	8.5
Tertiary industry	Tertiary industry	X_{19}	0.752	19	0.591	15	0.731	8.5
Export orientation	Gross value of exports	X_{20}	0.784	9.5	0.612	12.5	0.722	17
	Value of exports by primary goods	X_{21}	0.784	9.5	0.627	6.5	0.723	17
	Foreign capital actually used	X_{22}	0.730	22	0.539	22	0.723	17

[a]The rank orders are based on relational grade values with 2 decimal digits.

As shown in Tables 4 and 5, the most relevant explanatory variables (driving forces) in both Fujian and Taiwan are total population, per capita floor space, and urban population (1991–2001 in Fujian). It becomes more difficult to order the other driving forces as their importance ranks change over time. In Fujian, the second tier of most relevant factors consists of total expenditure by government and gross output value of farming in 1980–1990. The same two factors are joined by value of exports by primary goods and gross output value of forestry in 1991–2001. In Taiwan, the second tier of most relevant factors in 1973–1989 consists of gross output value of forestry, investment in agriculture, foreign capital actually used, and value of exports by primary goods. In 1990–1998, investment in agriculture is ranked first, gross output value of fishery is ranked third, and other important factors include gross output value of farming and primary industry.

Table 6 shows the ordered average relational grades by category for both regions. Two trends appear in Table 6. First, the ranking of the average relational grades by category is more stable over time in Taiwan than in Fujian. The top three categories in Taiwan are population and urbanization, primary industry, and export orientation. In Fujian, only the first ranking of population and urbanization is consistent over time. Second, the closest match between Taiwan and Fujian in terms of the overall ranking is between 1991–2001 in Fujian and 1973–1989 in Taiwan. In other words, the driving forces for cultivated land changes in Fujian in 1991–2001 have the same ranking order of importance as that in Taiwan in 1973–1989.

Discussion and conclusions

We assumed that similar land-use changes can occur in different regions as the regions pass through comparable stages of economic development at different times. Fujian is behind Taiwan by 15–20 years based on the start of economic development and the occurrence of industrial upgrade. This study found a similar time lag in cultivated land changes: greater rates of changes occurred from 1978 to 1989 in Taiwan and from 1991 to 2001 in Fujian, and the overall ranking of major driving forces for cultivated land changes was the same between Taiwan in 1973–1989 and

Table 5
Relational grades of change of cultivated land in Taiwan with a distinguishing coefficient of 0.5

	Factors		1973–1989		1990–1998		1973–1998	
			Relational grade	Order[a]	Relational grade	Order[a]	Relational grade	Order[a]
Population and urbanization	Total population	X_1	0.936	1	0.950	2	0.901	1
	Urban population	X_2	0.876	2.5	0.924	4	0.826	2
	Per capita floor space of residential buildings	X_3	0.884	2.5	0.885	5	0.823	3
	Per family annual income	X_4	0.764	10.5	0.781	12.5	0.719	10.5
Economic level	GDP	X_5	0.747	13.5	0.765	15	0.711	16
	Per capita GDP	X_6	0.753	13.5	0.781	12.5	0.714	16
	Total investment in fixed assets	X_7	0.741	17.5	0.746	17.5	0.711	16
	Total expenditure	X_8	0.733	20	0.745	19.5	0.705	16
Primary industry	Primary industry	X_9	0.770	8.5	0.873	7	0.722	10.5
	Investment in agriculture	X_{10}	0.840	5	0.958	1	0.794	5
	Gross output value of farming	X_{11}	0.773	8.5	0.881	6	0.732	7.5
	Gross output value of forestry	X_{12}	0.869	4	0.750	17.5	0.795	4
	Gross output value of animal husbandry	X_{13}	0.760	10.5	0.797	10.5	0.719	10.5
	Gross output value of fishery	X_{14}	0.752	13.5	0.933	3	0.707	16
Secondary industry	Secondary industry	X_{15}	0.742	17.5	0.801	10.5	0.702	20
	Gross output value of manufacturing industry	X_{16}	0.749	13.5	0.745	19.5	0.717	10.5
	Gross output value of construction enterprises	X_{17}	0.718	21	0.813	9	0.681	21
Tertiary industry	Tertiary industry	X_{18}	0.739	17.5	0.733	21	0.713	16
Export orientation	Gross value of exports	X_{19}	0.742	17.5	0.773	15	0.706	16
	Value of exports by primary goods	X_{20}	0.775	7	0.852	8	0.728	7.5
	Foreign capital actually used	X_{21}	0.795	6	0.774	15	0.740	6

[a]The rank orders are based on relational grade values with 2 decimal digits.

Table 6
Average relational grades of change of cultivated land by category in Fujian and Taiwan

Year	Population and urbanization		Economic level		Primary industry		Secondary industry		Tertiary industry		Export orientation	
	Relational grade	Order	Relational grade	Order	Relational grade	Order	Relational grade	Order	Relational grade	Order	Relational grade	Order
Fujian												
1980–2001	0.773	1	0.727	4	0.719	6	0.732	2	0.731	3	0.723	5
1980–1990	0.834	1	0.774	2	0.762	5	0.773	3	0.752	6	0.766	4
1991–2001	0.749	1	0.593	3.5	0.611	2	0.568	6	0.591	5	0.593	3.5
Taiwan												
1973–1998	0.817	1	0.710	5	0.745	2	0.700	6	0.713	4	0.725	3
1973–1989	0.865	1	0.744	4	0.794	2	0.736	6	0.739	5	0.771	3
1990–1998	0.885	1	0.759	5	0.865	2	0.786	4	0.733	6	0.800	3

Fujian in 1991–2001. Although these results apply only to cultivated land changes, they are encouraging enough that we are already planning to use the same assumption in other comparative case studies involving urban sprawl and specific land uses such as aquaculture.

This study found that Fujian had a greater rate of decline in both cultivated land per farm labor and productive cultivated land than Taiwan. Both phenomena are obviously influenced by land management policies. China's land management policies since the 1980s have been inconsistent and ineffective for protecting productive cultivated land (Cartier, 2001; Lin and Ho, 2003, 2005). But the phenomena can also be related to the level of economic development. For policies such as farm income enhancement and free land market, which have been implemented in Taiwan for years, are not possible at the current level of economic development in Fujian. This study did not examine land management policies as a driving force for cultivated land changes because grey relation analysis cannot accommodate factors that cannot be ranked. An option for examining land management policies as a driving force is to treat them as a dummy variable in regression analysis.

Quantitative data on China's agricultural land can be unreliable and difficult to obtain (Heilig, 1997). For example, 1995 official statistics listed China's arable land total at 95 Mha but more recent estimates have put the total in the range of 130–140 Mha (Ash and Edmonds, 1998) and even as high as 160 Mha (Smil, 1999). In another example, Yeh and Li (1997) reported that the loss of agricultural land in a county in Guangzhou was under reported by as much as 61.3%. We also faced a couple of data problems in our study. The use of a new data collection method by the Fujian Province Statistics Bureau made estimates of cultivated land generally higher after 1996. It would be difficult to adjust the before- and after-1996 data without direct help from the Bureau. We therefore used the data without adjustment in grey relation analysis. This probably accounted for the generally lower relational grades for 1991–2001 than for 1980–1990 in Table 4. But because the purpose of grey relation analysis was simply to rank the driving forces for cultivated land changes, this data problem should not affect the results or our interpretation of the results. The time periods for grey relation analysis were not identical between Fujian (1980–2001) and Taiwan (1973–1998) because of incompatible data sources. The problem, however, should not affect our interpretation of the time lag that was based on the sub-periods. As mentioned in the introduction, the practical difficulty in conducting comparative analysis lies in data availability and compatibility. We were able to overcome this difficulty to a large extent by having researchers from both Fujian and Taiwan, but not completely.

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