Research Report

Non-Agricultural Land Use in Post-Reform China*

Samuel P. S. Ho and George C. S. Lin

ABSTRACT Since the early 1980s the conversion of land to non-agricultural use has been arguably the most widespread and intense in China's history. The recent increase in non-agricultural land use has been caused largely by the rapid expansion of urban settlements and the construction of roads and stand-alone industrial sites. Among the factors contributing to these changes, rural–urban migration, urbanization and accelerating development are among the most important. Analysis of land use data from three coastal provinces suggests that variations in the share of land occupied for non-agricultural use among county-level administrative units can be explained largely by differences in population density, urbanization and level of development. While the conversion of land to non-agricultural use is bound to continue in the coming decade, recent institutional changes make it likely that future changes, particularly the encroachment on cultivated land, will be more restricted and better controlled.

Since the introduction of reforms in the late 1970s China has experienced unprecedented economic and social changes. The opening of its economy to trade and investment and the deepening of economic reform have produced double-digit rates of growth and dramatic structural changes in the economy. With the relaxation of its restrictive policy on rural–urban migration, China's rural population has also been on the move, and the rate of urban growth has accelerated. Rising per capita income and increased exposure to the outside world has also changed the lifestyle and consumption habits of a significant portion of the Chinese population. In turn these changes have caused land use in China to change in significant ways, and one of the most important is the rapid and extensive conversion of land to non-agricultural use.[1]

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1. For a general discussion of the factors that cause land use change, see Gerhard K. Heilig, "Neglected dimensions of global land-use change: reflections and data," *Population and Development Review*, Vol. 20, No. 4 (December 1994), pp. 831–859. For discussions of recent land-use changes in China, see, for example, Gerhard K. Heilig, "Anthropogenic factors in land-use change in China," *Population and Development Review*, Vol. 23, No. 1 (March 1997), pp. 139–168; Vaclav Smil, "China's agricultural land," *The China Quarterly*, No. 158 (June 1999), pp. 414–429, and Anthony Gar-on Yeh and Xia Li, "An integrated remote sensing and GIS approach in the monitoring and evaluation of rapid urban

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What is the pace of land conversion in recent years and where has it occurred? What factors have contributed to the conversion of land to non-agricultural use? Is it likely to continue at the current pace in the coming decades? This article provides answers to these questions by examining the available evidence at the national and regional levels. The following section quantifies the magnitude of change in non-agricultural land use in recent years. It then discusses why each of the main categories of non-agricultural land use (rural settlements, land used for transportation, urban settlements and stand-alone industrial and development zones) has increased in recent years. Then, using county-level data from three coastal provinces, it examines the effects of population density, urbanization and the level of economic development on non-agricultural land use. The article concludes by arguing that recent institutional changes, in particular the adoption of the 1998 Land Management Law, make it likely that future conversion of land to non-agricultural use, particularly the encroachment on cultivated land, will be more restrained and better controlled.

Recent Changes in Non-Agricultural Land Use

Until recently China had no reliable statistics on non-agricultural land use. This changed with the publication in 2000 of the first national survey of China's land resources. The survey found that in 1996 nearly 30 million hectares of China's land was occupied for non-agricultural purposes, of which built-up areas in rural settlements (undesignated towns and villages) accounted for 55.7 per cent, built-up areas in urban settlements (cities and designated towns) 9 per cent, transportation (railways, highways, rural roads, airports and harbours) 18.5 per cent, stand-alone industrial sites (industrial sites and economic development zones outside settlement areas) 9.4 per cent, and other uses (salt fields, cemeteries, land used by the military and so on) 7.4 per cent.[2] Because China is 70 per cent rural and its population resides mostly in the eastern third of the country, rural settlements and rural roads account for more than two-thirds of the land allocated to non-agricultural use and most of the non-agricultural land is located in the coastal and central provinces.

Because reliable national land use data exist only for 1996, changes in non-agricultural land use cannot be precisely measured. However, since the national survey was conducted county by county over a period of more than a decade, the direction of change in land use and the order of magnitude of that change may be deduced by comparing the raw survey data (the aggregate of survey data collected at the county level at various

footnote continued

growth for sustainable development in the Pearl River Delta, China," *International Planning Studies*, Vol. 2, No. 2 (1997), pp. 193–210.

2. Liu Yucheng (ed.), *Zhongguo tudi ziyuan diaocha shuju ji* (*A Compilation of Results from the Survey of China's Land Resources)* (Beijing: Quan guo tudi ziyuan diaocha bangongshi, 2000), pp. 20, 21 and 184.

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dates between 1984 and 1995) and the adjusted survey data (the raw survey data adjusted for land use changes between the survey date and 31 October 1996). This is done in Table 1. The raw survey data is designated in Table 1 as "c. 1990" because those who conducted the survey believe they approximate the land use pattern in 1990.[3]

Table 1 shows that between c.1990 and 1996 agricultural land (the sum of cultivated land, orchards, plantations, pastures and forests) remained essentially unchanged. However, land occupied by settlements, industrial sites and transportation increased by 8.5 per cent, a significant rise considering the short time span involved, while unused land declined by 1.2 per cent.[4] It would be wrong to conclude from these aggregate figures that the land converted to non-agricultural use was largely unused land. Agricultural land declined by 276,000 hectares in north-east China, by 545,000 hectares on the east coast, and by more than 1 million hectares in central China. These declines were almost entirely offset by increases in south-west China (227,000 hectares) and north-west China (1.4 million hectares). Nearly 80 per cent of the decline of 3 million hectares of unused land occurred in the south-west and north-west, and much of this was converted to agricultural land (mainly pasture).[5] On the other hand, almost 80 per cent of the total increase of 2.3 million hectares of non-agricultural land was in the north-east, on the east coast and in central China where the decline in unused land was relatively limited. Thus, the disaggregated data suggest that the recent conversion of land for non-agricultural use occurred primarily in the eastern third of the country, and the increase was largely at the expense of agricultural land.

Because the use of land for non-agricultural purposes in China is most intense in areas where cultivated land is concentrated, there is considerable tension between farming and non-agricultural land use. The tension is greatest in east coast China, a region that has less than 10 per cent of China's territory but accounts for 22 per cent of its cultivated land and 39 per cent of its non-agricultural land. For example, in 1995, the conversion of cultivated land to non-agricultural use accounted for more than two-thirds of the loss in cultivated land in the following areas on the east coast: Beijing, Tianjin, Shanghai, Hebei, Shandong, Jiangsu, Zhejiang and Fujian.[6] Because the eastern third of China, particularly the east coast, has some of the country's most productive agricultural land, it is not surprising that the loss of so much land has caused a great deal of government concern.

3. *Ibid.* p. 98.

4. However it should be noted that land use within agriculture changed dramatically. Cultivated land declined by 3.6% while other types of agricultural land (pasture, forest, plantation and orchard) all increased. For a discussion of these changes, see George C.S. Lin and Samuel P.S. Ho, "China's land resources and land-use change: insights from the 1996 land survey," *Land Use Policy*, No. 20 (2003), pp. 87–107.

5. Although roughly one-quarter of China's unused land (mostly wasteland consisting of exposed rock and gravel, sand, grassland, marsh land, etc.) is rated as reclaimable, the quality of the land is poor and the cost of reclamation very high. See Li Yuan (ed.), *Zhongguo tudi ziyuan* (*Land Resources of China*) (Beijing: Zhongguo dadi chubanshe, 2000), pp. 294–315.

6. *Ibid.* pp. 158–59.

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Table 1: **China's Land Use Pattern, by Region, c.1990 and 31 October 1996 (hectares)**

Region		*Total area*	*Agricultural land*[1]	*Non-agricultural land*			*Water area*	*Unused land*
				Total	*Settlements & industrial sites*	*Transport land*		
China	c. 1990	950,650,010	633,906,887	27,218,854	22,198,289	5,020,565	41,442,398	248,081,872
	31 Oct. 1996	950,676,195	633,736,518	29,542,982	24,075,287	5,467,695	42,308,827	245,087,868
	c.1990–1996	26,185	− 170,369	2,324,128	1,876,998	447,130	866,429	− 2,994,004
North-east[2]	c. 1990	79,183,263	63,930,995	3,777,837	2,902,791	875,046	4,452,736	7,021,695
	31 Oct. 1996	79,183,263	63,654,491	3,922,095	3,011,640	910,455	4,620,389	6,986,288
	c.1990–1996	0	− 276,504	144,258	108,849	35,409	167,653	− 35,407
East coast[3]	c. 1990	93,301,754	66,149,491	8,082,772	6,751,337	1,331,435	9,582,185	9,487,305
	31 Oct. 1996	93,327,872	65,604,758	8,956,313	7,470,543	1,485,770	9,738,736	9,028,066
	c.1990–1996	26,118	− 544,733	873,541	719,206	154,335	156,551	− 459,239
Central[4]	c. 1990	237,792,558	188,748,774	9,127,849	7,555,234	1,572,615	10,562,442	29,353,493
	31 Oct. 1996	237,792,674	187,745,661	9,934,657	8,185,520	1,749,137	10,925,551	29,186,805
	c.1990–1996	116	− 1,003,113	806,808	630,286	176,522	363,109	− 166,688
South-west[5]	c. 1990	256,530,091	184,083,905	3,937,927	3,147,473	790,453	8,528,023	59,980,237
	31 Oct. 1996	256,530,091	184,310,829	4,143,192	3,286,845	856,347	8,585,848	59,490,224
	c.1990–1996	0	226,924	205,265	139,372	65,894	57,825	− 490,013
North-west[6]	c. 1990	283,842,344	130,993,721	2,292,469	1,841,454	451,015	8,317,012	142,239,143
	31 Oct. 1996	283,842,294	132,420,778	2,586,727	2,120,740	465,987	8,438,303	140,396,486
	c.1990–1996	− 50	1,427,057	294,258	279,286	14,972	121,291	− 1,842,657

Notes:
[1]Includes cultivated land, *yuandi* (orchards, vineyards, and plantations), forest, and pasture.
[2]Liaoning, Jilin and Heilongjiang.
[3]Beijing, Tianjin, Hebei, Shandong, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong and Hainan.
[4]Inner Mongolia, Shaanxi, Shanxi, Henan, Hubei, Hunan, Anhui and Jiangxi.
[5]Guangxi, Sichuan (including Chongqing), Guizhou, Yunnan and Tibet.
[6]Gansu, Qinghai, Ningxia and Xinjiang.
Source: Calculated from data in Liu Yucheng (ed.), *Zhongguo tudi ziyuan diaocha shuju ji* (*A Compilation of Results from the Survey of China's Land Resources*) (Beijing: Quan guo tudi ziyuan diaocha bangongshi, 2000), pp. 20, 21, 28 and 29.

It is not possible to break down the increase in land occupied by settlements and industrial sites by its components because detailed raw survey data at the national level are not available. However, the provincial data that we do have suggest that rural settlements, despite being by far the largest user of non-agricultural land, accounted for only a relatively small share of the recent increase in non-agricultural land use. For example, reliable land surveys conducted in Shandong show that between 1992 and 1996 land for rural settlements accounted for less than 11 per cent of the increase, while that for urban settlements accounted for 33 per cent, for stand-alone industrial sites 32 per cent, and for transportation 23 per cent.[7] In other words recent increases in non-agricultural land use are largely attributed to urbanization, industrialization and road construction.

Why Did Non-Agricultural Land Use Increase?

This section examines in greater detail why each of the categories of non-agricultural land use has increased in recent years, beginning with the category that has experienced the smallest increase.

Land occupied by rural settlements. Although China's population growth has slowed in recent decades, its rural population still increased by over 75 million between 1980 and 2000, and this increase is undoubtedly one of the reasons why rural settlements have occupied more land.[8] Other things being equal, a larger population means more land is needed for housing and other non-agricultural purposes. But, in recent decades, two other factors besides population growth have contributed to the increased occupation of land by rural settlements, particularly in east coast China. Changing economic and political conditions in the early 1980s triggered a rural housing boom that lasted for more than a decade. Prior to 1978, slow income growth and tight political control kept rural residential construction to a minimum. But with rural reform came prosperity and more relaxed control, and the pent-up demand for better housing set off a major rural construction boom that used a large amount of land, including cultivated land.

The second factor is the rapid development of rural non-agricultural activities encouraged by the government's decision to allow peasants and rural collectives to undertake activities that previously were prohibited or tightly regulated.[9] The new policy allowed peasants not only to engage in traditional home industries but also in all types of commer-

7. The 1996 data are from Liu Yucheng, *Compilation*, p. 184, and the 1992 figures are aggregates of county level data collected in the field.

8. The State Statistical Bureau measures rural population as people who live in areas outside cities (*chengshi*) and designated towns (*jianzhi zhen*). According to this definition, rural population increased from 795 million in 1980 to 870 million in 1999, or by about 75 million (*Zhongguo tongji nianjian* (*China Statistical Yearbook*) (Beijing: Zhongguo tongji chubanshe, 2000), p. 95). However, this definition underestimates rural population as cities and designated towns include within their boundaries many rural settlements.

9. Samuel P. S. Ho, *Rural China in Transition* (Oxford: Clarendon Press, 1994), pp. 20–27.

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cial undertakings. In addition, it permitted townships and villages to set up collectively owned industrial and commercial enterprises (TVEs). Peasants and rural collectives responded to the policy change with enthusiasm, and the rural non-agricultural sector emerged in the 1980s as the most dynamic component of the Chinese economy. The taking of land by TVEs was extensive during the 1980s, when their number expanded dramatically, but even during the mid-1990s when growth had slowed, they were still taking tens of thousands of hectares of rural land (including thousands of hectares of cultivated land) a year.[10] While township enterprises were usually located in rural towns, village enterprises (those owned by villages or sub-village groups) were located on village land in or adjacent to rural settlements. The impact of village enterprises on the growth of land occupied by rural settlements has been particularly dramatic in east coast China, where much of China's rural industry at the village level is concentrated.

Land used for transportation. During the 1980s and 1990s motorization and the development of highways have significantly increased the amount of land used for transportation. Even though, between 1952 and 1980, China had more than doubled the length of its railways and increased the length of its roads from 127,000 to over 888,000 km, the density of its transport network in the early 1980s, both per population and per area, was still very low in comparison with that of other countries.[11] For example, in 1981 China, with a per capita income that was about 20 per cent higher than India, had a network of railways and roads that was only one-third as dense as India's in per capita terms and less than one-fifth in terms of per area of land. China's road network was particularly underdeveloped. In the early 1980s, China had 0.91 km of road per thousand people, as compared to 2.43 km in India and 11.82 km in Brazil.

During the 1980s – as light industries and services developed rapidly, as the de-collectivized agricultural sector became more commercialized, as the government shifted short-distance rail traffic to road transport, and as relaxed rules concerning travel encouraged greater individual mobility – China's road system became progressively more congested. Recognizing that reliable, efficient and economic transport is a necessary condition for social and economic development, transportation was assigned a top priority in the Seventh Five-year Plan (1986–90), and central and local governments began to invest heavily in the transport sector, particularly the building of roads.

To relieve congestion in and near urban centres, city and county governments constructed ring roads, improved existing roads, and added new ones to connect cities with satellite towns and neighbouring county

10. *Zhongguo tudi nianjian 1996* (*China Land Yearbook 1996*) (Beijing: Zhongguo dadi chubanshe, 1996), Table 18.

11. Jacques Yenny and Lily V. Uy, "Transport in China, a comparison of basic indicators with those of other countries," World Bank Staff Working Paper, No. 723 (1985), pp. 14–16 and 29–34.

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seats. Local governments at the township and village levels, particularly in the coastal provinces, also invested in rural roads to ease the transport of agricultural goods to market and to promote rural industrialization. However the most ambitious effort to expand China's road system came from the central government when it announced in the late 1980s its plan to construct the national trunk highway system (NTHS), a network of high speed highways that include 12 high-capacity toll roads, five "vertical" (north–south) highways and seven "horizontal" (east–west) highways totalling 36,090 km that will connect all cities with populations over 1 million and 98 per cent of those with populations between 0.5 and 1 million.[12] Construction of the NTHS began in 1990 and is currently scheduled for completion in 2010, ten years earlier than originally planned.

The development of road transport since the early 1980s has been extremely rapid. The number of civilian motor vehicles on China's road increased from 1.78 million in 1980 to 5.51 million in 1990 and 16.1 million in 2000, and the total length of highways increased from 0.88 million km in 1980 to 1.03 million km in 1990 and 1.40 million km in 2000.[13] By the end of 2000 China had completed 18,000 km of the NTHS, including the two most eastern vertical routes, the Tongjiang–Sanya coastal route that links the north-east to Hainan Island in the South China Sea and the Beijing–Fuzhou route. Currently about 98 per cent of China's counties and towns and nearly 91 per cent of its administrative villages are connected to either a local or a national highway.[14]

The various road projects undertaken during the 1980s and the 1990s, particularly the construction of the NTHS in the 1990s, required large amounts of land. In 1996 5.47 million hectares of land were used for transportation, of which highways occupied 1.33 million hectares and rural roads 3.77 million hectares; these numbers do not include the many miles of the NTHS completed after 1996.[15] Because the demand for transportation is greater in areas with higher population density and faster growing economies, most of China's road capacity is in the eastern parts of the country. In 1996, for every 100 square kilometres of land in east coast China, highways occupied 42.5 hectares and rural roads 107.8 hectares, densities that were roughly three times the national average. Since the early 1980s, because road construction has been significantly more active on the east coast than elsewhere in the country, it is in the coastal provinces where the conversion of land for use in transportation has been most intense.

12. Si-ming Li and Yi-man Shum, "Impacts of the national trunk highway system on accessibility in China," *Journal of Transport Geography*, No. 9 (2001), pp. 39–48 and "Zhongguo jiaotong fazhan guihua ("China communication development plan"), www.moc.gov.cn/gaihuang/plan/jtfzgh.htm.

13. *Zhongguo tongji nianjian* (*Statistical Yearbook of China*), 2001, p. 510.

14. PRC, Ministry of Communications, "The current status of China's transport and its development objectives during the Tenth Five-Year Plan," 2001.

15. The remaining 0.37 million hectares were occupied by railroads, pipelines, airports and wharves. All land use data in this paragraph are from Liu Yucheng, *Compilation*, pp. 202–203 and 208.

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Land occupied by urban settlements and stand-alone industrial sites. Since the early 1980s rural–urban migration, urbanization and industrial growth have accelerated in China, and their impact on land use has been widespread and profound.[16] China defines urban settlements as the officially designated cities (*chengshi*) and designated towns (*jianzhi zhen*). For the purpose of this discussion cities are grouped into very large, large, medium-sized and small by the size of the non-agricultural population (*fei nongye renkou*) living within the city proper (*shiqu*).[17] Very large cities are those with more than 1 million non-agricultural population in the city proper, large are those with 500,000 to 1 million, medium-sized are those with 200,000 to 500,000 and small are those with less than 200,000. Except in minority areas and sparsely populated regions where the designation criteria are less restrictive, "designated towns" include county seats not already designated as cities and seats of townships with a total population above 20,000, of which at least 2,000 is non-agricultural population.[18] In what follows land conversion in and near China's urban centres (very large and large cities) is examined first, followed by a discussion of land use changes in its secondary urban settlements (small and medium-sized cities and designated towns).

Land conversion in and near China's urban centres. Of China's 353 cities in 1986, 54 were "large" or "very large." Inadequate roads and poor infrastructure had limited the spatial growth of these cities so that, in the late 1970s, they had built-up areas that were small relative to their population and relative to the area covered by cities of comparable population in other countries. Since the early 1980s, as more rural residents moved into cities and as roads improved, the urban built-up areas of these cities have expanded rapidly. The development of stand-alone industrial sites (*duli gongkuang yongdi*) near urban settlements has also contributed to the urban sprawl. In past years, such sites were developed to accommodate industries such as coal mining, petroleum, steel and heavy chemicals, some located near cities but many elsewhere. However, since the mid-1980s many city governments have enclosed land for industrial estates. In the early 1980s, industrial enterprises and warehouses occupied about 30 per cent of the core area in Chinese cities, much higher than that found in cities in countries with market econom-

16. For evidence of accelerated rural–urban migration and industrial growth after 1980, see Dorothy J. Solinger, *Contesting Citizenship in Urban China: Peasant Migrants, the State, and the Logic of the Market* (Berkeley: University of California Press, 1999) and Chris Bramall, *Sources of Chinese Economic Growth 1978–1996* (Oxford: Oxford University Press, 2000).

17. Government statistics identify three classes of large cities: super-large (*chaoda*), extra-large (*teda*), and large (*da*). Super-large cities are those with more than two million non-agricultural residents and extra large are those with one to two million non-agricultural residents. In our classification, super-large and extra-large are combined into one category, "very large." The city proper of large cities usually includes both city and suburban districts. Besides a city proper, most large cities in China also have jurisdiction over several subordinate counties.

18. L. Zhang and Simon X. B. Zhao, "Re-examining China's 'urban' concept and the level of urbanization," *The China Quarterly*, No. 154 (June 1998), p. 333.

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ies.[19] When congestion seriously reduced the accessibility and the productivity of industrial activities in the city core, city governments relocated residents and economic activities from the core to suburban estates and shifted the vacated land to more productive commercial uses. Some of the new industrial estates in the suburbs and nearby townships were developed to receive industries relocated from the core area of cities, but many (particularly in the coastal provinces) were development zones (*kaifaqu*) established to attract new investments, mainly from foreign sources.

What happened in Guangzhou illustrates well the combined impact of rural–urban migration, urbanization and rapid industrialization on land use in many of China's urban centres. Because Guangzhou was at the forefront of urban reform and its economy industrialized rapidly during the 1980s and 1990s, it attracted millions of rural migrants.[20] Figure 1 presents two land use maps of Guangzhou *shiqu* as defined by its 2000 boundaries constructed from Landsat images taken in December 1988 and January 2000, and they show a doubling of the land used for non-agricultural purposes (urban built-up area, stand-alone industrial sites and development zones, rural settlement, and other non-agricultural land), rising from 35,000 hectares (less than 10 per cent of the total area) in 1988 to nearly 70,000 hectares in 2000.[21] With a negligible amount of unused land in the region, the increase in non-agricultural land was largely at the expense of agricultural land. Indeed, between 1988 and 2000 Guangzhou *shiqu* lost nearly 47,000 hectares of agricultural land, and much of that was cultivated land. Of the increase in land occupied for non-agricultural uses in Guangzhou *shiqu*, the expansion of urban built-up area accounted for 55 per cent and the development of stand-alone industrial and development zones 25 per cent. Urban sprawl was facilitated by large investments in infrastructure, particularly roads. Between 1979 and 2000, Guangzhou *shiqu* spent RMB 190 billion on infrastructure and increased the area covered by paved road from 342 to 2,805 hectares.[22]

Unfortunately, for lack of data, it is not possible to quantify the expansion of built-up areas in all 54 urban centres during the 1980s and 1990s. However, available remote sensing data show that the urban sprawl experienced by Guangzhou was shared by most of China's other urban centres, although only a few experienced it to the same degree. A comparison of Landsat images of 27 of China's largest urban centres taken during the 1980s and 1990s show that urban land (*chengshi yongdi*) in these cities increased from 3,267 square kilometres in 1986 to 4,907

19. *China: Urban Land Management in an Emerging Market Economy*, A World Bank Country Study (Washington, DC: The World Bank, 1993), p. xiii.

20. *Guangzhou tongji nianjian* (*Statistical Yearbook of Guangzhou*), 2001, pp. 51 and 53.

21. See Appendix 1 for a discussion of how the maps in this report were constructed. Unless noted otherwise, all land use data for Guangzhou *shiqu* and the "Wuxi region" cited here were derived from analyses of Landsat images taken in the late 1980s and late 1990s or 2000.

22. *Statistical Yearbook of Guangzhou*, 2001, pp. 112 and 218.

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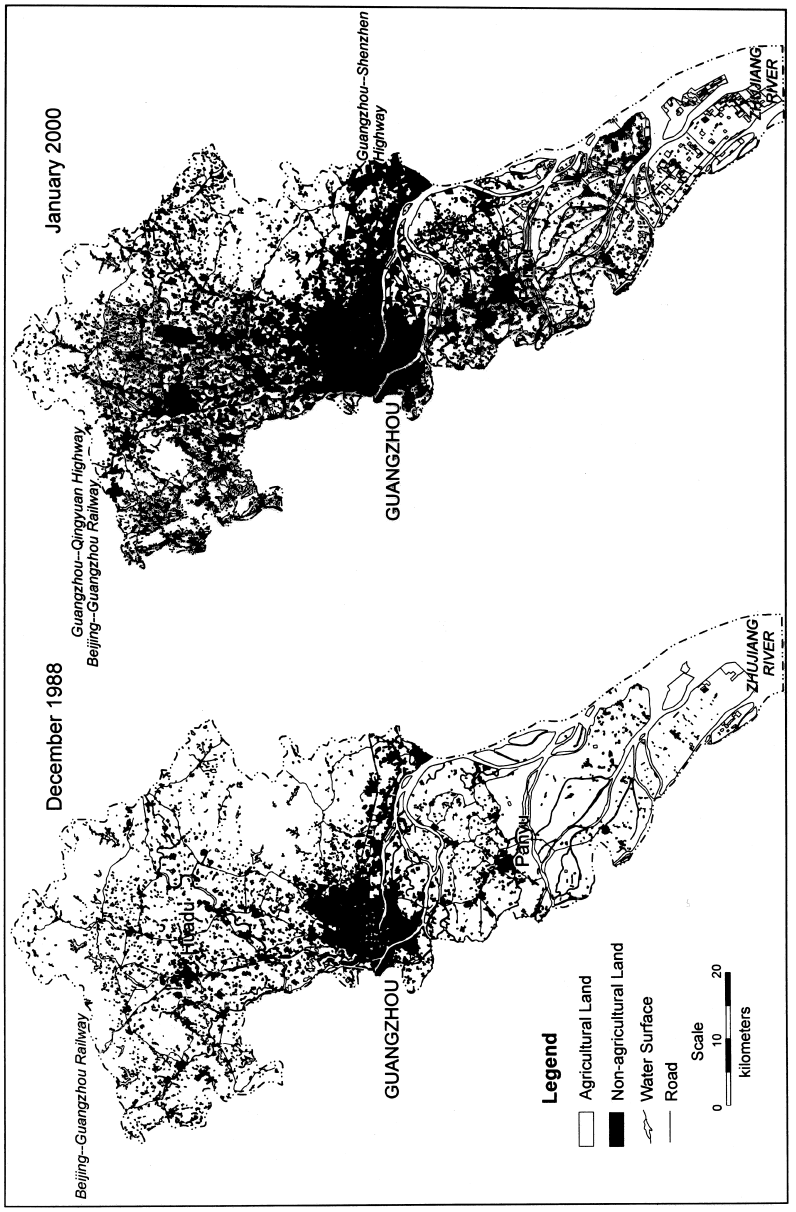


Figure 1: **Land Use in Guangzhou *Shiqu*, December 1988 and January 2000**

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square kilometres in 1996, or by 50 per cent.[23] Three of the 27 cities (Guangzhou, Dalian and Shijiazhuang) increased their built-up areas by 75 per cent or more, eight cities by between 50 per cent and 74 per cent, 12 by between 25 per cent and 49 per cent, and three by 24 per cent or less. Cities that increased their built-up areas the most were generally located in north-east and east coast China: the 15 located here increased their built-up areas by 59 per cent between 1986 and 1996. The remaining 12 cities are located in central, south-west and north-west China, and they expanded their built-up areas by 35 per cent between 1986 and 1996 although several of them (such as Zhengzhou, Changsha, Chengdu and Urumqi) expanded their built-up areas by 50 per cent or more.

Land conversion in and near China's secondary urban settlements. The increased use of land for urban and industrial purposes was not confined to areas near China's urban centres. Since the early 1980s, rural–urban migration, decentralized industrialization and the government's policy of planned urbanization ("control the growth of large cities, rationally develop medium-sized cities and actively develop small cities") have combined to cause China's secondary urban settlements to expand rapidly.[24] A good example is the Wuxi region (an area of about 2,300 square km comprised of Wuxi *shiqu*, Xishan *shi* and Jiangyin *shi*) in southern Jiangsu, and what happened there may be viewed as an intensified miniature version of what happened in many other regions, particularly in east coast China. Figure 2 presents two land use maps of the Wuxi region constructed from photographic prints of Landsat images taken in December 1987 and December 1996, and they show that non-agricultural land expanded dramatically between 1987 and 1996, and the increase was primarily at the expense of cultivated land.

The Wuxi region has two cities, Wuxi and Jiangyin. Wuxi was a medium-sized city in the 1970s that grew rapidly into a large city in the early 1980s. Jiangyin, on the other hand, was elevated to city status only in 1987, when it had an urban population of about 134,000, making it one of China's small cities. By 1996, Jiangyin had grown into a medium-sized city with an urban population of nearly 320,000. Figure 2 shows that, between 1987 and 1996, a significant amount of land in Wuxi *shiqu* and around the city of Jiangyin was converted to non-agricultural use. Our analysis of the Landsat photographs show that of the total increase in non-agricultural land in the Wuxi region between 1987 and 1996, 36 per cent was accounted for by increases within Wuxi *shiqu* (22 per cent) and the area in and nearby Jiangyin city (14 per cent).[25] Of the increase in non-agricultural land in the two cities, 37 per cent was accounted for

23. These and the following statistics are from Li Yuan, *Land Resources of China*, pp. 593–94. Li Yuan does not define "urban land" (*chengshi yongdi*), but most likely he is referring to built-up areas (urban settlements and stand-alone industrial sites) within the city proper (*shiqu*).

24. In the quotation, "large" cities include all cities with non-agricultural population greater than 500,000.

25. Included in the Jiangyin city area are Yaosai *zhen* and Chengjiang *zhen*.

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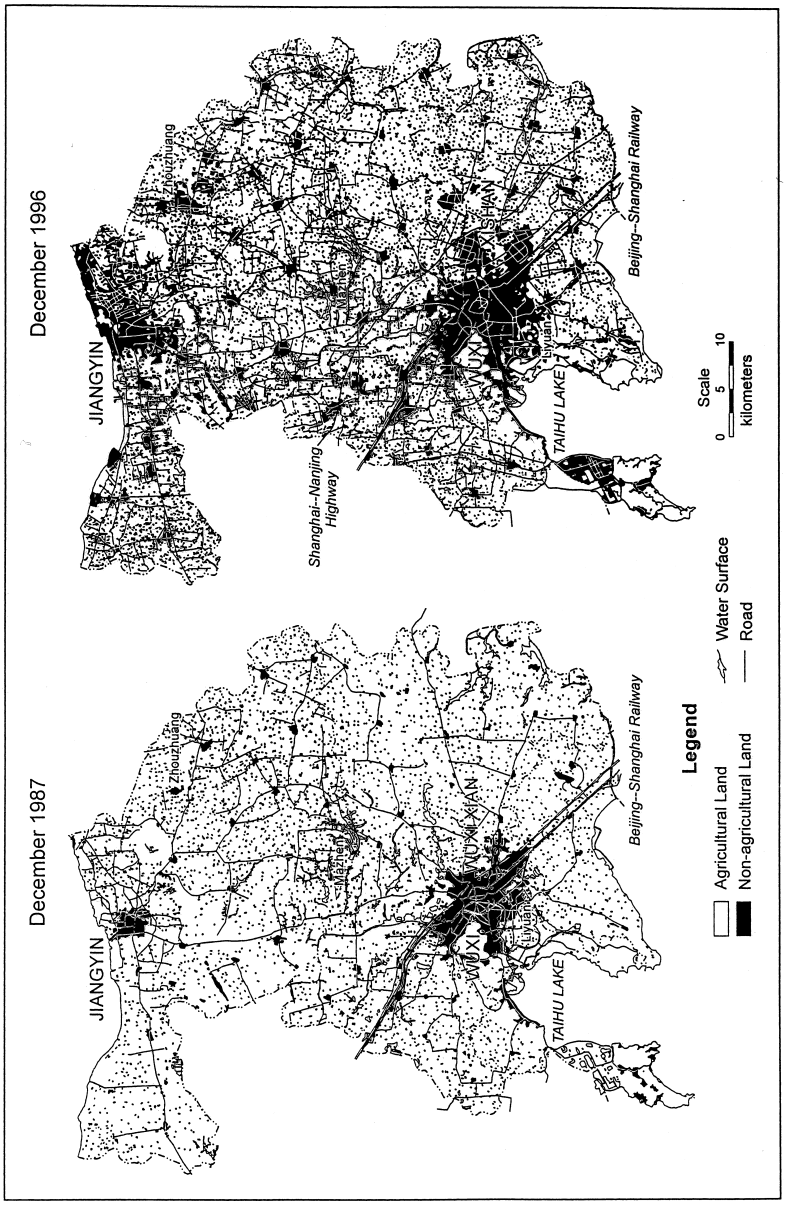


Figure 2: **Land Use in Wuxi *Shiqu*, Wuxi *Xian* (Xishan *Shi*) and Jiangyin *Shi*, December 1987 and December 1996**

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by urban settlements and 49 per cent by stand-alone industrial sites and development zones.

But the Wuxi region also contains some 60 designated towns, and Figure 2 shows that between 1987 and 1996 their use of land for non-agricultural purposes also increased dramatically. The region is in the heart of that part of southern Jiangsu where rural industrialization based on collectively owned TVEs began early and developed rapidly in the 1980s. To support local industries and to entice outside investments many of the townships in the region (indeed even some villages) have established industrial estates and development zones. In 1987 TVEs produced more than half of the region's industrial output, and most of them were located in or near the many towns and industrial and development zones.[26] In other words, because industries in the Wuxi region are widely dispersed, increases in non-agricultural land caused by industrialization have also been dispersed. Indeed, the Landsat photographs indicate that between 1987 and 1996 roughly 53 per cent of the increase in the use of land by urban settlements and by stand-alone industrial sites and development zones in the Wuxi region occurred in and near the many designated towns that dotted its countryside.

For China as a whole, the available evidence strongly suggests that the land occupied by small and medium-sized cities and that by designated towns have both increased dramatically. For example, of the nearly 300 cities in existence in 1984, urban built-up area in small cities grew faster than that in medium sized cities, which in turn expanded significantly more rapidly than that in large and very large cities.[27] But more important is that since the mid-1980s the number of small and medium-sized cities has increased rapidly. With fewer restrictions on rural–urban migration, rural residents moved in large numbers to county seats, some of which became sufficiently developed and populous to be elevated to city status. Between 1984 and 1996, the total number of cities in China increased from 295 to 666, and the comparative distribution of urban built-up area of cities by size class shows a significant downward shift to smaller size categories. Of the built-up area within the city proper reported by all cities in 1984, small and medium-sized cities accounted for 47 per cent.[28] By 1996 this had risen to 59 per cent.

The conversion of land for urban use in China has occurred in a manner that is even more dispersed than suggested by the data on small and medium-sized cities just presented. This is because only 52 per cent of the land identified by the 1996 land survey as occupied by

26. *Wuxi tongji nianjian* (*Statistical Yearbook of Wuxi*), 1988, p. 73.

27. China had 297 cities in 1984, and of these 286 reported data on urban built-up area in both 1984 and 1996. Of those cities with data, 157 were "small," 79 "medium-sized" and 50 "large" and "very large." Between 1984 and 1996, the urban built-up area of the 157 small cities expanded by 84%, that of the 79 medium-sized cities by 70%, and that of the 50 large and very large cities by 49%. Calculated from data in *Zhongguo chengshi tongji nianjian* (*Statistical Yearbook of Urban China*), 1985 (pp. 35–50) and 1997 (pp. 16–25 and 71–90).

28. This and the following statistics were calculated from data in *Statistical Yearbook of Urban China*, 1985 (pp. 35–50) and 1997 (pp. 16–25 and pp. 71–90).

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urban settlements was used by cities.[29] The other 48 per cent was occupied by thousands of designated towns that were scattered throughout the countryside. When the government began to liberalize its policy on migration, one of the first changes adopted was the decision in 1984 to permit rural residents to move to market towns (*jizhen*) as long as they took responsibility for their own grain rations.[30] Soon many of these market towns had populations sufficiently large to become designated towns, and the number of designated towns increased from more than 5,000 in the mid-1980s to about 12,000 in 1990, and 17,998 in 1996.[31] Between 1985 and 1996, the land used by designated towns increased from 9,627 square kilometres to 12,604 square kilometres, or by roughly 271 square kilometres per year.

The growth of designated towns and small/medium-sized cities has been particularly strong in the coastal provinces, the region with the most vibrant rural industrial sector. By the mid-1990s, roughly 40 per cent of China's small and medium-sized cities and designated towns were located in east coast China. Indeed, the four provinces with the highest density of towns in 1996 were all found on the east coast: Jiangsu with 868 designated towns in every 100,000 square kilometres, Zhejiang with 851, Guangdong with 846 and Shandong with 769.[32] These four provinces accounted for about 40 per cent of all workers employed by rural enterprises with ownership at the township and village levels. Given the concentration of small cities and towns and of rural industry in east coast China, the rapid growth of small cities and towns and the rapid development of rural industry since the early 1980s have had a significantly greater impact on land use here than elsewhere.

Analysing Land Use Patterns in Three Coastal Provinces

This section uses county level land use data from three provinces (Shandong, Jiangsu and Guangdong) to examine the impact of demographic and economic factors on non-agricultural land use.[33] The county level data are not for the same year, but are all from the 1990s (the years were determined by the availability of land use data at the county level: 1992 for Shandong, 1996 for Jiangsu and 1998 for Guangdong). Given China's size and diversity, three provinces, however important, cannot represent the entire country. However Shandong, Jiangsu and Guangdong

29. Li Yuan, *Land Resources of China*, Tables 2–7–4 and 2–7–5.

30. "Zhonggong zhongyang guanyu 1984 nian nongcun gongzuo de tongzhi, zhongfa yihao" ("Circular of the Central Committee of the Chinese Communist Party on rural work during 1984, document no. 1") in *Nongcun gongzuo tongxun* (*Rural Work Communications*), No. 7 (1984), pp. 3–8.

31. Li Yuan, *Land Resources of China*, p. 246.

32. Calculated from data in Liu Yucheng, *Compilation*, p. 190.

33. Chinese provinces are organized administratively into prefectures or "prefecture-level cities (*diji shi*)." Each prefecture has under its jurisdiction a city proper (*shiqu*) and a number of counties or/and county-level cities. Land use data were collected in the field for all counties (*xian*), county-level cities (*xianji shi*), and the city proper (*shiqu*) of prefectures in Shandong, Jiangsu, and Guangdong. For simplicity, in the text, we call all these localities "counties."

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account for nearly one-half of the total area in east coast China, and it may be argued that they represent this region reasonably well. Indeed, the land use pattern of east coast China and that of the three provinces are roughly similar (see Table 2).

Our analysis focuses on the impact on non-agricultural land use of three explanatory variables: population density, per capita real gross domestic product (GDP) and the ratio of non-agricultural population to total population. Population density captures the impact of a locality's past population growth from natural increase and net migration on its non-agricultural land use; per capita real GDP the effects of economic development (the locality's level of agricultural development, the strength of its rural industry, the presence or absence of state-owned industry in the locality, the state of its infrastructure and so on), and the ratio of non-agricultural population to total population the impact of urbanization (urban sprawl as well as the impact of urbanization on land use through its effect on consumption and investment).

For a preliminary measure of the impact of population density on non-agricultural land use, we organized the data as follows. First, we calculated the land use pattern in all counties and sorted them in descending order according to population density (calculated as year-end population per hectare of land area). Then we separated the counties into ten roughly equal population groups. Table 2 presents the results,[34] and they show an obvious positive relationship between population density and non-agricultural land use, that is, the higher the population density the greater share of the land is used for non-agricultural purposes in the locality. In fact, the share of land used for non-agricultural purposes in the 17 counties with the highest population density is about 7 times that of the 50 counties with the lowest population density. However, because Table 2 does not control for the effects of urbanization and level of economic development on non-agricultural land use, the relationship depicted is only suggestive and not conclusive.

To disentangle the influences of population density, urbanization and level of development on non-agricultural land use, a multivariate regression analysis is used to estimate the following equation.

(1) $Y = a + b_1 \log X_{1i} + b_2 \log X_{2i} + b_3 X_{3i}$, where

Y_i = the share of non-agricultural land in total land area in the ith county,

X_{1i} = population density (year-end population divided by land area) in the ith county,

X_{2i} = per capita real GDP in the ith county,

34. The results should be read as follows. The 17 counties with the highest population density accounted for 9.8% of the population in the sample and 2.2% of its land area, and their average population density was 26.74 persons per hectare. In these 17 counties, 59.8% of the land was used for agriculture, 36.4% for non-agricultural purposes and 3.8% was unused.

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Table 2: **Land Use Pattern of 273 Counties, County-level Cities and City Proper (*shiqu*) of Prefecture-level Cities in Shandong, Jiangsu and Guangdong, Arranged by Population Density in Descending Order**

				Distribution of land by use (percent of total land)								
						Non-Agricultural Land						
Number of localities	*Percent of population in sample*	*Percent of land area in sample*	*Average Population density (persons/ha)*	*Total land*[1]	*Agri-cultural land*	*Sub-total*	*Cities and Towns*	*Stand-alone industrial sites*	*Rural Settlements*	*Transport*	*Other*	*Unused land*
17	9.8%	2.2%	26.74	100.0%	59.8%	36.4%	10.2%	8.4%	11.7%	3.8%	2.3%	3.8%
22	10.0%	4.8%	12.63	100.0%	72.4%	22.5%	3.1%	2.7%	12.1%	3.6%	0.9%	5.1%
22	9.9%	5.9%	10.13	100.0%	77.4%	19.9%	2.1%	2.8%	11.1%	3.1%	0.8%	2.7%
23	10.2%	7.2%	8.55	100.0%	76.0%	18.7%	1.6%	1.8%	10.5%	3.3%	1.5%	5.3%
24	9.8%	7.7%	7.62	100.0%	78.0%	18.6%	1.3%	2.2%	11.1%	3.2%	0.8%	3.4%
27	10.3%	9.1%	6.85	100.0%	75.5%	17.5%	1.8%	2.3%	9.8%	3.0%	0.7%	7.0%
30	10.0%	10.1%	5.97	100.0%	76.8%	15.1%	1.3%	1.2%	9.0%	3.0%	0.7%	8.0%
28	9.9%	11.3%	5.30	100.0%	75.4%	14.2%	0.8%	1.1%	8.2%	2.7%	1.4%	10.4%
30	9.9%	13.9%	4.28	100.0%	80.9%	11.0%	0.8%	0.9%	6.2%	2.1%	1.0%	8.1%
50	10.2%	27.8%	2.21	100.0%	86.8%	5.0%	0.5%	0.8%	2.7%	0.7%	0.4%	8.2%
273	100.0%	100.0%	6.03	100.0%	79.4%	13.5%	1.3%	1.6%	7.4%	2.3%	0.8%	7.1%
		East coast China	4.93	100.0%	78.5%	10.7%	1.2%	1.4%	5.6%	1.8%	0.7%	10.8%
		China	0.54	100.0%	69.8%	3.3%	0.3%	0.3%	1.8%	0.6%	0.2%	27.0%

Note:
[1] Total area minus water area.
Source: Land use data were collected from 287 localities (county, county-level cities and city proper of prefecture-level cities) in Shandong, Jiangsu and Guangdong. Fourteen localities with inconsistent data were discarded. The data for Shandong are for 1992, those for Jiangsu are for 1996 and those for Guangdong are for 1998. The population data are from *Jiangsu tongji nianjian* (*Statistical Yearbook of Jiangsu*) 1997, pp. 352–53, *Shandong tongji nianjian* (*Statistical Yearbook of Shandong*), 1993, pp. 573, 614 and 615, and *Guangdong tongji nianjian* (*Statistical Yearbook of Guangdong*), 1999, pp. 631–32. The figures for East Coast China and those for China as a whole are calculated from data in Liu Yucheng, *A Compilation of Results*, pp. 20, 21 and 184.

Table 3: **Population Density, Urbanization and Level of Development on Non-agricultural Land Use**

Estimated coefficient	*OLS (t-statistic)*	*Standardized coefficient (relative weight)*
a	1.3256 (20.2479)*	
b_1	0.1040 (21.6690)*	0.7413 (75.13%)
b_2	0.0084 (1.5126)#	0.0700 (7.09%)
b_3	0.0876 (2.6087)*	0.1754 (17.77%)

Notes:
*, # denotes respectively 1% and 20% level of significance for a two-tail test.
R^2 (adjusted) = 0.7368, F = 254.86, Number of observations = 273.

X_{3i} = the ratio of non-agricultural population to total population in the ith county.

The expectation is that the share of land allocated to non-agricultural use (Y) is positively related to population density (X_1), level of economic development (X_2) and urbanization (X_3). Specifically, we expect b_1, b_2 and b_3 to be greater than zero. The coefficients, estimated by ordinary least squares regression, are presented in Table 3. To gauge the relative importance of the independent variables in the multiple regression model, the standardized coefficients are also calculated and presented.

The regression results are consistent with our expectations. The estimated coefficients are all statistically greater than zero. Of the explanatory variables, population density has the greatest impact on non-agricultural land use – a 1 per cent increase in population density increases the share of non-agricultural land in total land by 0.1040 per cent. The importance of population density is not surprising since population is the driving force behind much of the demand for non-agricultural land. Next in important is urbanization – a 1 per cent increase in urbanization increases the share of land allocated to non-agricultural use by 0.0876 per cent. The standardized coefficients show that the relative importance of the three independent variables in explaining the share of land allocated to non-agriculture use are 75.1 per cent for population density, 17.8 per cent for urbanization and 7.1 per cent for per capita real GDP. About 74 per cent of the variations in the share of land allocated to non-agriculture use at the county level are explained by differences in population density, urbanization and the level of development. With an F value of 255, the null hypothesis that the independent variables do not have an effect on the share of land allocated to non-agricultural use is rejected at the 1 per cent level of significance.

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To see whether "regions" make any difference in non-agricultural land use, we also estimated a dummy variable model (see Appendix 2). Strictly speaking, because the data for the three provinces are for different years, the dummy variable model is used to find out whether non-agricultural land use is different in "1992-Shandong" from that in "1996-Jiangsu" and "1998-Guangdong." The results show no "regional" difference in the impact of population density, that is, an increase in population density has the same positive effect on non-agricultural land use in all three provinces. However "regional" variations in the impact of urbanization and that of economic development were found. Specifically the impact of an increase in per capita GDP on non-agricultural land use was found to be greater in 1998-Guangdong than in 1996-Jiangsu and 1992-Shandong, and the impact of an increase in urbanization on non-agricultural use was found to be smaller (though still positive) in 1992-Shandong than in 1996-Jiangsu and 1998-Guangdong. It is interesting to note that 1998-Guangdong is the most developed (has the highest per capita GDP) of the three and that Guangdong experienced the most rapid rate of development during the 1980s and 1990s. On the other hand, 1992-Shandong is the least urbanized and the least developed of the three. The results suggest that there may be some form of non-linearity in development and urbanization, that is, once a region has reached a certain level of development (or urbanization), the impact of further development (or further urbanization) on increases in non-agricultural land use becomes greater.

Because economic and social variables are usually related, multicollinearity is a fact of life in most economic studies. Ours is no exception. Although there is no single sure test for detecting multicollinearity, there are several rules of thumb that are commonly used to measure its severity. We applied four such rules to our sample and found that the diagnostic results in three cases (pair-wise correlations among the explanatory variables, R^2 of auxiliary regressions and tolerance indicators) indicate no evidence of a serious multicollinearity problem, but the results in the fourth case (condition index) indicate severe multicollinearity.[35] Dropping one of the explanatory variables would reduce collinearity but by so doing we would commit a specification error since we believe all three of the variables are important in explaining non-agricultural land use. In any case, despite the fact that the explanatory variables are correlated to some extent, all coefficients in equation (1) are statistically

35. The rule of thumb is that multicollinearity is a serious problem if the pair-wise correlation coefficient between two of the explanatory variables is high, say in excess of 0.8 or 0.9, if the R^2 obtained from an auxiliary regression is greater than the overall R^2 (i.e., the R^2 obtained from regressing the dependent variable on all the regressors), if any of the tolerance indicators is below 0.1, or if the condition index is above 1000. However each of these rules has its shortcomings. For more on these rules of thumb, see Damodar N. Gujarati, *Basic Econometrics*, 3rd ed. (New York: McGraw-Hill Inc., 1995), pp. 335–39. In the case of our sample, the pair-wise correlation coefficient among the three explanatory variables used ranges between 0.31 and 0.66, the R^2 obtained from the auxiliary regression ranges from 0.17 to 0.48 while the overall R^2 is 0.74, the three tolerance indicators are 0.83, 0.56, and 0.52, and the condition index is 11,054.

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significant and are not sensitive to small changes in the data.[36] Although multicollinearity does not seem to have seriously affected the estimates of the coefficients, its presence, even though its level appears tolerable, does compromise to some extent the integrity of the least squares estimates. Nevertheless, we believe the estimated coefficients are useful and meaningful since they are robust and consistent with economic intuition.

Future Conversion of Land to Non-Agricultural Use

The conversion of land (including cultivated land) to non-agricultural use is bound to continue in the coming decades. Globalization and the deepening of economic reform will continue to stimulate rapid economic growth and structural change. With household registration no longer a constraint to individual mobility, rural–urban migration is almost certain to accelerate and with it the rate of urban growth. Because transportation and land use are intimately linked, there is also the danger that the current massive investments in ring roads and highways near cities may lead to excessive decentralization and sprawl with their accompanying undesirable impact on land use, some of which can already be observed. With the government now committed to develop the western provinces, the conversion of land to non-agricultural use in the west will accelerate.[37] But the greatest pressure for land conversion will continue to be in regions where population density is already high and where economic and urban growth is most rapid, such as east coast China, Liaoning, and parts of Hubei and Anhui.

Although demographic and economic changes are the primary forces that drive land conversion, policies and institutions also influence the process. Among the factors that contributed to the rapid conversion of land to non-agricultural use was the government's decision to undertake economic reform and move towards a market-oriented economy and its inability to manage effectively the land use changes that followed because the institutions (laws, regulatory and enforcement agencies, and so on) needed to regulate the relationships between land and its users were undeveloped.[38] In the mid and late 1980s the government used a hierarchical review and approval system to manage and control the conversion of land to non-agricultural use. But the system was ineffective, partly because local governments had a strong revenue motive to expropriate collective land for conveyance to commercial users and partly because lower level officials could find ways around the hierarchical approval process with relative ease.

China's commitment to economic reform is not likely to waver, but its

36. When a few randomly selected observations were dropped, the estimates did not change much.

37. For example, much of the unfinished parts of the NTHS are in the central and western parts of the countries.

38. For discussions of land use management in China during the 1980s and 1990s, see Samuel P. S. Ho and George C. S. Lin, "Emerging land markets in rural and urban China: policies and practices," *The China Quarterly*, No. 175 (September 2003).

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laws and regulations are now undergoing significant changes, and the pace of land conversion in the future will be determined in part by the extent to which these changes will improve the government's ability to plan and manage land use. Of the recent changes, the most important is the adoption of a newly revised Land Management Law, which went into effect in early 1999. The expectation is that the new law, which replaced the hierarchical approval system with strict rules that in effect centralized decision making concerning land conversion, will enable the government better to protect farmland and to manage the conversion of land to non-agricultural use.

The central government's wish to slow significantly the pace of land conversion to non-agricultural use, particularly in east coast China, is reflected in its overall land utilization plan (*tudi liyong zongti guihua*) for 1996–2010.[39] The plan calls for the amount of land occupied by settlements and stand-alone industrial sites to decline by 30,000 hectares between 1996 and 2010. It also projects zero or very small net decline in cultivated area in the coastal provinces. These targets may be unrealistic. For example, the latter (in fact zero net decline in Liaoning, Beijing, Tianjin, Shanghai, Jiangsu and Shandong) seems overly ambitious in view of the growing and persistent pressure on cultivated land from urbanization and industrialization, the need for additional transport infrastructure, and the limited amount of land suitable for reclamation in the region. So too is the government's projection that total land occupied by rural and urban settlements and by stand-alone industrial sites in the country will decline between 1996 and 2010. Indeed, with rural–urban migration and industrial growth expected to continue, the government projects that land occupied by urban settlements and stand-alone industrial sites will expand by 1.87 million hectares. Thus, for total land occupied by urban and rural settlements and by stand-alone industrial sites to decline, the government projection assumes that land occupied by rural settlements will decline by nearly 1.9 million hectares. How realistic is this? As more rural population moves to cities, rural population is bound to decline, but how likely is it that large amounts of rural construction land will be returned to cultivation? In 1997, after large numbers of its rural residents had moved to cities and towns, Jiangsu announced a plan to consolidate some of its villages into more densely populated "urban villages" in the hope that rural construction land can be converted to cultivation. When the idea was first put forward, the announced objective was to consolidate over 280,000 of its villages into 50,000 "urban villages," with an expected gain in cultivated land of about 200,000 hectares.[40] However, consolidation turned out to be more difficult and the gain in cultivated land significantly less than originally thought.[41]

39. Xiang Hongyi, *Zhongguo tudi ziyuan diaocha gongzuo zongjie* (*A Summary of the Survey of China's Land Resources*) (Beijing: Zhongguo dadi chubanshe, 2000), pp. 68–76.
40. *Renmin ribao* (*People's Daily*), 19 May 1997.
41. "Interview notes," Jiangsu, 31 May 2001.

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The central government recognizes that its overall land utilization plan may be overly ambitious, and does not consider its land use targets "mandatory." Rather it hopes that its land utilization plan, the recently revised Land Management Law and higher land prices on the emerging land markets will combine to put strong pressure on local governments and users to manage land use better. Adding to the pressure on local governments is the recent import of remote sensing technology from France that allows the central government to monitor land use in 66 cities with a population above 500,000. The new technology makes the central government less dependent on local governments for information on land use and thus makes local officials less able to hide sizeable illegal conversion of land to non-agricultural use.

There exists abundant evidence that non-agricultural land is used inefficiently in China. For example, government statistics show large amounts of land enclosed for development have remained idle.[42] This is a problem not only in areas close to cities but also in the countryside. For example, it is reported that idle land adjacent to villages in Hebei often exceeds the size of the village.[43] Another issue is that non-agricultural land is often used irrationally. The explosion in the number of small cities and towns in close proximity to one another has created duplications in industrial facilities and infrastructure. In the countryside, "hollow villages" (*kongxin cun*), that is, villages with underutilized land, have become increasingly common.[44] In other words, if land is used more rationally and intensively, existing settlements can support significantly more people without encroaching on additional land.

The increased institutional pressure on local governments and commercial users to use non-agricultural land more efficiently and more intensively is already having some effect. Local governments are now more actively seeking ways to use non-agricultural land more efficiently and intensively. For example, local governments that once applauded small town development ("a town every few miles") now consider the model unsuitable because it encourages excessive conversion of land to non-agricultural use. Now the talk is about scale and how to entice the rural population to locate in a smaller number of towns. For example, recently Zhanjiagang (a county-level city in south Jiangsu) classified four of its 20 designated towns as central towns (*zhongxin zhen*). In future, new investment and new industries will be directed to the central towns with the hope that rural population will be attracted to the new jobs in these towns.[45] Of course, how effectively and energetically

42. Li Yuan, *Land Resources of China*, p. 247.

43. "China's farmland loss rings alarm – satellite photographs reveal a serious problem," http://www.usembassy-china.org.cn/english/sandt/landloss.htm.

44. In rapidly developing rural areas, many villagers, when they have accumulated sufficient wealth, have built new and larger houses in the outskirts of the village (usually by encroaching on nearby farmland) rather than renovating their existing homes. As villagers moved to the outskirts, the village became "hollow" as the old parts of the village became increasingly empty of people. This phenomenon is not restricted to villages as it is also observed in many rural towns and small cities.

45. "Interview notes," Jiangsu, 2 June 2001

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the government uses the revised Land Management Law to manage and control land conversion and how quickly it allows land markets to develop will determine ultimately whether the conversion of land to non-agricultural use will slow significantly.

Appendix 1

This appendix describes how the two sets of land use maps presented in this report were constructed. The maps in Figure 1 (Guangzhou *shiqu*) are the results of computer processing of satellite images using ERDAS Imagine software. The supervised approach of maximum likelihood classification was used initially to extract land use information from the images. But because the highest achievable accuracy in classification was only 60–70 per cent, the automatic image classification was supplemented with visual (or manual) interpretation to extract the non-agricultural land use information. Experienced remote sensing experts at the Nanjing Institute of Geography and Nanjing University carried out the image interpretation. For consistency and comparability, the 2000 administrative boundaries of Guangzhou *shiqu* were superimposed on the Landsat images, and land use was classified into six categories (agricultural land, urban built-up area, stand-alone industrial and development zones, rural settlements, other non-agricultural land, and water area). ArcView software was used to perform the visual interpretation. Using on-screen digitizing, the polygonal boundaries of different land use types were traced, which were then coded according to the adopted land use categories. After the completion of visual interpretation, selective ground truth verification was conducted in the field. For land cover types found in localized areas that were particularly difficult to classify, field check was conducted, and corrections to the visual interpretations were made accordingly. ARC/INFO software was then used to edit and correct the digitized land cover polygons, and to build the topology for the polygons. Finally, area statistics were extracted for each category of land use.

The maps in Figure 2 (the Wuxi region) are constructed from visual interpretation of ortho-rectified photographic prints of satellite images in false colour composites enlarged to a scale of 1:100,000. Specialists at the Nanjing Institute of Geography familiar with the Wuxi region interpreted the land use information from these photographic prints. Specifically, the 1996 administrative boundary for the Wuxi region was superimposed on both the 1987 and 1996 photographs. By visually interpreting the shape, size, colour, shadow, texture and location, land use within the region was classified into eight categories (cultivated land, other agricultural land, urban built-up area, stand-alone industrial and development zones, rural settlements, transport land, other non-agricultural land, and water area). Because there is very little unused land in the Wuxi region, cultivated land was estimated as a residue. For land whose use was in doubt, classification was done after documentary research or ground truth verification. The results of visual interpretation were scanned into a computer and digitized into different layers by land use

Land Use Pattern in Guangzhou shiqu, 1988 and 2000 (land use as % of total area)

	1988	*2000*
Total area (hectares)	359,445	359,445
Per cent of total area		
Agricultural land	77.9%	64.9%
Non-agricultural land	9.7%	19.2%
Urban built-up area	4.6%	9.8%
Rural settlements	3.3%	4.7%
Industrial/development zones	0.7%	3.1%
Other non-agricultural land	1.1%	1.6%
Water area	12.4%	15.9%

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Land Use Pattern in the Wuxi Region, 1987 and 1996 (land use as % of total area)

	1987	*1996*
Total area (hectares)	228,222	228,222
Per cent of total area		
Agricultural land	88.0%	76.8%
Cultivated land	83.1%	72.0%
Non-agricultural land	9.1%	20.2%
Urban built-up area	3.8%	7.0%
Rural settlements	4.2%	7.2%
Industrial/Development zones	0.6%	4.9%
Other non-agricultural land	0.5%	1.2%
Water area	2.9%	3.0%

categories. The area of each type of land use was then calculated. Above are the estimated land use patterns for Guangzhou *shiqu* in 1988 and 2000 and for the Wuxi region in 1987 and 1996.

Figures 1 and 2 are computer printouts of the different types of land use (an overlaying of the different types of land use on a single map) determined by the analysis. But to keep the maps from being too cluttered, the land use categories used in the classification were aggregated and reduced to three: agricultural land (cultivated land + other agricultural land), non-agricultural land (urban built-up area + rural settlement + stand-alone industrial and development zones + other non-agricultural land), and water area.

The processing and interpretation of satellite images (or photographic prints of such images) are subject to errors. Because the spatial resolution of Landsat images is 30 metres, small rural settlements scattered in the countryside or in narrow bands along rivers are not always detected. Mistaken interpretations may also occur because the same kind of land use or land cover may have different spectral characteristics; conversely different kinds of land use or land cover may have similar spectral characteristics. Another problem is that much of the land used for industry in suburban areas is mixed in with rural settlements or located on the edges of towns and villages, and is therefore very difficult to delineate. Selective ground truth verification and cross checking with existing documents and local land use maps have reduced but not eliminated these errors. In the case of Guangzhou *shiqu* a small sample survey was conducted to check for accuracy, and the results suggest the accuracy of image interpretation and processing is about 80–90 per cent. Despite these many problems, we believe the land use maps are useful because the satellite images (or their photographic prints) were processed and interpreted consistently and because the purpose of the study is not to measure accurately the area of each type of land use but only to illustrate the trend in land use change.

Appendix 2

The following dummy variable model was estimated by ordinary least squares regression.

$$\begin{aligned} Y_i = {} & 1.1140 - 0.5042D_{2i} - 0.0759D_{3i} \\ & (3.6289)^{*} \ (-1.4544)^{\#} \ (-0.2323) \\ & + 0.0895\log X_{1i} - 0.0165D_{2i}\log X_{1i} - 0.0137D_{3i}\log X_{1i} \\ & (3.3976)^{*} \qquad (-0.5899) \qquad (-0.4909) \\ & + 0.0135\log X_{2i} + 0.0321D_{2i}\log X_{2i} - 0.0096D_{3i}\log X_{2i} \\ & (1.5124)^{\#} \qquad (2.1139)^{**} \qquad (-0.8274) \\ & + 0.1599\log X_{3i} - 0.0780D_{2i}\log X_{3i} - 0.1447D_{3i}\log X_{3i} \\ & (2.0070)^{**} \qquad (-0.7733) \qquad (-1.6829)^{***} \end{aligned}$$

adjusted $R^2 = 0.8066$, $F = 104.11$, number of observations = 273

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where Y_i, X_{1i}, X_{2i}, and X_{3i} are defined as in equation (1),

$D_{2i} = 1$ if the observation is Guangdong
$= 0$ otherwise

$D_{3i} = 1$ if the observation is Shandong
$= 0$ otherwise

The figures in parentheses are t statistics, and *, **, ***, # denote respectively the significance level of 1%, 5%, 10%, and 20% for a two-tail test.

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