Urban land expansion and cultivated land loss in the Beijing Tianjin region, China

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Abstract
Economic growth in China continues to nurture the urban expansion of large cities, causing the loss of an increasing amount of arable land. Cultivated land conservation in the urban fringe is important in mitigating the concomitant effects of urban growth on the environment. Due to strong State influence, possible policy differences between Beijing and Tianjin municipalities and Hebei Province are expected to be reflected in the land-use pattern. In this study, we examined quantitative land-use change in the Beijing Tianjin region using Geographic Information Systems and a 1 km grid dataset of the 1980s, 1995 and 2000. The results show difference in terms of the urban and cultivated land-use change pattern between Beijing and Tianjin municipalities as well as between the suburbs and outer counties in the study area. Urban expansion seems linked to existing urban centres, whilst change in cultivated land appears to be subject to administrative boundaries as well as market forces, indicating large-scale State influence on the land-use pattern. However, the results suggest that most changes in cultivated land occur at a local scale. As separate administrative areas try to meet State demands, land resources may not be used as effectively as possible. This study suggests that planners should pay increased attention to land-use patterns and policy implementation at small scales in order to enable effective urban-rural planning.
Key words:
Beijing Tianjin region, China; Urbanization; Land-use change; Cultivated land conservation; GIS

Introduction

Economic Reforms in 1978 caused unprecedented growth in many Chinese cities[6)18)26)], with concomitant impacts on the environment and ecosystem functions[14)24)]. Large cities continue to expand[30)] especially in the three major city regions concentrated along China's coast: the Hong Kong, Guangzhou, Shenzhen region in the Pearl River Delta, the Shanghai, Hangzhou, Suzhou region in the Yangtze River Delta, and the Beijing Tianjin region in the Haihe River Delta[29)]. The impact of various policies since 1978 has changed the land-use pattern dramatically[1)]. However, land-use policy is considered to be one of the key factors in slowing down land conversion speed[19)], and despite decentralization and the subsequent weakening role of urban planning[3)], the Central Government in China continues to play a significant role in urban and regional development[21)].

Much fertile and intensively cultivated land is located in river deltas, and urban growth in coastal city regions in China is often associated with the loss of arable land[5)8)19)24)]. China has a very low per-capita amount of arable land at only about 10% of the land area[2)] yet supports almost a quarter of the world population[8)]. In 1986 the State recognized the need to protect agricultural land[26)], but general academic consideration of this issue did not emerge until the mid 1990s[16)25)]. In 1994 the State implemented the Ordinance for Primary Farmland Protection, which prohibits the conversion of basic farmland to non-agricultural uses[5)]. Despite debate about the impact of arable land loss on China's food security[4)17)], farmland in the urban fringe has many ecological functions including providing habitats for wildlife and food production in proximity to the city, and plays a vital role in protecting the environment[27)].

Since the mid-1990s, many studies have been conducted concerning cultivated land loss, often quantifying land-use change, and often as a function of proximity to built-up areas[1)10)14)19)]. But most treat a study region as homogenous as far as land-use policy impact is concerned. The conflict between economic growth nurturing urban expansion and the need to protect cultivated land is at the root of inefficient cultivated land loss. This study attempts to integrate these two driving forces and analyze their differing impacts on the land-use pattern. The Beijing Tianjin region is chosen for detailed study not only because it is considered a typical region in facing competition between urban and cultivated land. It is also assumed that the driving forces shaping the land-use pattern and thus the impact on cultivated land loss are different. Market forces are considered strong, especially in Beijing, and the market model is simplified by the proximity of just two major cities. Administratively on the other hand, Beijing is the national capital whilst Tianjin is also administered directly by the Central Government but Hebei Province has been subject to less preferential treatment by the major policies to impact urban growth. Due to strong government presence in the Beijing Tianjin region[22)], of the three major urban regions in China, in this region the profound impact of the 1994 Ordinance[10)], is expected to be most clearly reflected in the land-use pattern. To illustrate the potential difference in land-use pattern between areas of different administrative hierarchy, the study is conducted at the county scale.

Methodology

Study area

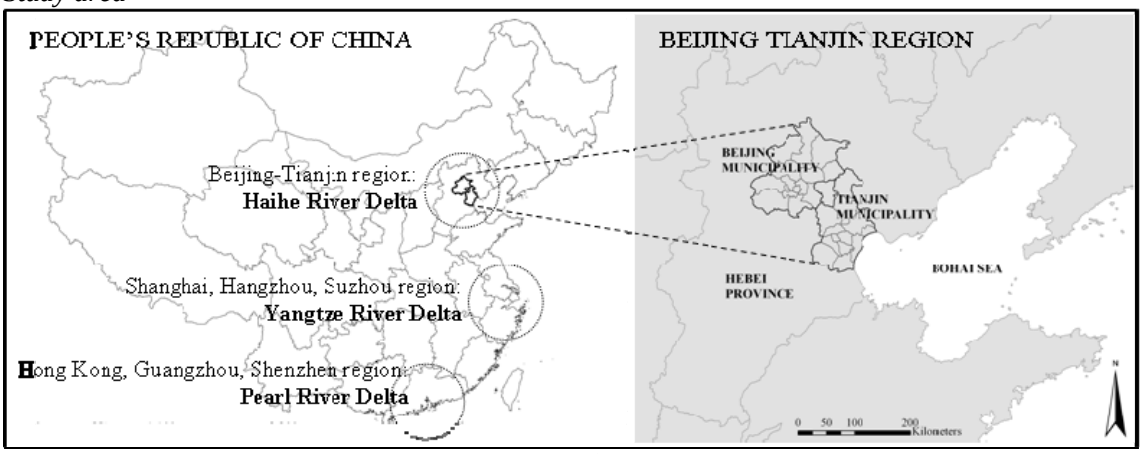

Figure 1: Geographic location of the Beijing Tianjin region

The Beijing Tianjin region is situated in north-eastern China in the Haihe River Delta. Beijing and Tianjin municipalities border each other and Hebei Province. Beijing and Tianjin cities are situated only about 100 km apart, but their relationship in recent decades has been marked by economic competition. Tianjin is the historical gateway to Beijing and was the most important industrial centre in Northern China until 1949[21)]. But after the rise of Communism, Beijing as the national capital was strengthened through massive investment as an industrial base[15)], despite the proximity to the major industrial centers Tianjin and Tangshan, causing the economy of Tianjin to decline. Even though Tianjin was favoured by the Open Door Policy in 1984 and developed the coastal district, foreign investment stagnated in the mid 1990s and the economy of Tianjin is still lagging whilst that of Beijing continues to grow. Linkages between Beijing and Tianjin had been reduced through policies, and today little cooperation exists between the two cities. The Tianjin region already faces severe environmental challenges which constrain its development[21)]. Regional planning has attempted to keep the two cities from merging[9)]. Hebei Province however has developing more slowly under the 1984 premise to let some get rich first[13)].

Land-use change is studied where the largest amount of urban expansion in the region is expected to have taken place, namely in the counties located between Beijing and Tianjin cities coinciding with the main transport arteries, a railway, highway and main road, connecting the two cities. The study area thus comprises the three suburbs of Beijing City: Haidian, Chaoyang, and Fengtai; Tong and Daxing, two outer counties belonging to Beijing Municipality; the four suburbs of Tianjin City: Beijiao, Dongjiao, Nanjiao and Xijiao; Wuqing, an outer county belonging to Tianjin Municipality; and Langfang, a county under Hebei Province.

Data

In order to analyze land-use change since the start of rapid urbanization in 1978 and the effect of the 1994 Ordinance for Primary Farmland Protection, a 1 km grid dataset provided by the Chinese Academy of Sciences of the 1980s, 1995 and 2000 is used. This data consists of mixed grid cells where each grid cell has a percentage of each land use. The land-use types included are urban land, rural settlements, construction land, cultivated land, woodland, grassland, water surfaces and unused land. The dataset also includes land-use change data describing the transforming area between land uses. 1:1,000,000 vector data of administrative boundaries were also provided by the Chinese Academy of Sciences.

Land-use type	
Urban land	- Land for built up areas in big, middle and small cities and towns
Cultivated land	- Wet fields for cultivation of rice, lotus and other water crops - Dry fields for dry crops and vegetables

Table 1: Description of urban and cultivated land included in 1km grid dataset

Data analysis

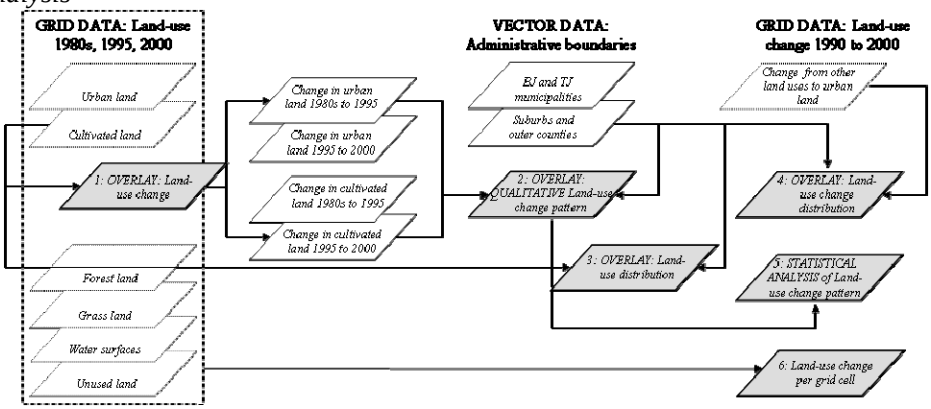

Figure 2: Overview of the methodology of the study

The data layers were overlaid for analysis using Geographic Information Systems (ArcMap, version 9.1, ESRI). In order to find the change in the amount in land-use, the layers of one land use in two time periods were subtracted from each other. The new change layer was then overlaid with the vector data of administrative boundaries to give a qualitative impression of the land-use change per administrative area. The amount of land-use change per county was found by making subsets per county. Next, statistical analysis was used in order to find whether the difference in land-use pattern as seen qualitatively was significantly different quantitatively. The data were divided into 5 groups, namely Beijing suburbs, Tianjin suburbs, Beijing outer counties, Tianjin outer counties, and Langfang. Non-parametric statistical tests were applied (SPSS, version 10.0); Kruskall-Wallis test was used to test for significant difference between all of the groups and Mann-Whitney test was applied to test for significant difference between each of the groups. Next, for a more detailed investigation of the different change patterns, the relationship of land-use change to change in cultivated and urban land was examined using a grid cell-by-grid cell comparison for Beijing and Tianjin municipalities.

Results

Qualitative land-use change pattern

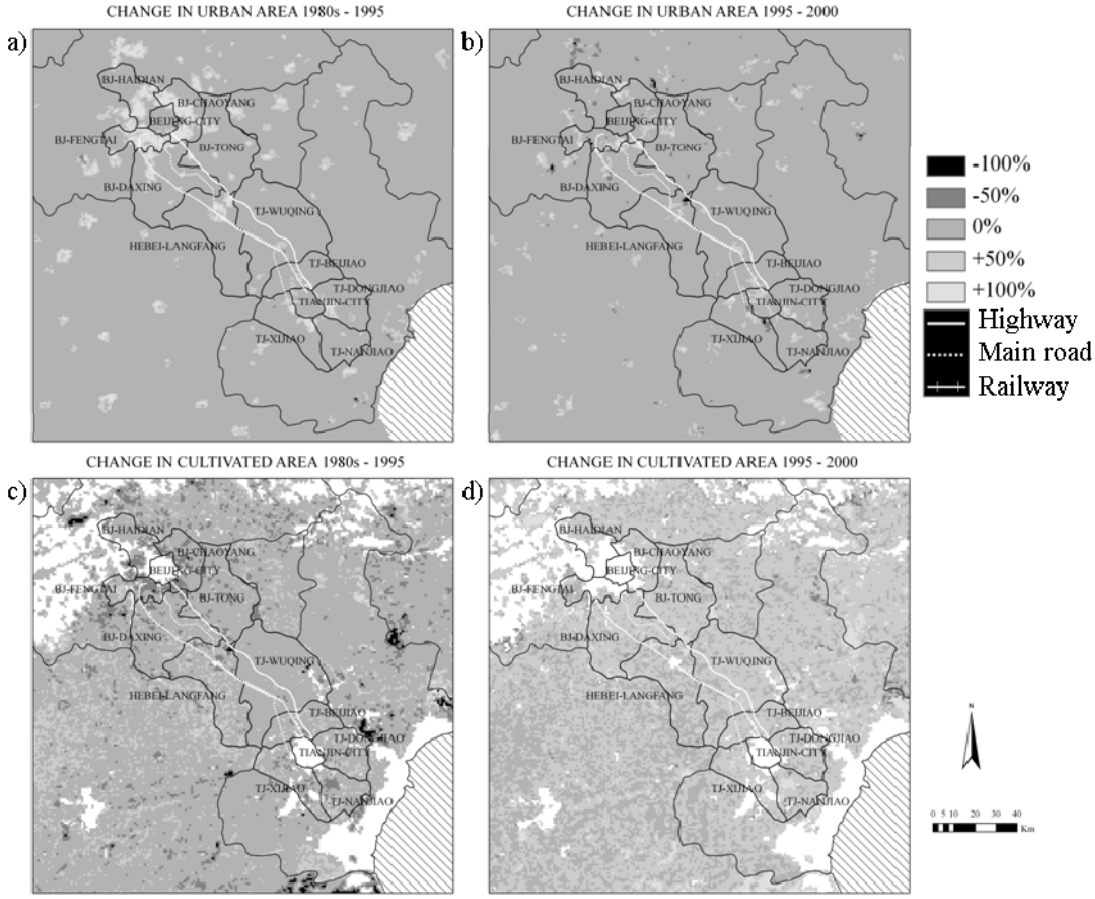

Figure 3: Change in urban and cultivated land area from the 1980s to 1995 and from 1995 to 2000

To illustrate the change pattern of urban and cultivated land, the data was reclassified into -100%, -50%, 0%, +50%, and +100% changes in land use. The results show that there is a strong relationship between urban land and existing urban centers. From the 1980s to 1995, there is an almost even belt of urban growth around Beijing City at a radius of about 6 to 17 km from the center (Forbidden City). Langfang City, which is situated roughly halfway between Beijing and Tianjin cities on the railway line, also has a belt of increase. But Tianjin City underwent much less urban growth than Beijing City, which took place mostly in Donjiao and Xijiao counties. The belt 1995 to 2000 around Beijing City is smaller, with much urban growth now located at an 8 to 14 km distance from the centre. Urban growth around Tianjin City was also less but there was increase in urban area within the city proper.

In concurrence with urban expansion, cultivated land decreased in the 1980s to 1995 in the three suburbs of Beijing City. In the rest of the study area however, the pattern of change in cultivated land seems clearly linked to administrative boundaries. Langfang County and the suburbs of Tianjin City display a pattern which is different to that of the other counties, with many 50% increases located inside their administrative boundaries in the 1980s to 1995 period. From 1995 to 2000, the difference remains visible, but with more no change grid cells in Langfang County and the suburbs of Tianjin whilst there seem to be many grid cells with increase in cultivated land in the other counties. By then, much cultivated land in the suburbs of Beijing has disappeared.

A further clear pattern is a cluster of cultivated land increase grid cells within 1-2 km from the 1980s to 1995, along a stretch where the Beijing Tianjin railway coincides with the main road between Beijing and Tianjin in Wuqing County (Fig. 3).

Land-use change amount distribution

The overall trend in land-use change in the study area from the 1980s to 2000 is that urban land almost doubled, increasing by 479 km^2, from 673 km^2 to 1,152 km^2. Almost all of the increase in urban area took place between the 1980s and 1995. Cultivated land on the other hand decreased overall by almost the same amount, by 494 km^2. However, it first decreased by 1,164 km^2 from the 1980s to 1995 but had increased again by 670 km^2 by 2000. The land-use change data revealed that 95% of the increase in urban area was from cultivated land and about 1% each from woodland, grassland and from water surfaces.

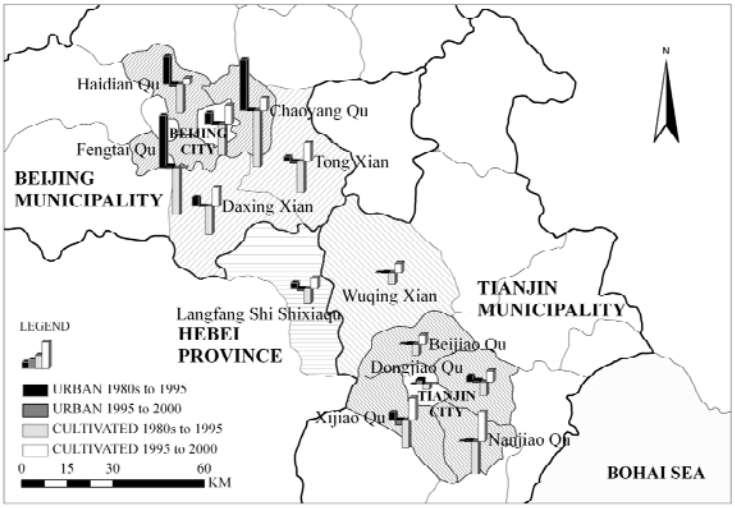

Figure 4: Land-use change as percentage of county area distribution in the study area

The trend in land-use change is different in Beijing and Tianjin municipalities and Hebei Province. Of the total amount of urban land in the study area from the 1980s to 2000, the percentage located in Beijing Municipality increased from 54% to 67% but decreased from 42% to 29% in Tianjin Municipality. In terms of cultivated land, Beijing and Tianjin Municipalities had roughly comparable amounts, 2,189 km^2 and 2,405 km^2 respectively in the 1980s, but by 2000, cultivated land had decreased by 403 km^2 in Beijing Municipality whereas in Tianjin Municipality it had only decreased by 66 km^2. However, the percentage of urban as well as cultivated land located in Langfang remained stable at around 4% and 16% respectively.

Of the overall increase in urban land, 65% took place in the suburbs of Beijing City and only 9% in the suburbs of Tianjin City from the 1980s to 1995. In the same time period in the outer counties of the study area, 17.5% of the overall increase in urban land was located in those belonging to Beijing Municipality, 8% in Langfang due to the growth of Langfang City, but only 0.4% in Wuqing, the outer county of Tianjin Municipality. In 1995 to 2000, the largest increase in urban area was by 1.4% in Dongjiao Suburb of Tianjin City, and urban land decreased in Haidian, Tong, Xijiao and Langfang.

In the suburbs of Beijing, cultivated land area decreased by approximately 50% in each suburb, due to urban expansion. But in the suburbs of Tianjin, although cultivated land area decreased in the first period, it increased again to a similar level as in the 1980s by 2000. In both outer counties of Beijing, cultivated land decreased by around 185 km^2 in the first period, and increased

by 120 km^2 in the second period. In Wuqing and Langfang however, the overall decrease in cultivated land was only 15 km^2 and 25 km^2 respectively.

Statistical analysis of the land-use change pattern

Statistical analysis was used to assess whether the qualitative pattern of land-use change found was significantly different in the 5 different groups of counties, namely Beijing suburbs, Tianjin suburbs, Beijing outer counties, Tianjin outer counties, and Langfang. Average land-use change per grid cell indicates the individual pattern of Beijing suburbs, whilst those of Tianjin suburbs and Beijing outer counties, and Tianjin outer counties and Langfang County seem more similar.

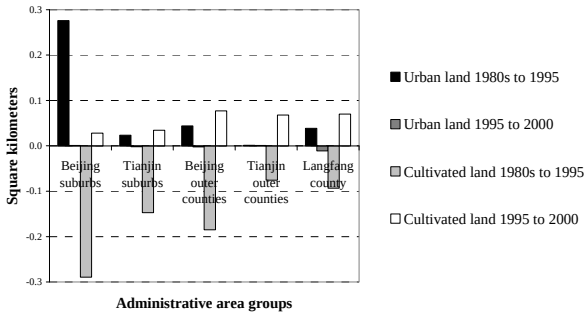

Figure 5: Average area of land-use change per grid cell (km^2)

Multiple comparison using Kruskall-Wallis test confirmed significant statistical difference ($p<0.05$) between the suburbs as well as the outer counties of Beijing and Tianjin and Langfang County from the 1980s to 1995 but not 1995 to 2000 in the outer counties and Langfang in terms of urban land ($p>0.05$). In terms of cultivated land, there was significant statistical difference in both periods. Mann-Whitney test showed that in terms of urban land, the suburbs of Beijing differed significantly ($p<0.05$) from the suburbs of Tianjin in both periods. However, the outer counties of Beijing and Tianjin and Langfang differed significantly in the 1980s to 1995, but not in 1995 to 2000 ($p>0.05$). In terms of cultivated land however there is significant difference between the suburbs of Beijing and Tianjin and the outer counties and Langfang in both periods.

Differences in scale of change

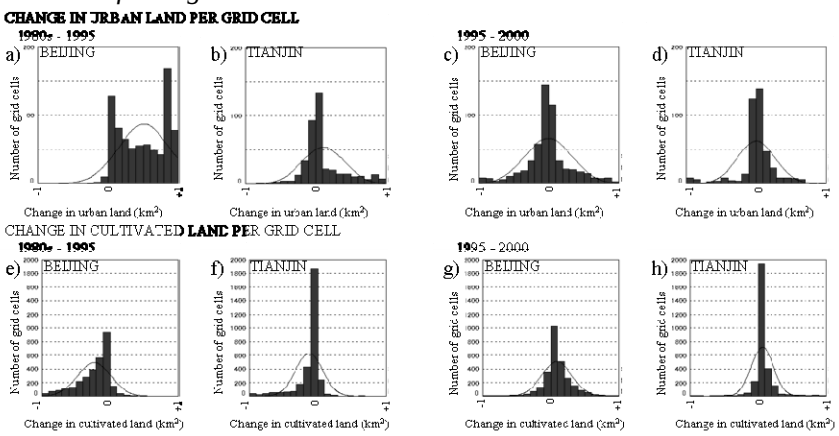

Figure 6: Area of land-use change per grid cell in urban land and cultivated land (km^2)

Histograms of the change in land use illustrate the difference between Beijing and Tianjin municipalities in greater detail. Most urban expansion took place between the 1980s and 1995 in Beijing Municipality, and took place predominantly in large parcels. In Tianjin Municipality on the other hand, urban expansion was much less and took place mostly in small parcels. From the

1980s to 1995, large increases in urban land by 0.9-1.0 km^2 took place in 202 grid cells in Beijing Municipality but only in 13 in Tianjin Municipality. However, from 1995 to 2000 urban expansion took place mostly in small plots in both municipalities. Furthermore, there are a number of large-scale decreases in urban land in both Beijing and Tianjin in 1995 to 2000. However in terms of change in cultivated land small-scale changes are dominant in both Beijing and Tianjin municipalities in both periods. Further, there seems to be some symmetry between decrease in cultivated land from the 1980s to 1995 and increase from 1995 to 2000 when comparing Figures 3e) with 3g) and 3f) with 3h).

Land-use change per grid cell

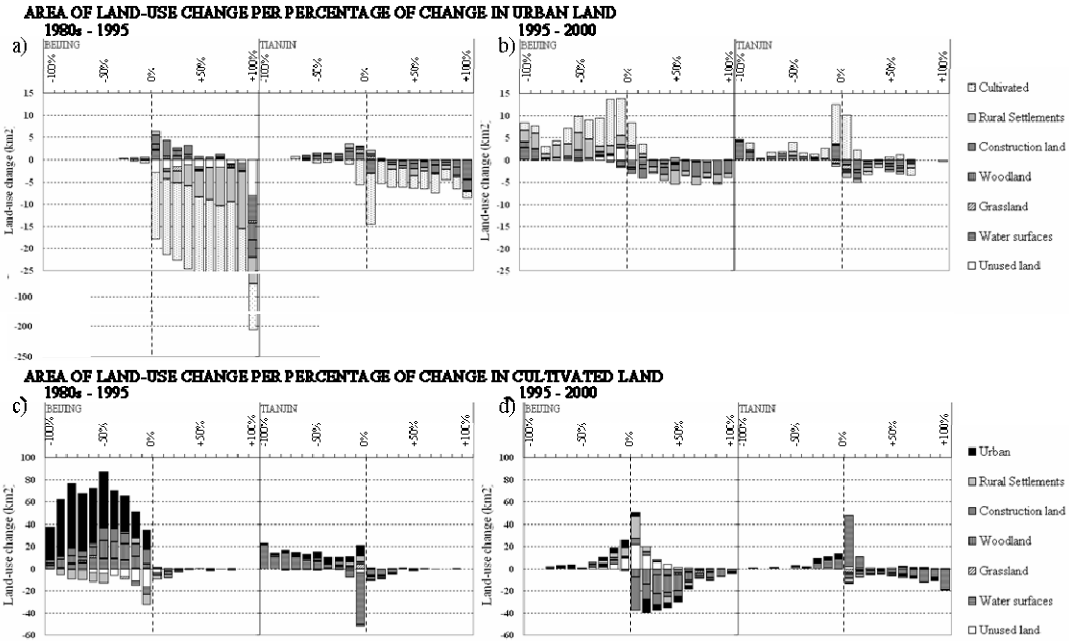

Figure 7: Area of land-use change per percentage of change in urban and cultivated land (km^2)

Grid cell-by-grid cell comparison of the different change patterns in Beijing and Tianjin municipalities revealed that from the 1980s to 1995, large-scale increases in urban area in Beijing were mainly correlated with decrease in cultivated land and rural settlements whereas in Tianjin large-scale increases were mainly correlated with a decrease in water surfaces. In both Beijing and Tianjin in the 1980s to 1995, small-scale increases in urban land were mainly correlated with decrease in cultivated land area. In 1995 to 2000 in Beijing, increases in urban land were correlated with decrease mainly in construction land and small-scale increases with increase in cultivated land. In Tianjin in the same period, small-scale increases were also mainly correlated with increase in cultivated land. Both in Beijing and Tianjin municipalities, large-scale decreases in urban land were associated mainly with increase in water surfaces in 1995 to 2000.

In Beijing Municipality from the 1980s to 1995, cultivated land decreases were correlated mostly with increase in urban land as well as increase in construction and woodland and water surfaces and decrease in rural settlements and unused land. From 1995 to 2000, small scale cultivated land increases in Beijing Municipality were correlated with increase in rural settlements and unused land as well as decrease mainly in construction land. However in the 1980s to 1995, small-scale decreases in cultivated land were mainly correlated with decrease in water surfaces and large-scale decrease were mainly correlated with increase in water surfaces. In 1995 to 2000, the opposite is true where small-scale increases in cultivated land are correlated mainly with increase

in water surfaces and large-scale increases are mainly correlated with decrease in water surfaces. Further, there is a strong symmetry between the land-use change in terms of cultivated land within Beijing as well as within Tianjin if urban land is discounted (Fig. 7c) and 7d)). In 1995 to 2000, Beijing did not have any large-scale increases in cultivated land.

Discussion

Figure 8: Wheat fields with small vegetable plots; rice fields; vegetables in rural house courtyard

The study confirms that urban expansion causes cultivated land loss. However, as the patterns for urban and cultivated land only partially overlap, it is suggested that urban expansion causes cultivated land loss directly, as when comparing the surrounds of Beijing City in Figures 3a) and 3b), but also indirectly, as shown by the correlation of cultivated land-use change with administrative boundaries. In China, urban land is owned by the State whereas farmland is mainly collectively owned[5)]. Thus, the State has strong influence on urban land increase. Previous studies have shown that the built-up area of Beijing City expanded in different directions in different time periods[6)11)14)23)] and that Beijing's development resembles that of cities in a free market economy, whereby urban expansion is related to distance from the city centre[6)]. The almost even belt of urban area increase around Beijing City observed in Figure 3a) suggests strong market forces. This pattern is observed less in Tianjin. Urban and rural land is administered by different ministries, causing conflict, and in the top-down land administration system[26)] agricultural production bases in order to ensure food supply[20)] must be designated by counties in accordance with provincial farmland protection plans[5)]. After Economic Reforms in 1978, massive urban growth caused cultivated land loss[8)19)24)], but after 1994, the conversion of agricultural land into urban land was strictly controlled[10)]. Thus in the study area, cultivated land decreased in the first period due to urban growth and increased in the second period as a result of the 1994 Ordinance for Primary Farmland Protection, as indicated by the large-scale pattern.

More detailed study of the indirect impact of urban expansion on cultivated land loss revealed further significant difference between Beijing and Tianjin municipalities and Langfang (Fig. 5). Beijing City is larger and underwent more growth in the 1980s to 1995 that spilled over into its suburbs and even outer counties (Fig. 3 and 4), consuming cultivated land and rural settlements in large parcels (Fig. 7a)). But in Tianjin the rate of urbanization was much slower[14)21)] (Fig. 4) and smaller in scale (Fig. 6). The predominance of small-scale changes in cultivated land (Fig. 8) suggests local responses by farmers in rural communities to government policies and market forces. After 1949, agricultural production and farmer initiative had decreased[19)], which the State intended to boost by implementing the Household Responsibility Production System in 1978, enabling farmers to sell surplus crops at a profit[20)28)]. This coincided with increased demand for fresh food such as vegetables in the increasingly wealthy cities[14)], causing an increase in farmland[1)]. Chinese statistical yearbooks confirm that in 1990 to 1995 in Beijing's suburbs, cultivated area decreased, but in the outer counties of Beijing and suburbs of Tianjin vegetable sown area as much as doubled, and increased in Wuqing from 53 km^2 to 245 km^2. The increase in cultivated land along transport arteries (Fig. 3c)) concurs with increase in villages, and is thought

to represent cash-crop production with good market access. However, in the initial 'gold rush' after Economic Reforms, city jobs were more profitable than agriculture, leading to further cultivated land decrease (Fig. 4), including farmland abandonment[2]. The development of rural industry as an important part of Rural Reforms[2], especially around Beijing[20], also had a major impact[25] leading to cultivated land fragmentation[11], degradation and loss[16][20].

After 1995 the urbanization rate decreased (Fig. 4) and Beijing and Tianjin outer counties and Langfang became statistically similar in terms of urban land. The decrease in urban land observed (Fig. 4) is thought to result mostly from land assigned to urban development being reassigned to rural land, as it is difficult to convert built-up area back to agricultural use. In Beijing the decrease in urban land was correlated with increase in village area, thus some villages may have reverted to their original status. In terms of cultivated land, the planned economy continues to influence rural areas[20]. But the impact of the 1994 Ordinance may have differed as the suburbs of Tianjin regained almost former levels of cultivated land despite small increases in urban land, but the outer counties of Beijing did not regain former levels despite also only small relative increase in urban land. It may be more difficult to increase cultivated land in more fragmented and degraded areas, such as the surrounds of Beijing, despite market forces. Further, Langfang lost much less cultivated land despite the growth of Langfang City (Fig. 4). Villages increased around Beijing in the second period, but a far greater number vanished in the first period (Fig. 7). Farmers traditionally cultivate land around villages, and the absence of villages may be connected to less increase in farmland. In addition, in the change in status from rural to urban in China farmers obtain the right to urban employment, and no longer engage in agriculture[7].

The combination of the predominance in small scale changes (Fig. 8) and the symmetry in the change patterns (Fig. 6 and 7) may suggest that local responses occurred *in situ*. Farmers remained administratively bound to rural areas[7], but rising life quality expectations may have caused gain by additional profit from the land. The 1994 Ordinance may have added incentive, so that cultivated land increase may have occurred as a joint result of State influence as well as the Household Responsibility Production System coming into fuller effect. However, increasingly farmers no longer depend on agriculture[20]. Cultivated area along the same section of the transport arteries mentioned above increased further in the second period (Fig. 3d)), but correlation between cultivated land increase and increase in villages was only found in Beijing Municipality (Fig. 7d)). Prior to 1978, vegetable grown area in Beijing City was substantial and the municipality was 86% self-sufficient[15]. However, after 1995 increase in vegetable sown area in the counties of the study area in Beijing was only marginal and now over half of Beijing City's vegetable supply is from Hebei and other provinces[14], whilst it was substantial in Tianjin's suburbs and increased to 329 km^2 in Wuqing (Chinese Statistical Yearbook). Tianjin Municipality had an overall lesser decrease than Beijing in villages, preserving the assumed precondition for cultivated land increase. Further, in Tianjin Municipality, change in cultivated land seems strongly correlated with change in water surfaces (Fig. 7c) and d)). This may be explained by the many rice paddy fields in the Tianjin region, which are often irrigated by a pond which is also used for fish farming. The association of change in water surfaces with very large-scale changes in cultivated land may be a separate phenomenon, such as large-scale aquaculture or reservoirs. The Beijing Tianjin region faces severe water shortages[15][21] and the allocation of water resources is becoming increasingly important not only in this intensively cultivated region. In Tianjin, much attention has been devoted to the economic growth of the coastal Economic Development Area[21] and less to the city proper and rural areas. Also, so far, detailed planning only exists for the city proper[26], and little attention has been paid to the implementation of farmland protection policies at the local level[16]. In city regions with urban growth across several administrative boundaries, new challenges for regional planning are implied[29].

Conclusion and outlook

This study suggests that it is important for sustainable urban-rural development in city regions in China that planners pay increased attention to land-use change at a detailed scale. More detailed scale analysis, for example by interview-survey and high-resolution land-use change pattern analysis by Geographic Information Systems, and especially in Tianjin, which has been studied less, is needed in order to increase understanding of the dynamics of land-use change at the local level and clarify to which degree market forces and State policies influence land-use change.

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