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Based on digital land use data from 1995 to 2000 and road data, the land use and landscape changes of Golmud, Qumaleb and Zhidoi are studied on a macro-scale. Land use and landscape changes in highway buffer zones and city expansion are special subjects. A new formula is used to define the exact degree of dynamic land use. To adequately define land use and landscape pattern changes, the buffer zones, illustrating the changes at different distances from the road, are recognized with ArcGIS 8.1 software. Prominent changes took place in land use and landscape patterns from 1995 to 2000, and the area of built-up land increased by 323.8%. The comprehensive degree of dynamic land use is 2.25, and the degree of dynamic land use of built-up land is the highest, followed by cultivated land. Woodland has the lowest value. The used degree index of land resources declined by 38.8 from 1995 to 2000. Landscape changed dramatically which influenced ecological processes immensely. Different from the corridor effect of other traffic routes, the corridor effect of this section of road is not obvious and its "point" radiation effect can be easily seen. The expanding range of Golmud City is confined to a 3 km buffer, while for Wudaoliang, it is 1 km. No land use change happened in the Nanshankou buffer.

Land use and landscape pattern change: a linkage to the construction of the Qinghai-Xizang Highway YAN Jianzhong1,3, ZHANG Yili1, LIU Linshan1, LIU Yanhua2, ZHENG Du1 (1. Inst. of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China; 2. The Ministry of Science and Technology, Beijing 100101, China; 3. College of Resources and Environment, Southwest Agricultural University, Chongqing 400716, China) Abstract: Based on digital land use data from 1995 to 2000 and road data, the land use and landscape changes of Golmud, Qumaleb and Zhidoi are studied on a macro-scale. Land use and landscape changes in highway buffer zones and city expansion are special subjects. A new formula is used to define the exact degree of dynamic land use. To adequately define land use and landscape pattern changes, the buffer zones, illustrating the changes at different distances from the road, are recognized with ArcGIS 8.1 software. Prominent changes took place in land use and landscape patterns from 1995 to 2000, and the area of built-up land increased by 323.8%. The comprehensive degree of dynamic land use is 2.25, and the degree of dynamic land use of built-up land is the highest, followed by cultivated land. Woodland has the lowest value. The used degree index of land resources declined by 38.8 from 1995 to 2000. Landscape changed dramatically which influenced ecological processes immensely. Different from the corridor effect of other traffic routes, the corridor effect of this section of road is not obvious and its "point" radiation effect can be easily seen. The expanding range of Golmud City is confined to a 3 km buffer, while for Wudaoliang, it is 1 km. No land use change happened in the Nanshankou buffer. Key words: land use change; comprehensive index of the degree of land use; diagnostic index of landscape; degree of dynamic land use; Qinghai-Xizang Highway CLC number: F301.24 1 Introduction In the extensive studies on LUCC, land use change in traffic route buffers has attracted more attentions. As the main driving force in corridors, traffic routes have ecological effects on different scales. In recent years, studies on the ecological effects of highways and trunk railways showed that: 1) they destroyed the habitat of wildlife and also affected the spread and transfer of species (Forman, 1998; Thierry Lode, 2000; Tove Hels, Erik Buchwald, 2001; Delgado Juan D et al, 2001; Tikka et al., 2001); 2) they created pollution of various kinds: solids, liquids, gases and noise as well as natural calamities such as landslides, which endanger the health of ecological systems (Lovich and Bainbridge, 1999; Eaton, 1999; Malawska et al., 2001; Finder, 1999; Zhang and Chen, 2000; Jiang and Du, 2000); 3) they changed the landscape pattern and ecological proc esses on different scales, which caused landscape fragmentation (H D van Bohemen, 1998; Daniel B Tinker et al., 1998; Borrego et al., 2000; Hubert Gulinck and Tim Wagendorp, 2002); and 4) they served as the expanding corridor of cities and towns in which cultivated land was quickly transformed into built-up land (Liu et al., 2000; Yu, 2001; Chen et al., 2000; Zhu et al., 2001; Long and Li, 2001; Zhang et al., 2002). Almost all these studies referred to were carried out in small areas without complex physical geographical conditions. In these studies, the ecological effects of highways involved only the highway itself or its fringes, while places more distant from it did not receive sufficient attentions. The Qinghai-Xizang (Tibet) Highway is located in a fragile ecological environment and has complex physical geographical conditions. The causes of desertification in Golmud on the Qinghai-Xizang Plateau and in the source region of the Yellow River have been studied in recent years, and results indicated that there were not only natural factors such as a rising temperature, a reduction in precipitation, an increase in evaporation, etc., but also human factors, such as overgrazing, excessively timber cutting and digging (Zhao et al., 1997; Wei, 1998; Sha et al., 2001; Dong, 1999; Bai et al., 2002). The land use change along the Qinghai-Xizang Highway had not been studied systematically. It is not clear how the Qinghai-Xizang Highway, as a corridor, drives the land use change and what is the scope of the influenced area as well as the influence mechanism. This paper took Golmud, Qumaleb and Zhidoi counties as a study area, using GIS software and ecological methods to investigate the land use and landscape pattern change from 1995-2000 on a macro-scale, and emphasized on the land use and landscape changes in buffer zones and land use change in city buffer zones. It will offer a scientific basis for the study of the influence degree of the Qinghai-Xizang Highway upon the land use changes in the 3 counties and the environmental process and mechanism, and the appraisal of construction and operation of traffic routes on the Qinghai-Xizang Plateau, especially for the second section of the Qinghai-Xizang Railway. 2 Study area and method 2.1 Study area The study area extends from 32o45´N to 37o45´N and 89o25´E to 97o18´E, consisting of Golmud, Qumaleb and Zhidoi counties in west Qinghai Province. The total area is about 24×104 km2. In 1995, the total population of the study area was 1.25×105, and the GDP was 9.8×108 yuan (RMB), while the population in 2000 was 1.4×105, and the GDP was 1.84×109 yuan. The study area, with a complex terrain, is the source area of the Yangtze and Yellow rivers. Topographically it is high in the north, descending from the west to the east. It is also the main part of the Qinghai-Xizang Plateau, surrounded by the mountains in west Sichuan Province, the Hengduan Mountains, the Qiangtang Plateau, Altun Mountains, dominated mainly by Bayan Har Mountains, Burhan Budai Mountains, and Tanggula Mountain Range which spread from east to west. The study area is categorized into 3 parts (Zheng, 1996; Sun, 1996). The plateau´s temperate arid section (IID) includes a part of the Qaidam Basin and the northern part of middle Kunlun Mountains with altitudes ranging from 2,600 m to 3,300 m, where the terrain and relief distribute in a pattern of concentric circles. The landscape is composed of high mountains, desert, wind-eroded hills and grass swales from the edge to the center in the basin. There are many salt lakes and wetlands in the lowest part of the flat swale, caused by inadequate drainage. The whole basin is slanted slightly from northwest to southeast. There is almost no vegetation in the center of the basin. The vegetation on the fringe of the basin is mostly bulrush, Phragmites communis, and Tamarix (Sun, 1996). The area is controlled by a continental climate having characters of aridity, long hours of sunlight, strong solar radiation, high evaporation, low air pressure, excessive gale, frost, sandstorms and hails. Winter is long and cold, and summer is cool and short. The difference in temperature between day and night is large (Zhou et al., 1987). The growth period is 189 days for crops, and is 211 days for grasses. The plateau´s sub-frigid semi-arid section (IC) mainly covers the open valley of the headstreams of the Tongtian River, including the open valley and lake basin of headstreams of Yellow River and Qiangtang Plateau, with an elevation of 4,000-5,000 m. The vegetation mainly consists of Stipa purpurea, Stipa basiplumosa, Carex moorcroftii, and Ceratoides compacta, with a little Kobresia pygmaea and some high mountain species. The climate is very cold because of the Himalayas, which prevent the southwest monsoon coming to the plateau from the Indian Ocean. There are only winter and summer seasons in a year. The winter season lasts about 7-8 months, while the summer season is short and cool. The growth season is 37-63 days for crops and is 89-114 days for grasses. The plateau´s sub-frigid semi-humid section (IB) is mainly located near the county towns of Qumaleb and Zhidoi, in the Golog-Yushu Plateau´s open valley and the Nagqu-Damqu headstreams open valley, with an average elevation of 4,000 m, and has good moisture conditions. The vegetation in this section mainly consists of high cold Communis, Kobresia pygmaea and some Stipa purpurea. The annual average temperature in this section is -2oC, precipitation is 407-411 mm, evaporation is 1369-1406 mm, crop growth season is 83-92 days, and grass growth season is 133-145 days. 2.2 Data The Resources and Environment Data Center of the Institute of Geographic Sciences and Natural Resources Research of CAS provided the 1:100,000 digital land use data (1995 and 2000) of the 3 counties and the 1:250,000 digital road data of the Qinghai-Xizang Highway. The 1:100,000 digital land use data are interpreted from the TM images of 1995 and 2000. The land use is classified into 3 levels (Liu, 1

996). The first level has 6 types: cultivated land, woodland, grassland, water area, built-up land (city, town and ot her residential area) and unused land, based on the attribute of land use. The second level has 28 sub-types and the third level has 8 types, which are mainly based on the terrain style of cultivated land. The storage format of the di gital map is coverage of every county, and the treatment software used is ArcGIS 8.1. The statistics referred to the second level and the sum indicated the first level. The sum of patch is 27,809 in 1995 and 19,808 in 2000. The 1:25 0,000 road data were digitalized manually on the 1:250,000 topographic map of the National Survey Service. 2.3 Study method The 1995 and 2000 coverage of the three counties were appended, and the two new coverage were overlain, land a rea being summed by attribute query, building a land use transformation matrix. Degree of dynamic land use is used t o indicate the rate of land use change and comprehensive index of degree of land use is used to indicate the land us e temporo-spatial pattern of the study area (Chen and Yang, 2001; Luo and Ni, 2000; Zhuang and Liu, 1997). The diagno stic indexes of landscape pattern such as fractal dimension, diversity index, dominant degree and fragmentation degre e are used to mirror the influence of land use change upon landscape pattern (Zhang, 2000). To find the role the Qing hai-Xizang Highway playing on land use change in the study area, the digital road map is joined, and a coverage of th e Qinghai-Xizang Highway is extracted to create a series of buffers. One type of buffer is created every 1 km at a di stance of 15 km from the road, while the other type of buffer is created every 5 km from 15 km to 50 km, and a final 60 km buffer is also created. Because buffers only show the average rate of land use change, a buffer zone is create d by erasing the adjacent buffer, referencing the theory of "route evaluation" in urban real estate appraisal, to det ermine the different land use changes of different distances to the road. Buffer zones distributed on each side of th e road, the width of which was 2 km in the 1 km to 15 km buffer zones and enlarged to 10 km in the 15 km to 50 km buf fer zones, and finally 20 km in the last zone. The buffer zones were overlain with the land use change map to create the land use change matrix of each buffer zone by attribute inquiry, and the land use change and landscape pattern in dexes were calculated. The built-up land coverage of Golmud, Qumaleb and Zhidoi was extracted, and the buffer zones w ere generated to illustrate the impact on land use change of built-up land. The buffer zones were overlain with the l and use change map, and the comprehensive deree of dynamic land use and the degree of dynamic land use were calculate d. 2.4 Index and implication 2.4.1 The used degree index of land resources comes from the study of Liu Jiyuan: 2.4.2 The diagnostic indexes of the landscape pattern and its ecological implication: 3 Land use change and landscape patte rn change of the study area 3.1 Land use change of the study area (1) Woodland had a net increase by 0.4%. The area c hanged from other land use types to woodland was 1,715.96 ha, while the area changed from woodland to other land use types was 2,310.02 ha. Woodland change occurred mostly in east Golmud. Shrub was added by 1,063.02 ha, and the spars e woodland was reduced by 449.76 ha (Tables 1-2 and Figure 2). The rest of the woodland had little change. (2) Grassl and was reduced by 6.26%. The area altered from other land use types to grassland was 1,017,891.94 ha and the area tr ansformed from grassland to other land use type was 224,200.4 ha. The change of grassland mostly occurred in Qumaleb County, in which 7.76% of the grassland was transformed into unused land and 0.24% was transformed into water area. T he main kind of land changed into grassland was unused land. Densely covered grassland increased by 245,714.1 ha, med ium covered grassland decreased by 211,749 ha, and sparsely covered grassland decreased by 797,635 ha. (3) Water are a increased by 7.17%. If bottomland is considered as unused land, water area only increased by 18,431.59 ha, about 1.3% of the total water area. 21,457.4 ha of water area were transformed into other land use types, mainly grassland and unused land, while 122,377.09 ha of other land use types were transformed into water area. Water area change most ly occurred in Golmud County. The river and trench area increased by 908.86 ha, the lake area increased by 19,503 h a, and they were transformed from grassland and unused land in desolate areas of Golmud and Zhidoi counties. Reservoi r and pond area was reduced by 1,232.67 ha, permanent glacier and snow-covered land area were reduced by 810 ha and c hanged into grassland and high cold tundra. Bottomland area increased by 82,488.1 ha, mainly comes from sparsely cove red grassland, sandy land and desert. (4) The transformation, occurring mainly near the cities and towns, was from bu ilt-up land into other land. The area of land which was changed into other uses from the built-up areas is 190.47 h a. The area changed from other land into built-up land was 13,320.31 ha. The area of built-up land increased by 32 3.8% in 5 years. The area of cities and towns increased by 978.87 ha, the area of rural inhabitant increased by 359.7 5 ha, the area of other built-up land increased by 11,790.23 ha. (5) The transformed area from other land use type, m ainly grassland, into unused land was 993307.37 ha, while during the same period, 307,043.5 ha of unused land were tr ansformed into other land use types. So in 2000 unused land area increased 6.96%. Sandy land was reduced by 307,04 3.5 ha, the desert was increased by 80,785 ha, salt and alkali land was reduced by 10,524 ha, swampland was reduced b y 49,364.9 ha, naked land was reduced by 99.6% and only 90.19 ha was remained unchanged. Rock land was increased by 1 20,332 ha, mainly comes from medium and sparsely covered grasslands. The other unused land was increased by 554,995 h

a, coming mainly rom poorly covered grassland. (6) The area transformed from cultivated land to other land use types was 8,203 ha, and the area changed from other land use types to cultivated land was 987.07 ha. The cultivated area was reduced by 51.43%, of which 7,326.64 ha were used as built-up land. (7) The comprehensive degree of dynamic land use is 2.25. The degree of dynamic land use built-up land ranked the highest, while cultivated land was the second, and woodland ranked the last. As for area changed, unused land was 1,300,350.9 ha, grassland 1,242,092.30 ha, water area 143,834.50 ha, built-up land 13,510.78 ha, cultivated land 9,190.07 ha, and woodland 4,025.98 ha. (8) The used degree index of land resources was 195.2 in 1995 and 156.4 in 2000. The underlying reason for the change was that a large area of grassland was transformed into unused land. 3.2 Change of landscape pattern (1) Total number of patches was increased 1999, and landscape fragmentation index (C) was increased from 0.115 to 0.124. The basic reason for the increase of the fragmentation index for cultivated land was that a large area of cultivated land was transformed for construction while a small area of grassland and unused land were cultivated (Table 3). The fragmentation index of woodland and grassland grew slightly while that of unused land remained steady, and that of water area decreased. The built-up land was expanded so the index of built-up land was decreased greatly. The increase of grassland will reduce the habitat quality of wildlife propagation and influence biodiversity. (2) The diversity index (H) was changed from 1.308 to 1.331. The proportion of grassland was decreased and that of unused land, water area, and built-up land was increased. The heterogeneity of the landscape increased accordingly which indicated an increase of natural disturbance and human activity. (3) The fractal dimension rose from 1.453 to 1.456 because the inter-transformation of water area, grassland and unused land was made the shape of patches more complicated. The fractal dimension of woodland and water area did not change while that of grassland, unused land and cultivated land was increased, and that of built-up land was decreased. The reason for the change was that a large amount of grassland and unused land was increased and cultivated land was decreased. The newly cultivated land area is small. (4) The landscape domination degree of woodland remained stable and that of grassland decreased significantly.The domination degree of built-up land and unused land was increased. It showed two major directions of land use changes: one was cultivated land being transformed into built-up land, which resulted in the increase of artificial landscape, the other was grassland and other land being transformed into unused land, which resulted in the increase of the primary landscape. The primary change is the increase of unused land resulted from desertification. (5) The landscape change in Golmud, Qumaleb and Zhidoi counties will profoundly change ecological processes and influence the development of stock raising and the survival of wildlives. Ultimately, it will influence the water supply at the upper reaches of the Yangtze, Yellow and Lancang rivers.
4 Land use change in the Qinghai-Xizang Highway buffer zones 4.1 Change of the used degree index of land resources Except for the 1 km, 40-45 km and 50-60 km buffer zones, due to the huge increase of built-up land area, the used degree index of land resources of other buffer zones decreased. 4.2 Comprehensive degree of dynamic land use of highway buffer zones It was proven that land use changes become more obvious in places near the railway. Such phenomenon an also be found in semi-urban area (Mashan District) land use changes and expansion of Beijing urban area(Chen et al., 2000; Zhu et al., 2001). The law of changing of comprehensive degree of dynamic land use in this study area differed from the above three areas. The index rose from the 1 km buffer zone to the 5 km buffer zone, then has vibrated a little around the 6-24 km buffer zone and rose a little from 25 km to 45 km until the huge vibration from 46 km to 60 km (Figure 4). It fell in the last buffer zone. The concentration and radiation effect of traffic routes are always defined by physical and socio-economic conditions. The effects are the largest in the area with good conditions, and the land use change, especially the change of cultivated land and built-up land, developed a corridor attenuating with increasing distance, as does the comprehensive degree of dynamic land use (Zhu et al., 2001). In undeveloped regions, the corridor effect just manifested itself near towns and cities and the change of cultivated and built-up land had the spot-shaped pattern, with little impact on land use change. The population density of the three counties was low; the population density in Golmud, Qumaleb and Zhidoi in 1995 was 0.68 people/km2, 51 people/km2, 0.26 people/km2 respectively and in 2000, it was 0.78 people/km2, 0.55 people/km2, 0.29 people/km2 respectively. Severe physical conditions, passing through of traffic, little artificial disturbance and other reasons shape the small contribution to the land use change of the buffer zones. 4.3 Degree of dynamic land use of each land use type in highway buffer zones Figures 7 and 8 show the relationship between the degree of dynamic land use and the distance to the road. The focus is on the degree of dynamic land use of the 40 km buffer zone because there is little cultivated and built-up land, the smallest change of which will generate a great change of the degree of dynamic land use. The indices for grassland, water area and unused land have the same trend, increasing with distance. The indices of cultivated land, built-up land and woodland have the same trend, decreasing with the distance, so the effect of the traffic route is manifested. The proportion of woodland, cultivated land and built-up land is small and the three types of land are distributed in

the eastern portion of the study area. From Figure 2, the spot-shaped effect of the Qinghai-Xizang Highway is very obvious. 4.4 Change of diagnostic indices of landscape pattern Although the diagnostic indexes of landscape pattern having no comparison, due to the fact that the patches are divided by buffer zones, the index of the same buffer zone in two moments has comparison. Table 4 shows the increase of the fractal dimension, diversity index and fragmentation degree. The change of the fractal dimension and diversity index is small. The change of the fragmentation degree in the range of the 15 km buffer zone occurred more frequently than which exceeds 15 km buffer zone due to the fact that the width on each side of the first 15 buffer zones is 1 km, while the other zones have the width of 5 km or 10 km. All together, the change of the landscape has no direct relationship with the distance to the road. On a large scale, the highway did not cause a notable change in the landscape of the buffer zones. 5 Land use change in city buffer zones 5.1 Land use change in Golmud Eight buffer zones were generated and the width of each buffer zone was 1 km. There was little change in land area as the distance to the city increased and the comprehensive degree of dynamic land use decreased (Figures 7 and 8). Expansion of built-up land occurred mostly in the 1 km buffer zone, increasing by 1,061.18 ha. The change of cultivated land was the same as that of built-up land because built-up land was mainly transformed from cultivated land. The degree of dynamic land use of woodland, grassland and unused land was similar. The expansion of Golmud was confined to 3 km. 5.2 Land use change in Nanshankou No land use change happened in the 5 buffer zones in Nanshankou from 1995 to 2000. 5.3 Land use change in Wudaoliang In the 1 km buffer zone, the built-up land was increased by 37.58 ha and the water area was increased by 2.62 ha. In other buffer zones, the water area was increased a little. The main land use change was desertification of grasslands and the desertified area was increased with the increasing distance from the highway. The extension of built-up land was confined to 1 km. 6 Discussion and perspectives (1) The formula of degree of dynamic land use is amended as K = × ×100%, which can clearly manifest land use change. Buffer zones are created by GIS to illustrate land use change at different distances from the highway because buffer only reflects the average rate of land use change. (2) From 1995 to 2000, woodland was increased by 0.45%; water area was increased by 7.16%; unused land was increased 6.96%; built-up land was increased by 323.8%; grassland was decreased by 6.3%; and cultivated land was decreased by 51.4%. The main changes in land use were in the grassland, which was transformed into unused land, as well as the increase of built-up land and the reduction of cultivated land. The change of woodland and cultivated land occurred near Golmud; and the change of grassland, water area and unused land occurred in Qumaleb; the change of built-up land mainly occurred at the fringes of cities and towns. Land use change caused fragmentation, which resulted in the increase of fractal dimension, dominant degree and diversity index, and the used degree index of land resources was reduced by 38.8. (3) Land use change and landscape pattern change in the buffer zones of the Qinghai-Xizang highway was studied on a macro-scale. (a) The used degree index of land resources in 3 buffer zones rose while other buffer zones fell. (b) The comprehensive degree of dynamic land use of buffer zone decreased with the increase of distance from the road. (c) The degree of dynamic land use of grassland, water area and unused land increased with the distance from the road while the degree of dynamic land use of built-up land, woodland and cultivated land underwent the reverse change. The proportion of woodland, cultivated land and built-up land was small and was only distributed to the east of Golmud. (d) The change of the fractal dimension and diversity index have no direct relationship with the distance to the road. (4) The radiation and concentration role of the Qinghai-Xizang Highway to the study area is spotty. The study shows that, obviously different from other traffic routes, the Qinghai-Xizang Highway has spotty influence on the study area. The study of spot buffers of Golmud, Wudaoliang and Nanshankou showed that the expansion of Golmud was defined in 3 km, Nanshankou had no land use change, and the expansion of Wudaoliang was confined to 1 km. It also showed that the influence of the Qinghai-Xizang Highway is spotty. (5) The study used only the land use data of 1995 and 2000, without considering the change of climate or socio-economic conditions. To study the land use change along the Qinghai-Xizang Highway and Qinghai-Xizang Railway more deeply, we plan to extend the study period as well as study area and probe the relationship of the change of climate, socio-economic condition and land use change along the route, and to study the landscape change on different scales. References

关键词： land use change; comprehensive index of the degree of land use; diagnostic index of landscape; degree of dynamic land use; Qinghai-Xizang Highway