地理学报(英文版) 2001年第11卷第3期

Soil quality and sustainable land use in urban-rural marginal area: a case study of Kaifeng

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Abstract: By using the basic theories of physical geography, land resources and ecology, this article analyzes the soil quality of the rural-urban marginal area in Kaifeng. Computer techniques, based on soil samples analysis, are used to study soil quality changes in the Kaifeng´s rural-urban marginal area. While focusing on nutrient circle key links of input and output in soil, relying on numerous practical survey data, this article reveals clearly the impact of land use change on soil quality.

1 The characteristic of soil quality change in urban-rural marginal area Located in the central-western part of the North China Plain, Kaifeng, a midium-sized city in China, is one of the famous ancient capital cities. It covers an urban area of 61.4 km2 with a population of 620,000. The urban-rural marginal area of Kaifeng is defined as a suburban area surrounding it, approximately covering an area of 388.9 km2 and having a population of 210,000. Most soils of this area belong to Aquic Cambisols because they were affected repeatedly by over-flows and sand distribution dynamics of the Yellow River flooding. These soils are still in young-developing stage even through several decades´ cultivation and maturity[6]. According to previous Chinese Soil Taxonomy, these soils could be divided into saline-alkali soil and aeolian soil 50 years ago. However, they have decreased greatly in area nowadays after several transformations. Now, they are only sporadically distributed along the benchland of the Yellow River and the southwestern part of the marginal area (Figure 1). Compared with other areas, the amerlioration and evolution of the soil quality in the marginal area have distinctive regional features. 1.1 To improve saline-alkali soil and aeolian soil by warping with silt-laden Yellow River water To improve the quality of saline-alkali soil and aeolian soil by warping with highly silt-laden Yellow River water is a unique way adopted locally along the river bank. By doing so, it can not only alter the properties of the original soil thoroughly but also change the previous land use pattern completely. In the marginal area, the improved soil by warping in the past dozens of years covers an area of approximate 6,700 ha, accounting for 1/4 of the total soil acreage. The cultivation patterns of this kind are also quite different due to the variation of the thickness and quality of silt. When the thickness exceeds 50 cm, soil quality generally reaches the best level and gets effective warping. Hence, two crops per year by rotating rice and wheat with Yellow River water can be practiced. Simultaneously, when silt thickness is less than 30 cm, soil quality is relatively low, where peanut could be grown once a year. However, silt-up soils will have salt accumulated in the surface partially when sustained drought occurs, for they are at the initial stage of soil forming and their cultivating courses are short. Moreover, the ripening level of the tillage layer is also low and often lumpy and its lower sandy layer or sanilized layer is always parted from the top silted soil clearly. The topsoil will become sticky when mixed with water. 1.2 To improve sandy loam soil by planting rice with Yellow River water Based on the fact of high salt content and sandy texture of the soil, Kaifeng´s marginal area has vigorously developed rice production by planting rice on silted-up land since the late 1950s. After the high silt contained Yellow River was used to irrigate paddy field, the ground level rose by several centimeters one year. Contrarily, the ground water table declined. In this case, paddy soil can be desanilized by flooding or leaching. Therefore, soil salt in tillage layer can be held in winter and spring. In other words, sandy soil was improved through this method of warping. At the same time, the single sparse rice planting practiced in the springs of the 1950s has been shifted to nowadays´ intensive irrigated rice-wheat rotation pattern, and the yield of crops has been increased greatly. The acreage of this soil is the largest in suburban area, covering about 15,908 ha, w

hich accounts for 60% of the total soil acreage. 1.3 To level and improve sandy soil by stripping off topsoil The imp act of urban expansion on the marginal area is very significant. In the past, people used to adopt measures, such as reversing silt covering sand, mixing silt with sand, planting trees to tackle sandy soil and sand hill etc., to impro ve local environment. But since the late 1980s, with the economic development and urban expansion in Kaifeng, large t racks of agricultural land within the marginal area has been occupied and the miscellaneous demand for construction l and has been raised. Whereas the national policy of protecting primary farmland, especially land to vegetables and no n-staple food for urban consumption, and expanding cropland constitute the special demand for sandy soil for it is fi t for multi-use land including building material, cropland use and so on. After the 1990s, facing with the situation that no wasteland can be reclaimed and the external demand for construction, in addition with convenient communicatio n and prompting of economic interests, sandy soils within the marginal area become an important source of sand for bu ilding and object of arable land expansion. Therefore, sand hills within the marginal area have been leveled as uplan d even after being tackled. The surface of upland is also usually stripped off for planting peanut, or watermelon mai nly. The area of this soil is about 557 ha, accounting for 2% of the total soil acreage. But the degree of developmen t is very low, as its soil-forming period is short. The soil is structureless with small specific heat and is loose. Therefore the temperature here varies greatly between day and night, there are small organic and nutrient contents i n soil, crops can´t grow normally. 1.4 Vegetable garden soil based on long-term intensive cultivation Vegetable plant ation has always been a major land use pattern in eastern and southern suburbs. The cultivating duration within the m arginal area is generally up to 15 to 20 years because of urban expansion. This period is not long enough for farmer s to develop typical vegetable soil. However, long-term more intensive cultivation than other patterns, including mas s absorbing urban garbage and manure, underground water irrigation, repeated plowing of soil, manure and pesticide ap plication and so on, made the soil loose and easy to plow and having high fertility, of course, it also resulted in l ight soil pollution. In recent years, the attraction of market demand for high-income product brought the vegetable l and close to city with convenient communication into more intensive and high quality vegetable land or grape garden s. The acreage of this soil is about 3394 ha, accounting for 12% of the total soil. It is also the highest quality ar able land within marginal area and is easy to plough and has appropriate sand-clay ratio, while it also has good capa city of keeping water and nutrition, and resists drought or waterlogging. 2 Investigation analysis and appraisal of s oil quality change 2.1 Soil quality investigation and sample analysis In order to learn the actual situation of soil quality change of Kaifeng´s urban-rural marginal area, we made new investigations of soil samples in the whole area o fter rice harvesting and before wheat fertilization at the beginning of summer. To make comparison with the study in 1982 survey more conveniently, we take identical soil samples according to the location map of soil sampling sites st rictly and sampled the same tillage layer of soil. Then adding 18 more section points based on the change in land us e patterns, we got 62 groups of samples altogether this time. Finally, we adopt the same attribute analysis method o f soil samples used in the 1982´s investigation, which is completed by Nanjing Institute of Soil Science, CAS. 2.2 So il quality appraisal 2.2.1 Soil quality appraisal parameters selection According to the features of local soils, usin g the present research accomplishment for reference, we select some factors that have significant impact on crop grow th as appraisal factors, such as pH value, organic matter (OM), total nitrogen (TN), and available phosphorus (AP), a vailable potassium (AK), cation exchange capacity (CEC) etc. 2.2.2 Parameter standardization To eliminate the unit di fferences in each other parameters so as to make mixed computation the parameters must be standardized firstly. Secon d, to avoid the shortcoming of less comparable which lies in the frequently used method such as standard difference a nd standard gradation method, we adopt the following method after comparison and screening. If the detected value of factor is at worst level, in other words, if Xi?Xmin, then If the detected value of factor is at bad level, in other words, if Xmin?Xi?Xmid, then If the detected value of factor is at middle level, in other words, if Xmid?Xi?Xmax, the n If the detected value of factor is at ´good´ level, in other words Xi>Xmax, then Pi=3. In the equations 1, 2 and 3, P indicates the index of single factor quality, Xi indicates detected value of certain factor, Xmin indicates the classifying criteria of ´bad´ level, Xmid indicates the classifying criteria of ´middle´ level, Xmax indicates the cl assifying criteria of ´good´ level, and i indicates factors (i=1, 2, 3, 4, 5, 6). Being alkalescent trail of local so il, the negative correlation exists between soil pH value and land productivity. Thereby, if pHirrigated land (1.33)> paddy land (1.22)>orchard (1.18)>upland (0.60). Second, not all the dynamic changes of soil quality are the same. Th e nutrient of upland decreased but the irrigated land and vegetable land were ameliorated. The organic matter conten t of upland decreased by 27.78%, total nitrogen decreased by 36.13%, and cation exchange capacity decreased by 44.0 9%. The organic matter content of irrigated land increased by 14.08%, cation exchange capacity decreased by 1.36%. Th e organic matter content of paddy land decreased by 17.09%, total nitrogen decreased by 22.87%, and cation exchange c

apacity decreased by 33.16%. The organic matter content of vegetable land increased by 21.85%, total nitrogen increas ed by 61.46%, and cation exchange capacity decreased 11.07%. 3.3.2 Different land use, adjustment resulting in differ ent changes of soil quality The structure of agricultural land in Kaifeng´s urban-rural marginal area has changed sha rply since 1981. The acreage of paddy, upland, vegetable land reduced. The acreage of irrigated land and orchard expa nded. The dominant changes are that the upland changed into orchard, irrigated land; and the paddy changed into irrig ated land and partial vegetable land changed into orchard. The influence assessment of these kinds of land use chang e is analyzed below. (1) Upland changed into orchard irrigated land Upland changed into orchard refers to the non-irr igated land on which peanuts were planted in the past changed into apple orchard. It mainly happened in Liuyuankou To wnship. It manifests from the investigation: the deficit quantity of soil nutrient in the orchard occupies 19% of th e crop needed, a slight improvement after 3-5 years when the picking season of the fruits comes because of the input of material and amelioration of fertilization and management. The deficit quantity of nitrogen and phosphorous decrea sed but the deficit quantity of potassium increased. The organic matter and total nitrogen are surplus; i.e., soil qu ality ameliorated when upland changed into orchard (Table 5). The reason for this situation lies in the change of mat erial input and management. The cultivation of upland is extensive and the input of organic fertilizer and chemical f ertilizer is less. So the replenishment of soil nutrient is deficient after the harvesting of crops. When the upland changed into orchard, organic matter and chemical fertilizer increased, the productivity is heightened and the soil q uality can he ameliorated gradually. The result of upland change into irrigated land assembles that of upland change into orchard. (2) Paddy field of single rice changed into irrigated land of rice-wheat rotation This kind of change r efers to the land on which only one rice was planted in 1982, and changed into rice-wheat rotation after the irrigati on in 1998. This kind of change varies almost all over the urban-rural marginal area, especially in North Suburban (B eijiao) Township. The quality of chemical fertilizer and organic fertilizer needed is less for single rice plantatio n, and only one ploughing each year. The quality of soil ameliorated and the quantity of water and fertilizer needed increased after the irrigation practice. In addition, non-tillage method was practiced in wheat planting in autumn. T he amount of organic matter, nitrogen fertilizer increased obviously, and began to be accumulated. The deficiency of phosphorous and potassium still exists, but the deficiency decreased sharply, the deficiency for phosphorous decrease d from 64% to 18%, and that for potassium decreased from 50% to 14%. Above all, the deficiency of total nutrient decr eased from 38% to 9%. For example, the deficiency in 1982 for organic matter content of the soil samples of North Sub urban Township was 34.6 kg/ha, but the deficiency changed into surplus of 17.4 kg/ha in 1998; the soil quality has in creased since the change of paddy field into irrigated land. (3) Vegetable land changed into orchard land This kind o f change refers to the vegetable land in 1982 changed into apple or grape orchard in 1998, which mainly happened in E ast Suburban Township. The vegetable land was managed very meticulously, and the input of organic fertilizer was pai d much attention to. For example, in 1982, the input of organic fertilizer to per ha of vegetable plot was mainly exc rement and cake fertilizer, the average amount of input per ha of which is 133.33 kg, equals to net nitrogen 2.76 k g, phosphorus 0.41 kg, potassium 0.71 kg, and organic matter 34.27 kg. Moreover, 0.8 kg chemical fertilizer nitrogen and 0.19 kg phosphorous per ha was input without applying potassium fertilizer. 218.33 kg vegetables yielded per ha e very year. According to this figure, it is estimated that 1.22 kg nitrogen, 0.57 kg phosphorous, and 1.39 kg potassiu m per ha were lost, 0.69 kg chemical fertilizer was washed away from surface flow per year. The balance of nutrient p er ha is a surplus of nitrogen 1.78 kg, organic matter 17.61 kg and a deficiency of phosphorous 0.104 kg, potassium 0.68 kg. Generally, total nutrient was surplus lightly. The soil quality might improve gradually if the land was kep t as the vegetable plantation. But the surplus of nutrient turned into deficiency after the change, the soil quality degraded slightly also. Especially the surplus of nitrogen nutrient of 0.44 kg per ha turned into a deficiency of 0.0 48 kg. The surplus amount of organic matter decreased by about 6.67 kg and the deficiency of phosphorous and potassiu m became larger. It can be concluded from the above analysis that the change of soil quality has a close relationshi p with the input balance of fertilizer. At the same time, different land use patterns and different yields determine d the input of fertilizer. So long-period land use in the urban-rural marginal area formed the actual sequence of pro fit decline: vegetable land, orchard land, irrigated land, upland, which reflects the normal regular pattern and lon g-period tendency on land use. However, sustainable resources use requirement of sustainable development should keep soil nutrient balanced and soil quality improved. Hence, simple input does not satisfy sustainable land use. On one h and, it is necessary to keep certain input of fertilizer replenishing deficiency of soil nutrient and to maintain nut rient and soil quality balance. On the other hand, the current irrational land use must shift so as to heighten the u tilizing rates of material-energy and the sustainability of land use. At the same time, proper environmental protecti on and scientific guidance are needed to achieve sustainable land use.

关键词： urban-rural marginal area; land use change; soil quality; soil nutriment balance