Assessment of Cultivated Land Quality Grades and Analysis of Soil Nutrients and Salinization in Arid Regions: A Case Study of the Minqin Oasis (Postprint)

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Abstract

To comprehensively understand the farmland quality, soil nutrient status, and salinization conditions of the Minqin Oasis, fully utilize county-level cultivated land resources, analyze and study the farmland quality classification as well as the current status of soil nutrients and salinization in the Minqin Oasis, provide a scientific basis for timely and accurate assessment of oasis farmland productivity conditions, and simultaneously furnish improvement measures for soil nutrient and salinization obstacles in oasis farmland. Based on the relevant requirements of the Ministry of Agriculture and Rural Affairs' "Farmland Quality Survey, Monitoring and Evaluation Measures" (Ministry of Agriculture, 2016 No. 2) and the national standard "Farmland Quality Grade" (GB/T33469-2016), a county-level evaluation system for the Minqin Oasis was constructed. Through comprehensive application of spatial analysis, fuzzy mathematics, analytic hierarchy process, and comprehensive index methods, a comprehensive evaluation of farmland quality grades in the Minqin Oasis was conducted. The results indicate: (1) The average farmland quality grade of Minqin Oasis is 3.26; grades one through seven are distributed, while grades eight, nine, and ten are absent; grades three and four constitute the main grade distributions of Minqin Oasis farmland, with area proportions of 31.63% and 28.27%, respectively. Grades one and two are predominantly distributed in the central Quanshan District and the dam area irrigation agriculture zone. Grades three and four are mostly distributed in the lake area irrigation zone. Grades five, six, and seven are more commonly distributed in the oasis edge zone. (2) The average soil organic matter content in Minqin Oasis farmland ranges between 10.00~15.00 $g \cdot kg^{-1}$, and the average total nitrogen content ranges between 0.50~1.00 $g \cdot kg^{-1}$, both at relatively low levels overall. Available phosphorus and readily available potassium are at medium levels overall. The average soil nutrient content

is relatively low in Changning District, the northeastern border area between Quanshan District and the dam area, and towns in the lake area (Changning Town, Donghu Town, Nanhu Town, Quanshan Town, Xiqu Town). (3) The area of salinized farmland in Minqin Oasis is 32240.36 hm^2, accounting for 30.09% of the total farmland area in Minqin Oasis; it is predominantly mild salinization. Mild salinization is mostly distributed in towns of the lake area such as Hongshagang Town, Hongshaliang Town, and Xiqu Town; moderate salinization is distributed in Changning Town and along the wind-sand line in the Huanhe District. These evaluation results are of great significance for the scientific management and sustainable utilization of cultivated land resources in Minqin Oasis and for the development of oasis agriculture.

Full Text

Evaluation of Cultivated Land Quality and Analysis of Soil Nutrients and Salinization in Arid Areas: Taking Minqin Oasis as an Example

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Abstract

The Minqin area in Gansu Province, China, features a typical temperate continental arid climate with unique natural conditions suitable for sugar accumulation in crops. However, recent massive exploitation of groundwater resources has caused groundwater levels to decline, water mineralization to increase, and land desertification and salinization to expand significantly, severely restricting agricultural development in this arid region. Based on the Ministry of Agriculture and Rural Affairs' "Measures for Investigation, Monitoring and Evaluation of Cultivated Land Quality" (2016 No. 2) and the national standard "Cultivated Land Quality Grading" (GB/T33469-2016), this study constructs a county-level evaluation system for the Minqin Oasis. Using comprehensive methods including spatial analysis, fuzzy mathematics, analytic hierarchy process, and comprehensive index, the cultivated land quality grades of the Minqin Oasis were evaluated. The results show that the average cultivated land quality grade is 3.26, with land distributed across grades one through seven (grades eight, nine, and ten are absent). Grades three and four constitute the main body, accounting for 31.63% and 28.27% of the area, respectively. Grades one and two are primarily distributed in the central Quanshan District and dam irrigation areas, while grades three and four are mostly found in lake irrigation areas. Grades

five, six, and seven are predominantly located at oasis margins. The average soil organic matter content ranges between 10.00–15.00 $g \cdot kg^{-1}$, and total nitrogen between 0.50–1.00 $g \cdot kg^{-1}$, both generally at low levels. Available phosphorus and potassium are at medium levels. Salinized cultivated land covers 32240.36 hm^2, representing 30.09% of total cultivated land, with light salinization being dominant, followed by moderate and severe salinization (7.46%). Light salinization is mainly distributed in Hongshagang, Hongshaliang, Xiqu, and other towns in the lake area, while moderate salinization occurs in Changning town and along the wind-sand line in the Huanhe District. Overall, Minqin Oasis cultivated land suffers from nutrient deficiency, particularly in organic matter and total nitrogen, and is predominantly lightly salinized. Spatially, nutrient content is low in Changning, the lake area, and along wind-sand lines, with obvious salinization. To improve land quality and fertility while reducing salinization, intensified efforts should focus on cultivated land in lake areas, river-circling areas, and wind-sand zones.

Key words: cultivated land quality evaluation; analytic hierarchy process; arable land resource management information system of a county; Minqin Oasis

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Cultivated land is an essential and irreplaceable resource for human survival and agricultural production, directly influencing agricultural structure, productivity, and product quality. In arid regions, soil serves as the carrier for oasis vegetation, and its quality critically affects plant growth. The Minqin Oasis, located in the northeastern Hexi Corridor of Gansu Province, features a typical temperate continental arid climate with abundant sunlight and large diurnal temperature variations, creating favorable conditions for crop growth, particularly for sugar accumulation in fruits and melons. However, recent large-scale groundwater exploitation has led to declining water tables, increased water mineralization, and expanded desertification and salinization, severely constraining agricultural development in this arid region. While previous studies have examined soil moisture, salinity, and nutrient changes under various land use patterns in the Minqin Oasis, comprehensive research on cultivated land quality grading and the current status of soil nutrients and salinization remains lacking. This study addresses this gap by establishing a county-level evaluation system based on the Ministry of Agriculture and Rural Affairs' "Measures for Investigation, Monitoring and Evaluation of Cultivated Land Quality" and the national standard "Cultivated Land Quality Grading" (GB/T33469-2016). Utilizing the county cultivated land resource management information system and comprehensive methods including spatial analysis, fuzzy mathematics, analytic hierarchy process, and comprehensive index, this research evaluates the cultivated land quality of the Minqin Oasis to provide scientific basis and countermeasures for its protection and improvement.

1.1 Study Area Overview

The Minqin Oasis is located in the lower reaches of the Shiyang River in Minqin County, Gansu Province. It is surrounded by the Badain Jaran Desert to the west, north, and east, with the northern section of the Hexi Corridor' s Beishan Mountain to the south. The central area features a narrow, flat oasis belt formed by Shiyang River alluviation, representing a typical desert oasis in China. The region has a typical temperate arid desert climate characterized by long sunshine hours, large diurnal temperature variations, and frequent winds throughout the four seasons. The average annual temperature is 7.8°C, with 163 frost-free days, effective accumulated temperature of 3655.6°C, and minimal annual precipitation (rain/snow). Annual evaporation reaches 2644 mm, with average relative humidity below and aridity index greater than, making it one of China' s most arid regions. The Minqin Oasis has a plain landform that can be divided into alluvial-proluvial plains, aeolian plains, and lacustrine plains. Soil types include several subcategories, mainly gray-brown desert soil, saline soil, aeolian sandy soil, meadow soil, and irrigated warped soil. Saline soil is a regional soil with large distribution area, while irrigated warped soil is one of the main cultivated soils. Oasis irrigation agriculture is the primary agricultural type in northwest China. Based on irrigation canal systems, the Minqin Oasis is divided into three major irrigation zones: the dam area, Quanshan area, and lake area.

1.2 Evaluation Methods and Steps

1.2.1 Data Collection and Organization The evaluation collected field survey data on geographic location, natural conditions, production conditions, and soil profile characteristics; laboratory analysis data on soil organic matter, macro-, meso-, and micro-element contents; statistical data from yearbooks and agricultural statistical yearbooks; data from the second soil census; information on high-standard farmland construction and other agricultural infrastructure; water conservancy zoning data; cultivated land quality monitoring point data; and historical field experiment data.

1.2.2 Sample Collection and Processing The layout of evaluation sample points directly affects the accuracy of cultivated land quality assessment. The fundamental principles are to ensure sample points are typical and representative while maintaining spatial distribution uniformity. During sample layout, soil maps, land use status maps, and administrative division maps were overlaid to form evaluation units. Based on the number, area, soil type, cropping system, crop types, yield levels of evaluation units, and requirements from the Ministry of Agriculture and Rural Affairs' "Measures for Investigation, Monitoring and Evaluation of Cultivated Land Quality" issued to Gansu provinces/autonomous regions, the quantity and location of cultivated land quality evaluation sample points were determined, ensuring each evaluation unit had sample points with uniform distribution. In [year], a total of [number] soil samples were col-

lected across [number] towns in the county, roughly following the standard of one sample point per 667 hm^2. Sampling depth was 0–20 cm, with sampling routes designed as [description]. Sampling locations, depths, dates, and personnel were recorded, with duplicate labels prepared while maintaining detailed sampling records. Sample testing was conducted according to current effective standards including "Cultivated Land Quality Grading" (GB/T33469-2016).

1.2.3 Evaluation Unit Division and Data Acquisition An evaluation unit is a spatial entity composed of various factors affecting cultivated land quality and represents the smallest unit of assessment. Therefore, the rationality of evaluation unit determination directly relates to the reasonableness of evaluation results and the magnitude of workload. Based on principles of factor difference, similarity, and boundary integrity, this study used a combined overlay method with soil maps, cultivated land use status maps, and Minqin Oasis administrative division maps to divide evaluation units and scientifically obtain unit data. For quantitative data such as soil nutrient content, spatial interpolation was employed to convert point data into raster data overlaid on evaluation unit maps to obtain information for each unit. For qualitative factors such as irrigation capacity, a point-to-area method was used to connect point attributes to evaluation unit maps. Based on management units obtained from overlay intersection of soil maps, cultivated land use status maps, and administrative division maps, and considering system operational efficiency and fragmentation of management units, small polygons with areas less than 5000 m^2 were merged with adjacent units, resulting in a Minqin Oasis cultivated land resource management unit map with [number] management units generated.

1.2.4 Evaluation Indicators and Their Weights According to indicator selection principles and following the evaluation standards for cultivated land quality in the Gansu-Xinjiang region, a three-level hierarchical structure was established comprising target, criterion, and indicator layers to meet the requirements and characteristics of Minqin Oasis cultivated land quality evaluation. The target layer is cultivated land quality; the criterion layer includes site conditions, soil management, nutrient status, profile characteristics, cultivated layer physicochemical properties, and health status; the indicator layer contains [number] indicators. The Delphi method and analytic hierarchy process were combined to determine indicator weights for the Minqin Oasis (Table 1).

1.2.5 Membership Function Construction Membership function types include the upper-constrained, peak-shaped, lower-constrained, linear, and conceptual types. [Table 2 shows the functional indicators and their membership functions for Minqin Oasis cultivated land quality evaluation, including effective soil layer thickness and groundwater depth with formulas such as $=1/[1+\cdots]$].

1.2.6 Comprehensive Scoring and Grading According to the "Cultivated Land Quality Grading" standard (GB/T33469-2016), the comprehensive index

of cultivated land quality (IFI) for evaluation units in the Minqin Oasis was calculated using the additive method with values between grades one and seven. The formula is as follows:

$$IFI = \sum (F_i \times C_i)$$

where IFI is the comprehensive index of cultivated land quality, F_i is the membership degree of the ith evaluation indicator, and C_i is the combined weight of the ith evaluation indicator. Evaluation results underwent centralized review through yield verification, comparative verification, expert validation, and field verification to ensure scientific accuracy and local applicability.

1.2.7 Grading Standards for Main Soil Traits The Minqin Oasis uses the equal-interval method to classify cultivated land quality into [number] grades. Soil nutrient grading standards follow the Gansu-Xinjiang region' s Mengning-Gan agricultural and pastoral secondary zone criteria (Tables 10 and 11).

2 Evaluation Results and Analysis

2.1 Cultivated Land Quality Grade Analysis

The total surveyed area of cultivated land quality in the Minqin Oasis is 107160.14 hm^2. Cultivated land quality grades range from one to seven, with no distribution of grades eight, nine, or ten. Using the area-weighted method, the average cultivated land quality grade is 3.26. The area proportions from grade one to seven are 7.94%, 18.73%, 31.63%, 28.27%, 9.61%, 2.47%, and 1.34%, respectively, with grades two, three, and four occupying the largest shares (Figure 1). Analysis of spatial distribution according to the three major irrigation systems (dam area, Quanshan area, and lake area) reveals that grades one and two are mainly distributed in central Quanshan District and the dam area. Datang Town has the largest area of grade one land (28.92%), while Quanshan Town has the largest area of grade two land (12.64%), with scattered distribution in Caiqi and Chongxing towns. These grade one and two lands feature high irrigation guarantee rates, good groundwater quality, high production performance, few limiting factors, strong cultivability, and soil types dominated by irrigated warped soil, meadow soil, and fluvo-aquic soil. Grades three and four are primarily distributed in the lake area, particularly in Xiqu Town where they account for 10.42% and 15.88% respectively, with scattered distribution in Hongshaliang, Jiahe, and Quanshan towns. The irrigation conditions and water quality of grades three and four are generally inferior to grades one and two. Lake area soils are mainly lacustrine saline-alkali irrigated warped soil with severe salinization. Although the average accumulated temperature is higher than in surrounding lake areas, saline-alkali hazards reduce soil quality compared to dam area irrigated warped soil. Grades five, six, and seven are predominantly distributed at oasis margins, with Nanhu Town concentrating grades six and seven (50.15% and 57.74% respectively).

These lands have poor cultivability and are dominated by aeolian sandy soil and saline soil (Figure 2).

[Figure 1: see original paper]

[Figure 2: see original paper]

2.2 Soil Nutrients and Salinization Spatial Distribution

2.2.1 Soil Nutrients and Spatial Distribution Characteristics Protecting soil and improving soil fertility to continuously enhance production capacity represents an important goal for sustainable agricultural development. In cultivated land productivity evaluation, soil nutrient status largely determines productivity levels, and nutrient content significantly affects crop yields. Understanding soil nutrient variations provides a theoretical basis for agricultural production. Soil organic matter is a key indicator of soil nutrient content and an important source of various nutrients, particularly nitrogen and phosphorus. Its colloidal properties enable adsorption of numerous cations, conferring soil fertility retention and buffering capacity. Thus, organic matter content directly influences soil fertility performance. Nitrogen, phosphorus, and potassium are essential nutrients for plant growth. Total nitrogen content is a crucial indicator of soil nitrogen supply status; available potassium, easily absorbed by crops in the short term, directly reflects soil potassium supply capacity; and available phosphorus is an important indicator of soil phosphorus supply. Analysis reveals that soil organic matter in the Minqin Oasis is mainly concentrated at 10.00–15.00 $g \cdot kg^{-1}$ (low level), accounting for 81.39% of the area, with no distribution at high or relatively high levels, indicating generally low organic matter content. Total nitrogen is concentrated at 0.50–1.00 $g \cdot kg^{-1}$ (low level), representing 97.33% of the area, with only 0.14% at medium level and none at high or relatively high levels, showing obvious nitrogen deficiency. Available phosphorus is concentrated at 20.00–30.00 $mg \cdot kg^{-1}$ (medium level), accounting for 64.69% of the area. Available potassium is concentrated at 150.00–200.00 $mg \cdot kg^{-1}$ (medium level), representing 99.99% of the area. Both available potassium and phosphorus have limited distribution at high or relatively high levels but none at low levels (Table 13).

Spatially, soil organic matter and total nitrogen in most towns are at relatively low levels, while available potassium and phosphorus are at medium levels. Specific distribution patterns show that at the junction of dam and Quanshan areas, and in some Huanhe District towns (Caiqi, Daba, Datang, Dongba, Sanlei), average contents of organic matter, total nitrogen, available phosphorus, and potassium are relatively high, with Caiqi Town having the highest organic matter and nitrogen contents. In contrast, the northeastern border between Changning District and Quanshan District, and lake area towns (Changning, Donghu, Hongshaliang, Nanhu, Quanshan, Shoucheng, Xiqu) have relatively low average nutrient contents, with Nanhu Town being the lowest (organic matter 9.39 $g \cdot kg^{-1}$, total nitrogen 0.56 $g \cdot kg^{-1}$) (Table 14).

2.2.2 Soil Salinization and Spatial Distribution Characteristics Located inland, the Minqin Oasis has a typical temperate arid desert climate with strong sunlight, long sunshine hours, scarce precipitation, and obvious water shortage. In recent years, large-scale and unreasonable groundwater exploitation has caused repeated consumption and concentration of groundwater, with increasing mineralization creating favorable conditions for soil salinization. As groundwater is extracted for irrigation, soil salts are redistributed, land becomes increasingly barren, and large-scale salinization forms. Soil salinization degree is an important indicator of cultivated land quality, and timely, accurate understanding of salinization status is crucial for preventing further deterioration, improving saline-alkali soils, and enhancing agricultural productivity. Analysis of salinization levels and spatial distribution shows that the Minqin Oasis has total cultivated land of 107160.14 hm^2, with salinized cultivated land covering 32240.36 hm^2 (30.09% of total). Salinization occurs at varying degrees: light salinization accounts for the largest area (61.46% of salinized land), moderate salinization ranks second (31.08%), and severe salinization is smallest (7.46%) (Figure 3).

[Figure 3: see original paper]

Salinization status varies among towns: Light salinization occurs in lake area towns including Hongshagang, Hongshaliang, Xiqu, and Donghu, with Xiqu Town having 9598.17 hm^2 of lightly salinized land (29.77% of its cultivated area). Moderate salinization is found in Changning town and along the wind-sand line in Huanhe District, with Changning Town having the largest moderately salinized area (11.52%). Some towns at the northeastern junction of dam and Quanshan areas (Daba, Dongba, Quanshan, Shuangcike) show no salinization (Table 15).

3 Discussion

Cultivated land quality is a crucial indicator reflecting production capacity and an important guarantee for national food security and social stability. Arid and semi-arid regions account for [percentage] of China' s territory, making dryland agriculture a vital component of Chinese agriculture. The Minqin Oasis represents a typical arid region oasis agriculture system where cultivated land quality determines agricultural development. Analysis shows the average cultivated land quality grade is 3.26, distributed across grades one to seven (absent in grades eight to ten), with grades three and four being predominant, indicating overall medium-level quality.

In cultivated land productivity evaluation, soil nutrient status largely determines productivity levels and significantly affects crop yields. Understanding nutrient variations provides a theoretical basis for agricultural production. Soil organic matter is a key indicator of nutrient content and an important source of nutrients, particularly nitrogen and phosphorus. Its colloidal properties enable cation adsorption, conferring fertility retention and buffering capacity, directly

influencing soil fertility performance. Nitrogen, phosphorus, and potassium are essential nutrients. Total nitrogen content is a crucial indicator of nitrogen supply status; available potassium reflects soil potassium supply capacity; and available phosphorus indicates phosphorus supply capacity.

Analysis reveals that Minqin Oasis soil organic matter is concentrated at 10.00–15.00 $g \cdot kg^{-1}$ (low level), with total nitrogen at 0.50–1.00 $g \cdot kg^{-1}$ (obvious deficiency), while available potassium and phosphorus are at medium levels. It is recommended to appropriately control phosphorus and potassium fertilizer application in agricultural production. However, whether to supplement nitrogen fertilizer requires further investigation, as farmers tend to over-apply nitrogen despite theoretical severe deficiency, creating a paradox that needs resolution to achieve cost reduction and efficiency improvement.

Soil salinization is a major manifestation of land degradation and an important factor affecting agricultural production and ecological security in arid and semi-arid regions. This study shows that salinized cultivated land covers 32240.36 hm^2 (30.09% of total), predominantly light salinization. The Minqin Oasis, located in northwest inland China far from the ocean, receives little moisture with scarce precipitation and dry climate, representing a typical temperate continental climate and one of China' s most extremely arid regions. Frequent winds and sandstorms create conditions where soluble salts in weathered materials are not easily leached but accumulate in surface soil through evaporation, leading to salinization. In low-lying areas of the lake region (Xiqu, Shoucheng southeast, Shuangcike, Liuba, Jiahe east, Changning, Changsheng), lacustrine saline-alkali irrigated warped soil is predominant, with severe salinization damaging crop growth. Reduced inflow water, increased domestic and agricultural water consumption, large-scale groundwater exploitation causing water table decline, increased mineralization, and irrational irrigation methods directly reduce regional water quantity and quality, exacerbating soil salinization. Therefore, in salinized areas, grain crop area should be reduced while promoting salt-tolerant crops (cotton, fennel) and anti-alkali cultivation techniques (plastic film mulching, under-film drip irrigation).

Overall, Minqin Oasis cultivated land suffers from nutrient deficiency, particularly organic matter and total nitrogen, with predominant light salinization. Spatially, nutrient content is low in Changning, the lake area, and along wind-sand lines in Huanhe District, with obvious salinization. Future efforts to improve land quality and amend salinization should intensify focus on cultivated land in lake areas, Huanhe District, and wind-sand zones.

4 Conclusions

(1) The average cultivated land quality grade in the Minqin Oasis is 3.26, distributed across grades one to seven (grades eight, nine, and ten are absent). Grades three and four constitute the main body, accounting for 31.63% and 28.27% of the area, respectively. Grades one and two are

mainly distributed in central Quanshan District and dam irrigation areas. Grades three and four are predominantly found in lake irrigation areas. Grades five, six, and seven are mostly located at oasis margins.

(2) Average soil organic matter content ranges from 10.00–15.00 $g \cdot kg^{-1}$, and total nitrogen from 0.50–1.00 $g \cdot kg^{-1}$, both at low levels. Available phosphorus and potassium are at medium levels. Spatially, nutrient content is higher at the junction of dam and Quanshan areas and in Huanhe District towns (Caiqi, Daba, Datang, Dongba, Sanlei), while lower in the northeastern border between Changning District and Quanshan District, and in lake area towns (Changning, Donghu, Nanhu, Quanshan, Xiqu).

(3) Salinized cultivated land covers 32240.36 hm^2 (30.09% of total), predominantly light salinization, followed by moderate salinization, with severe salinization being smallest (7.46%). Light salinization is mainly distributed in lake area towns (Hongshagang, Hongshaliang, Xiqu), while moderate salinization occurs in Changning town and along wind-sand lines in Huanhe District.

In summary, analyzing the distribution of cultivated land quality grades and the status of soil nutrients and salinization in the Minqin Oasis provides a basis for timely understanding of land productivity, preventing deterioration of soil limiting factors, and improving saline soils and agricultural productivity.

References

[1] Feng Yaozu, Geng Qinglong, Chen Shuhuang, et al. Evaluation of soil fertilities of farmland at county level based on GIS and analysis of obstacle factors[J]. Xinjiang Agricultural Sciences, 2011, 48(12): 2281-2286.

[2] Liu Fei. Characteristics of soil water and salt and its relationship with groundwater in Minqin Oasis[D]. Lanzhou: Lanzhou University, 2019.

[3] Yang Pengpeng. Study on the physical and chemical properties and salinization of Minqin Oasis zone[D]. Lanzhou: Lanzhou University, 2018.

[4] Jiang Wanbei. Study of land degradation remote sensing monitoring method in the arid region using Minqin County[D]. Beijing: China Agricultural University, 2017.

[5] Li Dan, Zhang Bo, Dai Shengpei, et al. Comparison of soil fertility and physical properties of farmland, wasteland and returning farmland to forest in Minqin Oasis[J]. Soil, 2011, 43(3): 398-405.

[6] Liu Fei, Chen Peiyuan, Yu Haichao, et al. Spatial distribution characteristics of soil water and salt under different land use types in Minqin[J]. Arid Land Geography, 2020, 43(2): 406-414.

[7] Zhao Yibo, Lei Shaogang, Liu Ying. Spatial variability and influencing factors of soil nutrients in Shengli mining area[J]. Soil, 2020, 52(2): 356-364.

[8] Zhang Shichang. A research on the spatial distribution and types of the development level of agricultural modernization within arid oasis taken Minqin for example[D]. Lanzhou: Lanzhou University, 2016.

[9] Zhang S L, Zhang X Y, Liu X B, et al. Spatial distribution of soil nutrient at depth in black soil of northeast China: A case study of soil available potassium[J]. Nutrient Cycling in Agroecosystems, 2013, 95(3): 319-331.

[10] Tian Liwen, Qi Yongchun, Dai Lu, et al. Evaluation of soil nutrient content and its distribution of cultivated land in south of Xinjiang: Taking Aksu Prefecture as an example[J]. Journal of Nuclear Agriculture, 2020, 34(1): 214-223.

[11] Deng Baoshan, Wahf Halik, Dang Jianhua, et al. Coupled analysis of spatio temporal variability of groundwater depth and soil salinity in Keriya Oasis[J]. Arid Land Geography, 2015, 38(3): 599-607.

[12] Zhang Bin, Yang Lian' an, Yang Fanli, et al. Spatial distribution of soil nutrients and their influential factors in apple production area: A case study of Liquan County, Shaanxi Province[J]. Soil, 2016, 48(4): 777-784.

[13] Yuan Weihan. Soil nutrients change and yield effect of N and K in low mountain and hill of Yanshan[D]. Baoding: Hebei Agricultural University, 2013.

[14] Shi Bowen, Lai Xin, Li Jie, et al. Effect of interaction between manure and urea on transformation of nitrogen in brown red soil[J]. Journal of Nuclear Agriculture, 2017, 31(5): 938-945.

[15] Liu Yanling, Li Yu, Qin Song, et al. A discussion on land fallow rotation problems in ecologically fragile areas of the southwest karst area: A case study of Guizhou Province[J]. Chinese Journal of Eco-Agriculture, 2018, 26(8): 1117-1124.

[16] Zhang Hui, Wang Yang. Spatial differentiation of cropland pressure and its socio-economic factors in China based on panel data of 342 prefectural level units[J]. Geographical Research, 2017, 36(4): 731-742.

[17] Xu Zhichao, Yu Dongsheng, Pan Yue, et al. Temporal characteristics of soil fertility of cropland requisition compensation in the typical region of Yangtze River Delta, China[J]. Chinese Journal of Applied Ecology, 2018, 29(2): 617-625.

[18] Zhang Chao, Qiao Min, Yun Wenju, et al. Trinity comprehensive regulatory system about quantity, quality and ecology of cultivated land[J]. Journal of Agricultural Machinery, 2017, 48(1): 1-6.

[19] Gao Yifan. Spatial variability of soil nutrients and evaluation of cultivated land quality in farmland of Shaanxi Province[D]. Yangling: Northwest A & F University, 2019.

[20] Qu Yuling. Soil and water conservation in China[J]. China Agricultural Technology Extension, 2015, 31(9): 39-42.

[21] Li Baoxiong, Han Qingxian. The causes of desertification and salinization in oasis of Minqin County and their control approaches[J]. Soil and Water Conservation in China, 1989(7): 41-65.

Note: Figure translations are in progress. See original paper for figures.