Precise Accounting of Current Water Resource Carrying Capacity in Arid Regions Based on Google Earth Engine: A Case Study of the Xinjiang Production and Construction Corps (Postprint)

Authors: Jingxin Li

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Abstract

In recent years, water resource overexploitation has led to frequent production and ecological problems in the Xinjiang Production and Construction Corps (hereinafter referred to as "the Corps"), and scientific and precise assessment of the current water resource carrying capacity can provide important references for the Corps' socio-economic development and ecological environment governance. The vast majority of the Corps' socio-economic water use is irrigation water; therefore, the accuracy of cultivated land area data significantly affects the evaluation results of the current water resource carrying capacity. However, in reality, there are certain biases in statistical data of cultivated land area, which increases the uncertainty in assessing the current water resource carrying capacity. Based on this, by introducing the Google Earth Engine (GEE) big data platform and the net cultivated land coefficient, the cultivated land area was precisely revised; and three irrigation water use scenarios—conventional irrigation, film-mulched irrigation, and mixed irrigation—were simulated to construct a three-category water use accounting system, enabling precise assessment of the water resource carrying capacity of the Corps and its various divisions. The results indicate that the cultivated land correction factor for the Corps is 1.27, suggesting approximately a 27% deviation in the Corps' cultivated land area; in the mixed irrigation scenario, which is close to actual water use, the total water demand for the Corps based on statistical cultivated land area data is 106.45$\times 10^8 m^{\{3\}, with a 9.20\times 10^8 m}\{3\}$, representing a 7.16% overload, and among the 13 divisions, only the 4th and 10th divisions are not overloaded in water use, indicating that the excessive occupation of limited water resources by irrigation water and the appropriation of large amounts of ecological water are the key factors leading to water resource overload and frequent production and

ecological problems in the Corps. This study achieves a scientific and precise assessment of the Corps' current water resource carrying capacity and can provide references for water resource utilization and optimal allocation, as well as regional sustainable development in the Corps.

Full Text

Accurate Calculation of Water Resources Carrying Status in Arid Areas Based on Google Earth Engine: A Case Study of Xinjiang Production and Construction Corps

LI Jingxin[1,2], XU Erqi[1], ZHANG Hongqi[1]

[1]Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[2]University of Chinese Academy of Sciences, Beijing 100049, China

Abstract

In recent years, frequent production and ecological problems have occurred in the Xinjiang Production and Construction Corps (hereinafter referred to as the "Corps") due to the overloading of water resources utilization. Scientific and accurate assessment of water resources carrying status can provide important references for the Corps' socioeconomic development and ecological environment management. Irrigation water accounts for the vast majority of the Corps' socioeconomic water consumption; therefore, the accuracy of cultivated land area data significantly influences the evaluation results of water resources carrying status. However, statistical data on cultivated land area contains certain biases in reality, which increases the uncertainty in assessing water resources carrying status. Based on this, this study introduces the Google Earth Engine (GEE) big data platform and net cultivated land coefficient to precisely revise cultivated land area; and simulates three irrigation water use scenarios—conventional irrigation, above-mulch irrigation, and mixed irrigation—to construct a "living-production-ecology" water accounting system for accurately assessing the water resources carrying status of the Corps and its divisions. The results show that the cultivated land correction coefficient for the Corps is 1.27, indicating that approximately 27% of the cultivated land area is not included in statistics. In the mixed irrigation scenario, which is closest to actual water use, the total water demand of the Corps based on statistical cultivated land area data is 106.45$×10^{8}$ m^3, representing a 9.20% surplus relative to the Corps' total water diversion. After correcting the cultivated land area through GEE, the Corps' total water demand is 125.64$×10^{8}$ m^3, with only two divisions (the Fourth and Tenth Divisions) not exceeding their water use limits. This indicates that irrigation water use excessively occupies limited water resources and encroaches upon substantial ecological water use, which is the key factor leading to water resource overloading and frequent production-ecological problems

in the Corps. This study achieves a scientific and accurate assessment of the water resources carrying status of the Corps and can provide references for water resources utilization, optimal allocation, and regional sustainable development.

Keywords: water resources carrying status; accurate calculation; Google Earth Engine; Xinjiang Production and Construction Corps; irrigation water; overload rate

1 Study Area Overview

The Xinjiang Production and Construction Corps (hereinafter referred to as the "Corps") was established in 1954 and undertakes the national responsibility of garrisoning and cultivating border areas[27]. The Corps comprises 14 divisions, among which the Eleventh Division is a construction engineering division, while the remaining 13 divisions are agricultural production divisions. Since the water consumption of the Eleventh Division is very limited, it was not included in the total water demand accounting scope of the Corps. The spatial distribution of each division is shown in Table 1.

Northern Xinjiang has relatively high irrigation water-saving levels and a relatively humid climate, where 28.86% of the Corps' total water consumption supports 54.99% of the total cultivated land area. The 13 divisions in Southern Xinjiang are mainly distributed along the edge of the Tarim Basin, using 69.06% of the Corps' total water consumption to support 42.21% of the total cultivated land area. Eastern Xinjiang has only the Thirteenth Division, whose total water consumption and cultivated land area account for 2.80% and 2.07% of the Corps' proportions, respectively.

2 Data Sources and Analysis Methods

2.1 Data Sources

Data on total water resources and water supply for the Corps and its divisions were obtained by consulting the Corps Statistical Yearbook, local water resources bulletins, and government gazettes. Since water supply data for each division in 2017 were not published, and the Corps' water diversion has remained basically stable around 120$\times 10^{8}$ m^3 in recent years, this study uses 2016 water supply data for each division as the benchmark to assess the water resources carrying status of the Corps and its divisions. Additionally, data on total cultivated land area, total sown area, main crop planting scale, population, and industrial added value for the Corps and its divisions were obtained from the *Corps Yearbook* and *Xinjiang Production and Construction Corps Statistical Yearbook*.

2.2 Analysis of Water Resources Carrying Status in the Corps

Given that the divisions and regiments of the Corps are relatively scattered throughout the Xinjiang Uygur Autonomous Region, the amount of in-stream ecological water use within jurisdiction is difficult to measure. Therefore, this study only considers off-stream ecological water use required for urban greening and other purposes. Under this background, water resources carrying status refers to the overload degree of theoretical socioeconomic and ecological water demand relative to actual water supply under current socioeconomic development levels. The calculation formula is as follows:

$$C = \frac{D - S}{S} \times 100\%$$

where C is water resources carrying status (%); D is theoretical water demand of the study area (10^8 m^3); and S is actual water supply (10^8 m^3). When $C < 0$, regional water resources utilization is not overloaded, and the absolute value of C represents current water resources utilization rate; when $C > 0$, regional water resources utilization is overloaded, and the carrying status represents the current water resources utilization overload degree—the larger the C value, the more severe the overload. Referring to the water quantity carrying status discrimination rules in the *National Water Resources Carrying Capacity Monitoring and Early Warning Technical Outline (Revised Draft)*, the water resources carrying status judgment criteria are established as follows: when $C < -10\%$, regional water resources utilization is not overloaded; when $-10\% \leq C \leq 0$, regional water resources utilization is in a critical state; when $C > 0$, water resources utilization is overloaded. The overload statuses are further categorized as general overload ($0 < C \leq 10\%$), moderate overload ($10\% < C \leq 20\%$), and severe overload ($C > 20\%$).

2.3 Correction of Crop Sown Area Based on GEE Big Data Platform

To improve the accuracy of carrying status assessment results, this study extracted cultivated land within each division's jurisdiction using massive medium-resolution imagery provided by the GEE cloud computing platform. High-resolution image sample areas were obtained based on Google Earth, and the net cultivated land coefficient (the proportion of non-irrigated area such as field ridges removed from cultivated land) was calculated to achieve precise measurement of the net irrigated cultivated land area in the study area.

First, all Landsat images covering the Corps' jurisdiction in 2016 that had undergone atmospheric correction were screened. The median value of each band and each pixel of the selected images was taken for compositing to generate a cloud-free Landsat image collection, which was then interpreted using a Random Forest (RF) classifier. Each band of the composited Landsat images was used as input parameters for the classifier, with parameters set as tree number = 100 and pixel size = 30 m × 30 m for cultivated and non-cultivated land interpretation. High-definition data for 100 cultivated and non-cultivated areas were randomly selected from Google Earth as training samples, and 100 cultivated sample data points were extracted as verification points. The overall interpretation accuracy was 95.38%, which is sufficiently high to meet subsequent analysis requirements.

This study determined the number of sample plots by division based on the Corps' cultivated land scale and calculated the net cultivated land coefficient. Specifically, the First, Sixth, and Eighth Divisions each had 10 sample plots; the Twelfth, Thirteenth, and Fourteenth Divisions each had 5 sample plots; and the remaining divisions each had 8 sample plots. The sample plot area was set at 300 m × 300 m. High-resolution images from Google Earth were used to extract and calculate the total area of each sample plot and the total non-cultivated land area within the sample plot, thereby calculating the net cultivated land coefficient of the sample plot. This approach enabled correction of the cultivated land area for each division and further correction of crop sown area as follows:

$$Sn_i' = Sn_i \times \frac{A_i'}{A_i} = Sn_i \times I_i$$

$$T_i = \frac{A_i'}{A_i}$$

where Sn_i' represents the corrected sown area of crop n in division i (10^2 hm^2); Sn_i represents the sown area of crop n in division i before correction (10^2 hm^2); A_i' is the cultivated land area of division i obtained from remote sensing interpretation (10^2 hm^2); I_i is the net cultivated land coefficient of division i; A_i is the cultivated land area of division i in statistical data (10^2 hm^2); and T_i is the cultivated land correction coefficient.

2.4 Calculation of Total Water Demand and Various Water Demands in the Corps

2.4.1 Calculation of Total Water Demand and Various Water Demands in the Corps The actual water demand of the Corps includes socioeconomic water demand and ecological water demand. Socioeconomic water demand comprises domestic water demand and production water demand, while ecological water demand in this study only includes off-stream ecological water demand. The specific calculation formula is as follows[25]:

$$W = W_{life} + W_{production} + W_{ecology}$$

where W represents total water demand (10^8 m^3); W_{life}, $W_{production}$, and $W_{ecology}$ represent domestic, production, and ecological water demands (10^8 m^3), respectively. The sub-calculation formulas for production and ecological water demands are as follows:

$$W_{production} = W_{urban} + W_{industrial} + W_{agricultural}$$

$$W_{agricultural} = W_{planting} + W_{livestock} + W_{forest-grass}$$

$$W_{ecology} = W_{off-stream}$$

where W_{urban} and $W_{industrial}$ represent urban public and industrial water demands (10^8 m^3), respectively; $W_{planting}$, $W_{livestock}$, and $W_{forest-grass}$ represent planting, livestock, and forest-grassland irrigation water demands (10^8 m^3), respectively; and $W_{off-stream}$ represents off-stream ecological water demand (10^8 m^3). The total Corps water demand and water demand of each department is the sum of the corresponding water demands of each division.

2.4.2 Calculation of Planting Industry Water Demand Planting industry water demand is calculated based on crop irrigation quotas and the precisely corrected sown area. According to investigations by the Chinese Academy of Engineering[25] on water supply and demand in Xinjiang, differential calculations were implemented for various water use quotas in northern Xinjiang, southern Xinjiang, and eastern Xinjiang divisions when estimating the Corps' total water demand. Crop irrigation quotas were determined based on the *Xinjiang Uygur Autonomous Region Local Standard—Agricultural Irrigation Water Quota (DB 65/3611-2014)* (hereinafter referred to as the "Standard") and field survey results. Three scenarios were established:

Conventional irrigation scenario ("conventional" scenario): Crops were calculated using the conventional irrigation quota values at a 75% irrigation guarantee rate specified in the Standard. Due to the development of irrigation water-saving technologies, this scenario would overestimate water demand for some crops to a certain extent and can be considered the upper limit of planting industry water demand, i.e., a high water demand scenario.

Above-mulch irrigation scenario ("mulch" scenario): Crops were calculated using the above-mulch irrigation quota values at a 75% irrigation guarantee rate specified in the Standard. For some crops that rarely use water-saving technologies for irrigation, this scenario would underestimate water demand to a certain extent and can be considered the lower limit of planting industry water demand, i.e., a low water demand scenario.

Mixed irrigation scenario ("mixed" scenario): This scenario integrates different irrigation quota standards from the Standard and field survey conditions, setting corresponding irrigation quotas based on the actual main irrigation modes for different crops. According to field investigations, cotton widely employs high-level water-saving irrigation technologies during planting; therefore, the above-mulch irrigation quota at a 75% irrigation guarantee rate was used as the water demand for cotton. For grain crops such as wheat, corn, and rice, the conventional irrigation quota at a 75% irrigation guarantee rate is generally lower than the actual irrigation amount. Therefore, the final irrigation quota was increased by 30% of the difference between the conventional irrigation quota and the above-mulch irrigation quota on the basis of the conventional irrigation quota to make it closer to the actual irrigation amount. Other crops were calculated using the conventional irrigation quota at a 75% irrigation guarantee rate.

Since soil salinity content is generally high in southern Xinjiang, cultivated land and garden plots must be irrigated once before planting each year[12,26-28]. Considering the water-saving technology level of the Corps' planting industry production[25], the salt-leaching irrigation quota was uniformly set at 1950 $m^3 \cdot hm^{-2}$ based on actual survey conditions, and the water required for salt-leaching irrigation was included in the water demand for cultivated land and garden plot planting. The final planting industry water demand calculation formula is:

$$W_{planting} = \sum_{n=1}^{N}(Sn_{ni} \times Q_{ni} \times 10^{-2}) + 1950 \times C_i$$

where n represents the main crop types in the division; Sn_{ni} is a function of condition r. When calculating the planting industry water demand before correction for division i, $Sn_{ni} = Sn_i$; when calculating after correction for division *i$, $Sn_{ni} = Sn'_i$; Q_{ni} represents the irrigation quota for crop* n* in division i (m^{3} · hm{-2}); s is a discriminant function—if division i is located in southern Xinjiang (i.e., the First, Second, Third, and Fourteenth Divisions), then $s = 1$, otherwise $s = 0$; and C_i is the cultivated land area of division i (10^{2} hm^{2}).

2.4.3 Calculation of Non-Planting Industry Water Demand Non-planting industry water demand includes domestic water, urban public water, industrial water, and agricultural water (forest-grassland irrigation and livestock water) in production water, as well as in-stream and off-stream ecological water in ecological water[25]. The specific calculation process is shown in Table 3.

3 Results and Analysis

3.1 Analysis of Cultivated Land Correction Coefficient and Planting Scale

Figure 1 shows the sown area before and after interpretation correction and the cultivated land correction coefficient for the 13 divisions. Overall, the Corps' cultivated land correction coefficient is 1.27, indicating that approximately 27% of cultivated land is not included in statistics. Among the 13 agricultural production divisions, the Fifth Division has the highest correction coefficient at 1.48, while the Sixth Division has the lowest at only 1.11. The average correction coefficients for the 8 divisions in northern Xinjiang, 4 divisions in southern Xinjiang, and 1 division in eastern Xinjiang are 1.24, 1.33, and 1.35, respectively. Eastern Xinjiang has the highest coefficient, but this region only includes the Thirteenth Division, which ranks fourth among all divisions. Northern Xinjiang has the lowest overall correction coefficient, but the divisions with the highest and lowest coefficients are both located in northern Xinjiang. Although the Eighth Division's correction coefficient of 1.23 is lower than the Corps average, its corrected planting scale remains the largest due to its cultivated land area far exceeding other divisions (over 30×10^{4} hm^{2}). The Fourteenth Division in southern Xinjiang has the smallest corrected cultivated land area at 1.40×10^{4} hm^{2}. According to regional statistics, the total sown areas of the 8 northern Xinjiang divisions, 4 southern Xinjiang divisions, and 1 eastern Xinjiang division are 110.76×10^{4} hm^{2}, 46.85×10^{4} hm^{2}, and 3.46×10^{4} hm^{2}, respectively, accounting for 68.76%, 29.09%, and 2.15% of the Corps' total sown area.

[Figure 1: see original paper]

3.2 Analysis of Water Demand in the Corps

Based on statistical cultivated land data, the Corps' total water demands under the "conventional," "mulch," and "mixed" irrigation scenarios are 115.87×10^{8} m^{3}, 96.53×10^{8} m^{3}, and 106.45×10^{8} m^{3}, respectively, with significant differences among divisions (Figure 2). Compared with the Corps' actual engineering water supply of 117.24×10^{8} m^{3}, none of the three scenarios are overloaded, but the "conventional" and "mixed" irrigation scenarios are in a critical state, with surpluses of 1.17% and 9.20%, respectively. The Corps' agricultural water proportion is extremely high, with agricultural water demands under the three scenarios accounting for 95.68%, 94.98%, and 95.30% of total water demand, respectively, indicating that agricultural production scale determines the water demand of each division.

Based on remote sensing-corrected cultivated land data, the Corps' total water demands under the "conventional," "mulch," and "mixed" irrigation scenarios are 137.65×10^{8} m^{3}, 114.24×10^{8} m^{3}, and 125.64×10^{8} m^{3}, respectively—about 20×10^{8} m^{3} higher than calculations based on statistical data. Only the "mulch" irrigation scenario does not exceed the Corps' actual water supply of 117.24×10^{8} m^{3}. Although the correction coefficient in eastern Xinjiang is the highest, the region only includes the Thirteenth Division, whose water demand remains relatively small. Under the three irrigation scenarios, the total water demand of the Corps is 125.64×10^{8} m^{3} in the mixed irrigation scenario.

[Figure 2: see original paper]

Under the mixed irrigation scenario, the First Division has the highest total water demand, followed by the Eighth Division; the Twelfth Division has the lowest, with the Ninth, Tenth, Thirteenth, and Fourteenth Divisions also having relatively low water demands. Since grain crops (rice, wheat, and corn), cotton, and other crops have different irrigation quotas, each division's total water demand is also affected by planting structure. Most divisions have smaller grain planting scales than cotton, so the increase in grain water demand is offset by the decrease in cotton water demand. Only the Fourth and Ninth Divisions have slightly higher water demands in the "mixed" scenario than in the "conventional" scenario; the remaining divisions have medium water demands in the "mixed" scenario.

Under the mixed scenario, water demand components for each division are basically dominated by planting (Table 4). The Ninth Division is the only division without cotton planting, so its water demand in the mixed scenario is higher than in the conventional scenario. Additionally, the Fourth Division has the largest sown area of grain crops (rice, wheat, and corn) among all divisions, accounting for 52.51% of major crop area, while cotton accounts for only 4.79%, making its total water demand in this scenario reach 4.36×10^{8} m^{3}, even higher than the 4.42×10^{8} m^{3} in the conventional scenario. The Twelfth Division has relatively high water demand for other industries and domestic/ecological uses, with domestic, industrial, urban public, and off-stream ecological water demands accounting for 11.06%, 0.30%, 3.32%, and 0.41%, respectively, ranking first among all divisions, indicating a relatively high industrialization level. In contrast, the Fourteenth Division in southern Xinjiang has a total water demand of 2.50×10^{8} m^{3}, with a water demand scale closest to the Twelfth Division, but its agricultural water proportion is the highest at 98.06%, leaving almost no water for other uses, with industrial water accounting for only 0.27%—the lowest among all divisions, indicating a small industrial development scale.

3.3 Analysis of Water Resources Carrying Status in the Corps

3.3.1 Water Resources Carrying Status Based on Statistical Data Based on the mixed irrigation scenario calculated from statistical data, the water resources carrying status of each division was analyzed (Table 5). The Corps' total water supply is 117.24×10^{8} m^{3}, and the total water demand under the mixed irrigation scenario is 106.45×10^{8} m^{3}, which does not exceed the supply. In this scenario, a total of 6 divisions are in a critical state, while the other 7 divisions show varying degrees of overload. The Eighth Division has the highest water resources overload at 1.98×10^{8} m^{3}, while the Ninth Division has the most severe overload status. The Fourth and Tenth Divisions have relatively high water resources surpluses of 9.61×10^{8} m^{3} and 9.76×10^{8} m^{3}, respectively, with surplus ratios as high as 9.19% and 9.99%.

From a regional perspective, the Second and Third Divisions in southern Xinjiang are not overloaded; the First and Fourteenth Divisions are generally overloaded with degrees of 4.70% and 3.25%, respectively. Eastern Xinjiang's Thirteenth Division is moderately overloaded at 27.34%. Among all divisions, although the Twelfth Division has the lowest total water demand in the Corps, it is in a critical state due to its agricultural water demand proportion being the lowest. The Ninth Division, with the most severe overload status, and the Eighth Division, with the largest overload volume, are both located in northern Xinjiang. Additionally, the Fifth and Twelfth Divisions in northern Xinjiang have water supply surpluses of 0.23×10^{8} m^{3} and 0.27×10^{8} m^{3}, respectively.

3.3.2 Water Resources Carrying Status Based on Remote Sensing-Corrected Cultivated Land Data The total water demand under the mixed irrigation scenario estimated based on remote sensing-corrected cultivated land data is 125.64×10^{8} m^{3}, indicating that the Corps' water resources utilization is overloaded by 7.16%, and the contradiction between water supply and demand is more prominent in local areas (Figure 3). Only the Fourth and Tenth Divisions are not overloaded; the Second, Sixth, and Twelfth Divisions are in a critical state; and the other divisions have varying degrees of overload, with 5 divisions in general overload status and 4 divisions in severe overload status. Among the overloaded divisions, the First Division has the highest overload volume at 5.46×10^{8} m^{3}, mainly due to its excessively large agricultural production scale and constraints from agricultural production conditions. The Eighth Division ranks second in overload volume due to its largest cultivated land scale in the Corps—although it has advanced water-saving technology, its excessive scale leads to severe water resources overload of about 4.94×10^{8} m^{3}. In terms of overload degree, the Ninth Division still has the highest water resources overload degree, followed by the Thirteenth Division (moderate overload), and the Eighth and First and Fifth Divisions.

[Figure 3: see original paper]

4 Conclusions

Using the GEE big data platform, this study accurately measured the Corps' actual cultivated land area and planting scale through precise remote sensing interpretation. Simultaneously, it constructed a comprehensive "living-production-ecology" water accounting system, achieving accurate accounting of the Corps' water use and providing references for water resources utilization, optimal allocation, and regional sustainable development. The main conclusions are as follows:

1) The Corps' cultivated land correction coefficient is 1.27, indicating that approximately 27% of cultivated land is not included in statistics, with division-level coefficients ranging from 1.11 to 1.48. The total water demands of the Corps under the conventional irrigation, above-mulch irrigation, and mixed irrigation scenarios calculated from statistical data are 115.87×10^{8} m^{3}, 96.53×10^{8} m^{3}, and 106.45×10^{8} m^{3},

respectively. Compared with the Corps' actual engineering water supply total of 117.24×10^{8} m^{3}, none of the three irrigation scenarios reaches overload. However, after remote sensing correction of cultivated land area, the total water demands under the three scenarios are 137.65×10^{8} m^{3}, 114.24×10^{8} m^{3}, and 125.64×10^{8} m^{3}, respectively. Only the above-mulch irrigation scenario is not overloaded.

2) Comparing the Corps' water demand under the mixed irrigation scenario before and after cultivated land area correction shows that before correction, the Corps' water resources were not overloaded and still had surplus, while after correction, the results show that the Corps' total water resources are overloaded by 7.16%. Only 2 of the 13 divisions are not overloaded. Existing studies have found phenomena such as cultivated land salinization, vegetation degradation, surface water cutoff, and groundwater level decline in the Corps[5,12,20,25], which provide strong evidence of water resources overload. Therefore, accurate correction of cultivated land area is key to achieving precise assessment of water resources carrying status. The comprehensive "living-production-ecology" water accounting system constructed in this study enriches water use details and structure, becoming an important foundation for precise analysis of water resources carrying status.

3) According to the *Xinjiang Production and Construction Corps Statistical Yearbook* and the calculation results of this study, agriculture uses 96.01% of economic water to produce only 21.69% of output value, while industry and services use 2.95% of economic water to produce 78.31% of output value. Relying solely on agriculture is insufficient to drive the Corps' economic development. The principle of "determining land by water"[12,20] must be adhered to, and production methods must be transformed while ensuring food security[25] to guarantee water use for new industrialization and urbanization. Additionally, the distribution of water resources within the Corps' jurisdiction does not completely match the socioeconomic development pattern, and the reasons for overload vary among divisions and regions. There is an urgent need to accelerate basin water resources allocation, strengthen refined management, and comprehensively improve water resources carrying capacity[12,20,25,31].

References

[1] Huang Huiping, Zhang Chen. LUCC and analysis of water resources effect in arid area: A case of Ganzhou District, Zhangye, Gansu Province[J]. Research of Soil and Water Conservation, 2009, 16(4): 270-274.

[2] Shao Shuanglin, Chen Hongyan. Evaluation of water resources utilization and water use level of Xinjiang Production and Construction Corps[J]. Water Conservancy Planning and Design, 2010(3): 38-39, 49.

[3] Zhou Hongfei, Wu Bo, Wang Yugang, et al. Ecological achievement of Xinjiang Production and Construction Corps and its problems and countermeasures[J]. Bulletin of Chinese Academy of Sciences, 2017, 32(1): 55-63.

[4] Cheng Gang. Agricultural development and oasis ecosystem evolution in Shihezi reclamation zone: Based on the analysis about the ecosystem service function[D]. Shihezi: Shihezi University, 2013.

[5] Feng Ling. Influence to oasis ecological environment owing to the way of water resources in Shihezi[J]. Journal of Shihezi University (Philosophy and Social Science Edition), 2005, 19(2): 9-12.

[6] Tan M H, Zheng L Q. Increase in economic efficiency of water use caused by crop structure adjustment in arid areas[J]. Journal of Environmental Management, 2019(230): 386-391.

[7] Chen Z K, Niu Y P, Zhao R H, et al. The combination of limited irrigation and high plant density optimizes canopy structure and improves the water use efficiency of cotton[J]. Agriculture Water Manage, 2019(218): 139-148.

[8] Yang G, Li F D, Chen D, et al. Assessment of changes in oasis scale and water management in the arid Manas River Basin, northwestern China[J]. Science of the Total Environment, 2019(691): 1086-1098.

[9] Yang G, Tian L J, Li X L, et al. Numerical assessment of the effect of water saving irrigation on the water cycle at the Manas River Basin oasis, China[J]. Science of the Total Environment, 2020(707): 135587, doi: 10.1016/j.scitotenv.2019.135587.

[10] Li Nianliang. Water resources allocation and optimization simulation of Xinjiang Corps Thirteenth Division[D]. Xi'an: Xi'an University of Technology, 2019.

[11] Zhang Min. Preliminary analysis of existing problems and solutions of water saving irrigation development in Xinjiang Construction Crops[J]. Water Saving Irrigation, 2013(7): 79-80.

[12] Chinese Academy of Engineering. Study of strategy on water resources in sustainable development of Xinjiang[R]. Beijing: Chinese Academy of Engineering, 2012.

[13] Hu Y F, Hu Y. Land cover changes and their driving mechanisms in Central Asia from 2001 to 2017 supported by Google Earth Engine[J]. Remote Sensing, 2019, 11(5): 554, doi: 10.3390/rs11050554.

[14] Chinese Academy of Engineering. Special report and research report on Sustainable Utilization of Water and Soil Resources and Ecological Civilization Construction in Xinjiang[R]. Beijing: Chinese Academy of Engineering, 2014.

[15] Hu Yunfeng, Shang Lingjie, Zhang Qianli, et al. Land change patterns and driving mechanism in Beijing since 1990 based on GEE platform[J]. Remote Sensing Technology and Application, 2018, 33(4): 573-583.

[16] Li Jianjun, Luo Geping, Ding Jianli, et al. Effect of progress in artificial irrigation and drainage technology on the change of cultivated land pattern in the past 50 years in Manasi River Watershed[J]. Journal of Natural Resources, 2016, 31(4): 570-582.

[17] Li Mingsi, Liu Hongguang, Zheng Xurong. Spatiotemporal variation for soil salinity of field land under long term mulched drip irrigation[J]. Transactions of the Chinese Society of Agricultural Engineering, 2012, 28(22): 82-87.

[18] Yu Piaojia, Xu Hailiang, Qiao Mu, et al. Arable land in the Manas River Basin based on CBERS data[J]. Arid Zone Research, 2009, 26(6): 846-851.

[19] Wang Zhenhua, Yang Peiling, Zheng Xurong, et al. Soil salinity changes of root zone and arable in cotton field with drip irrigation under mulch for different years[J]. Transactions of the Chinese Society of Agricultural Engineering, 2014, 30(4): 90-99.

[20] Chen Zhikai, Wang Hao. Research on the supply and requirement development trend, rational allocation and sustainable utilization of water resources in Xinjiang[R]. Beijing: Chinese Academy of Engineering, 2012.

[21] Jiao Huiqing, Sheng Yu, Zhao Chengyi, et al. Modeling of multiple ions coupling transport for salinized soil in oasis based on COMSOL[J]. Transactions of the Chinese Society of Agricultural Engineering, 2018, 34(5): 100-107.

[22] Li Hongshan, Li Jiejun, Wu Rui, et al. Simple discussion on problems existed in forest for farm protection and countermeasures[J]. Journal of Gansu Forestry Science and Technology, 2007, 32(3): 79-81.

[23] Liu Yanzhen. Status quo and countermeasures of underground water of Agricultural Eighth Division[J]. Water Conservancy Science and Technology and Economy, 2011(17): 36-37, 44.

[24] Wang Dong, Meng Tao, Wang Yunzhi. Status quo analysis and countermeasures of underground water overdraft in Shihezi City, Xinjiang[J]. Ground Water, 2007, 29(2): 78-80.

[25] Wu Bin. Study on groundwater system evolvement law and water environment effect of Shihezi City[D]. Urumqi: Xinjiang Agriculture University, 2007.

[26] Wang Cheng, Yao Baolin, Wang Xingpeng, et al. Soil salt transfer law and water consumption characteristics for cotton with drip irrigation under mulch with dry sowing and wet seeding[J]. China Rural Water and Hydropower, 2012(10): 25-30.

[27] Wang Jing, Liu Guangming, Deng Jie. Industry supporting, ecology protection and urban sustainable development: A case of the Urumqi[J]. Arid Land Geography, 2016, 39(4): 868-876.

[28] Li Hailong, Wang Ling. Suitable oasis scale in Manas River Basin in the context of climate change[J]. Arid Land Geography, 2019, 42(1): 113-120.

[29] Fang Chuanglin. Strategic thinking and spatial layout for the sustainable development of urban agglomeration in northern slope of Tianshan Mountains[J]. Arid Land Geography, 2019, 42(1): 1-11.

[30] Zhang Xiaoyu, Xu Duanyang, Luzhou Yangfan, et al. Evolution simulation and regulation of production living ecological water system in Alax based on system dynamics[J]. Journal of Arid Land Resources and Environment, 2019, 33(8): 107-113.

[31] Wang Zhenhua. Salt movement trends in cotton fields with long term drip irrigation under mulch in typical oasis and irrigation management[D]. Beijing: China Agricultural University, 2014.

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