

Pattern of Employment-Structure Transformation of Rural Labor in Oasis Areas of Arid Regions and Its Economic Effects

Huang Jing, Xue Dongqian, Han Chen, Xu Jiaxiu

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Abstract

Studying the transformation of the employment structure of the rural labor force in arid-zone oases is conducive to the sustainable development of agriculture and rural areas. Taking Ganzhou District, a typical oasis in the middle reaches of the Heihe River, as an example, this study uses the structural transformation index and quadratic assignment procedure (QAP) regression analysis to examine the pattern and economic effects of the transformation of the rural labor employment structure in arid-zone oases from 2011 to 2020, and further explores its transformation mechanism and regulatory pathways. The results show that: (1) The rural labor employment structure presents a stable “132” pattern, with a low overall degree of transformation, dominated by refined intra-industry adjustments, and a strengthening trend toward local employment. (2) Township labor forces have formed typical transformation modes characterized by the rise of non-agricultural industries and a balanced structure of the three industries. Spatially, transformation in the core oasis area is relatively slow, the employment structure in the peripheral area is diversified, and industry category shifts are pronounced in the desert-oasis transition zone. (3) The economic pulling effect of non-agricultural industries on labor has been increasing, and the impact of employment structure transformation on income shows stage-specific characteristics: in the early stage, transformation in forestry and services is the main driving force; in the later stage, the role of construction transformation becomes prominent; and in the long term, income growth depends on the sustained positive effects of internal agricultural structural adjustment, among which the optimization of the local employment structure is key to promoting income improvement. (4) The transformation of the rural employment structure is a compound process triggered by rigid constraints on water resources, reinforced through ecological feedback, adjusted through livelihood adaptation, and ultimately manifested as economic responses and spatial differentiation. Accordingly, a zonal regulatory pathway is proposed: promoting the integration of the three industries in the core area, prioritizing the development of non-agricultural industries in the peripheral area, and cultivating a virtuous cycle mechanism of out-migration for work and return entrepreneurship in the transition zone. The findings provide a theoretical basis and practical reference for the rational allocation of rural labor resources and the optimization of the employment structure in arid-zone oases.

Full Text

Pattern of Employment-Structure Transformation of Rural Labor in Oasis Areas of Arid Regions and Its Economic Effects

—A Case Study of Ganzhou District

Huang Jing¹, Xue Dongqian², Han Chen¹, Xu Jiaxiu¹

(1. College of Environment and Life Sciences, Weinan Normal University, Weinan 714099, Shaanxi, China; 2. College of Geography and Tourism, Shaanxi Normal University, Xi'an 710119, Shaanxi, China)

Abstract: Studying the transformation of the employment structure of rural labor in oasis areas of arid regions is conducive to the sustainable development of agricultural and rural areas. Taking Ganzhou District, a typical oasis in the middle reaches of the Heihe River, as an example, this study applies the structural-transformation index and the quadratic assignment procedure (QAP) regression analysis method to investigate the pattern of rural labor employment-structure transformation and its economic effects in the oasis areas of arid regions from 2011 to 2020, and explores the mechanism of employment-structure transformation and regulatory pathways. The results show that: (1) The employment structure of rural labor presents a stable “132” pattern; the overall degree of transformation is not high, dominated by refined adjustment within industries, and the trend of local employment has strengthened. (2) Township labor has formed two typical transformation modes: upgrading of non-agricultural industries and balance among the three-sector structure. Spatially, transformation in the oasis core area is relatively slow, employment structures in peripheral areas are diversified, and sectoral-category conversion in the desert-oasis transition zone is intense. (3) The economic driving effect of non-agricultural industries on labor has been increasing, and the influence of employment-structure transformation on income shows stage-specific characteristics: in the early stage, transformation in forestry and services is the main driving force; in the later stage, the effect of transformation in construction becomes prominent; over the long term, it depends on the sustained positive effect of internal structural adjustment within agriculture, among which optimization of the local employment structure is key to promoting income growth. (4) The transformation of rural employment structure is triggered by rigid constraints of water resources, strengthened through ecological feedback, and adjusted through livelihood adaptability; ultimately, it manifests as a compound process of economic response and spatial differentiation. On this basis, this paper proposes a zonal regulatory pathway featuring “the core area promoting integration of the three industries, the peripheral areas focusing on the development of non-agricultural industries, and the transition zone cultivating a virtuous circulation mechanism of migrant work and return-home entrepreneurship.” The research results provide theoretical evidence and

practical reference for the rational allocation of rural labor resources and the optimization of employment structure in oasis areas of arid regions.

Keywords: oasis rural areas; labor employment; structural transformation; economic effects; QAP regression analysis

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Oases, relying on their unique hydrological and geographical conditions, have become the zones in arid regions where resources are most concentrated, population is densest, and agricultural production is most active¹. In the arid regions of northwestern China, oases are not only key areas for maintaining ecological balance, but also core zones for ensuring national food security and promoting rural revitalization and the modernization of agriculture and rural areas². However, the development of rural oasis areas in arid regions faces dual ecological and economic constraints: (1) irrational land use and extensive irrigation have intensified conflicts over water resources and caused ecological degradation³; (2) a large amount of labor remains in farming and animal husbandry, and a single employment structure constrains farmers' income growth and economic development⁴. On this basis, promoting the transformation of the employment structure of rural labor is the key to realizing rural revitalization, agricultural and rural modernization, and regional sustainable development in oasis areas of arid regions.

As the most dynamic element in rural development, labor—and the transformation of its employment structure—profoundly affects agricultural production efficiency, rural economic structure, and even the stability and sustainable development of rural society⁵. Since the acceleration of industrialization and urbanization in the late twentieth century, transformation of the employment structure of labor has gradually become a focus of academic research. Based on labor theory⁶ and the “dual pull” model⁷, scholars have explored the mechanisms by which rural labor shifts from agriculture to cities and non-agricultural industries⁸, and have examined the effects of changes in economic development⁹, industrial structure¹⁰, and the labor market¹¹ on employment promotion.

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Author profile: Huang Jing (1989-), female, PhD, lecturer, mainly engaged in research on adaptive transformation of rural oasis areas in arid regions. E-mail: huangjing1@wnu.edu.cn

Corresponding author: Xue Dongqian (1965-), male, PhD, professor, mainly engaged in research on regional sustainable development. E-mail: xuedq@snnu.edu.cn

interactions, and analyzed the influence of educational culture^[14], gender roles^[15], intergenerational relations^[16], and facility construction^[17] on employment transformation. In recent years, with the advancement of rural revitalization and digital-village construction, research has further expanded to mechanisms of rural labor-force transfer^[18] and return migration^[19-20] under strategic influence, the role of digital technologies in employment^[21], and the influence of digital cultural tourism on labor return flows^[22]. In the oasis system of arid regions, labor mobility is driven not only by economic laws, but is also constrained by water-resource scarcity and ecological fragility^[23]. Water-resource constraints directly restrict the carrying capacity of agricultural labor, promoting the transfer of labor from water-intensive agriculture to water-saving industries and non-agricultural sectors^[4,24]; at the same time, the particularity of oasis agriculture also promotes the formation of a flexible employment structure between planting and ecological service industries^[25]. Although new business forms such as specialty agriculture, rural tourism, and rural e-commerce help expand employment space, their implementation effectiveness still depends heavily on policies for sustainable water-resource management and ecological protection^[26]. Existing studies have provided a theoretical foundation for understanding labor-force transfer in arid regions, but this process is long-term and complex; empirical analysis requires reliable data support, while difficulty in data acquisition constrains research depth. In addition, existing studies mostly focus on metropolitan fringes^[27], tourist destinations^[28], and poverty-stricken mountainous areas^[29], while insufficient attention has been paid to the transformation of the employment structure of rural labor in oasis areas.

Oases are the core carriers of ecological, economic, and social functions in arid regions. Taking the Heihe River, China's second-largest inland river, as an example, the middle-stream oasis concentrates about 90% of the basin's cultivated land, population, and total production value. It is not only an important production base for agricultural products in Northwest China, but also a national ecological-security barrier^[30]. In recent years, climate warming has increased ice- and snowmelt water from the Qilian Mountains, while the continuous expansion of cultivated land in the middle reaches has resulted in an excessively high proportion of agricultural water use and the encroachment of ecological water

use, threatening regional ecological stability and constraining sustainable agricultural and rural development^[1]. Against this background, the traditional, single agricultural structure and employment model have become difficult to adapt to the new demands of oasis rural development. The years 2011-2020 were not only a key stage in which the contradictions among people, land, and water became prominent in arid-region oases, but also an important period in which China comprehensively advanced rural revitalization and agricultural and rural modernization. Driven by multiple policies, environmental factors, and development factors, rural transformation became a typical feature of this stage. Therefore, taking the oasis of Ganzhou District in the middle reaches of the Heihe River as an example, this study analyzes the transformation characteristics and economic effects of the employment structure of the rural labor force from 2011 to 2020, explores its formation mechanism, and constructs a regionally adaptive regulation pathway, with the aim of optimizing the allocation of labor resources and promoting ecological-environment improvement and sustainable rural development.

1 Data and Methods

1.1 Research Framework

The development of oasis villages in Ganzhou District has long been constrained by water resources and ecological fragility^[23]. The traditional employment model of high-water-consuming agriculture has become difficult to sustain, and existing research still has insufficient understanding of the particularity and complexity of the employment transformation process in oasis villages. To this end, this study constructs a four-in-one comprehensive research framework of “pattern-effect-mechanism-regulation,” aiming to reveal the internal logic of the structural transformation of the rural labor force in oasis villages under the background of human-water relationship evolution (Fig. 1). First, at the “transformation pattern” level, from the two scales of the entire district and townships, the study analyzes spatiotemporal changes in the number of employed persons, industrial distribution, and structural transformation index, revealing the spatial differentiation characteristics of labor transfer from traditional agriculture to secondary and tertiary industries. Second, at the “economic effect” level, it evaluates the per capita economic effects of different employment sectors and quantifies the interactive relationship between employment-structure transformation and regional economic development. Third, at the “formation mechanism” level, from the perspective of system coordination, it discusses the compound process in which water-resource and ecological constraints drive transformation of the production system, trigger reorganization of the employment structure, and give rise to differentiated regional economic effects. Finally, at the “regulation pathway” level, by combining sustainability tests and spatial mapping results, it proposes zoned guidance strategies and implements differentiated employment-structure optimization and adaptation measures in the oasis

Fig. 1 Research framework on the transformation of rural labor employment structure and its economic effects in oases of arid regions

Figure 1: Fig. 1 Research framework on the transformation of rural labor employment structure and its economic effects in oases of arid regions

core area, marginal area, and desert-mountain transition belt, so as to achieve coordination between people and water and sustainable rural development.

1.2 Overview of the Study Area

The Heihe River originates in the Qilian Mountains and extends to Juyan Lake at its tail end. Bounded by Yingluo Gorge and Zhengyi Gorge, it is divided into upper, middle, and lower reaches. The upper reaches are the runoff-generating area of the Heihe River Basin; the middle reaches have developed irrigated agriculture; and the lower reaches belong to an extremely arid region^[31]. Ganzhou District is located in the middle reaches of the Heihe River and is under the jurisdiction of Zhangye City, Gansu Province (38°32′–39°24′N, 100°06′–100°52′E). The district is 65 km wide from east to west and 98 km long from north to south, with a total area of 3661 km². Within the district are the southern Qilian Mountains, the northern Heli Mountains and Longshou Mountains, and the central Zoulang Plain; the terrain is high in the north and south and low in the middle, with elevations of 1369–3639 m (Fig. 2). In 2020, the resident population of Ganzhou District was 51.91×10^4 , of which the rural population accounted for 46.43%. It has jurisdiction over 18 townships. With reference to relevant studies^[32], these are divided into the oasis core area (including Wujiang Town, Jing'an Township, Shajing Town, Mingyong Town, Xindun Town, Chang'an Town, Liangjiadun Town, Shangqin Town, and Xiaoman Town), the marginal area (including Ganjun Town, Longqu Township, Damantown, Dangzhai Town, Jiantan Town, and San 阡 Town), and the desert-mountain transition belt (including Huazhai Township, Anyang Township, and Ping Shanhu Township). Because of long-term overdependence on irrigated agriculture, together with the expansion of artificial oases and high-intensity groundwater exploitation, Ganzhou District has already shown an obvious problem of oasis degradation^[32], making it an ideal study area for exploring the employment transformation of the rural labor force and optimizing and adjusting the people-land-water relationship.

1.3 Research Methods

1.3.1 Structural Transformation Index

To clarify the transformation of the rural labor-force employment structure, this paper introduces a structural transformation index to describe the characteristics of changes in the labor-force employment structure during the process of rural transformation and development^[33]. The specific calculation formula is as follows:

Fig. 2 Schematic diagram of the study area

Figure 2: Fig. 2 Schematic diagram of the study area

Fig. 1 Research framework on the transformation of rural labor employment structure and its economic effects in oases of arid regions

(a) Location map (b) Township topographic map

Note: The map was prepared based on the standard map with approval number GS(2019)3266 from the Standard Map Service website of the Ministry of Natural Resources; the boundaries of the base map were not modified.

Fig. 2 Schematic diagram of the study area

$$\theta = \cos^{-1} \left\{ \frac{\sum_i P_i(t) \times P_i(t-n)}{\sqrt{[\sum_i P_i(t)^2] \times [\sum_i P_i(t-n)^2]}} \right\} \quad (1)$$

In the formula: θ is the structural transformation index, used to measure changes in the employment structure between different time points; $P_i(t)$ is the proportion of employment type i in total employment in year t ; $P_i(t-n)$ is the proportion of employment type i in total employment in year $t-n$. When the population of all employment types at the time point is not ...

changes, θ is 0; conversely, if among the entire set of employed persons in year $t-n$ one type is involved, while among the entire set of employed persons in year t another type is involved, then θ is 90; in other cases, θ varies between 0 and 90. This index can be used to measure the degree of change in the employment structure between any two years.

1.3.2 QAP regression analysis

To analyze the impact of the transformation of the rural labor employment structure on economic development, this paper draws on the quadratic assignment procedure (QAP) regression method in social network analysis [34]. From the perspective of structuralist relations, it analyzes the influence of differences in the transformation of employment structures among townships on changes in the gap in farmers' per capita net income.

This paper takes the transformation differences in the shares of township employment in crop farming, forestry, animal husbandry, fishery, industry, construction, services, and migrant employment as the driver-factor matrices, and takes the change differences in township farmers' per capita net income as the explained-variable matrix. Based on QAP regression analysis, a model is constructed for the driving factors of differences in changes in township farmers' per capita net income. The expression is as follows:

$$I = f(P, F, A, FS, ID, C, S, O) \quad (2)$$

In the formula: I is the matrix of differences in changes in township farmers' per capita net income; P is the matrix of transformation differences in the share of township employment in crop farming; F is the matrix of transformation differences in the share of township employment in forestry; A is the matrix of transformation differences in the share of township employment in animal husbandry; FS is the matrix of transformation differences in the share of township employment in fishery; ID is the matrix of transformation differences in the share of township employment in industry; C is the matrix of transformation differences in the share of township employment in construction; S is the matrix of transformation differences in the share of township employment in services; and O is the matrix of transformation differences in the share of township migrant employment.

1.4 Data sources

The data involved in this study—rural and township labor resources, distribution of personnel by employment industry, total income of each industry, and farmers' per capita net income in Ganzhou District from 2011 to 2020—come from the *Ganzhou District Statistical Yearbook*, the *Ganzhou District Agricultural Statistical Yearbook*, and the *Ganzhou District Township Yearbook*. To facilitate analysis of the characteristics of labor employment-structure transformation, the rural labor employment industries are divided, according to broad industrial categories, into the primary industry, secondary industry, and tertiary industry; the detailed categories included are shown in Table 1.

2 Results and analysis

2.1 Spatiotemporal pattern of the transformation of the rural labor employment structure

2.1.1 Overall pattern Judging from changes in rural labor resources and employed persons in Ganzhou District from 2011 to 2020 (Fig. 3), labor resources showed a process of “first increasing and then decreasing.” Although the number of employed persons fluctuated accordingly, the magnitude of fluctuation was relatively moderate. The proportion of employed persons in total labor resources ranged from 87.97% to 91.07%, showing an overall downward trend, reflecting that the overall scale of rural labor employment in Ganzhou District was generally stable, but faced the challenge of pressure on employment capacity.

Judging from the distribution proportions of rural labor employment by industry in Ganzhou District from 2011 to 2020 (Table 2), the employment structure presented a “primary industry > tertiary industry > secondary industry” “132”

Fig. 3 Rural labor resources and employed persons in Ganzhou District from 2011 to 2020

Figure 3: Fig. 3 Rural labor resources and employed persons in Ganzhou District from 2011 to 2020

pattern. During this period, the primary industry always occupied the dominant position, with the proportion of employed persons ranging from 50% to 60%; within it, crop farming and animal husbandry were the main forms of employment. The tertiary industry ranked next, with employment mainly in “other services, transportation, storage and postal services, wholesale and retail, accommodation and catering.” The secondary industry had the lowest employment share, and its internal structure showed that the proportion employed in construction was significantly

Table 1 Overview of rural labor employment by industry group in Ganzhou District

Broad industrial category	Detailed categories
Primary industry	Crop farming, forestry, animal husbandry, fishery
Secondary industry	Industry, construction
Tertiary industry	Transportation, storage and postal services; information transmission, computer services and software; wholesale and retail; accommodation and catering; scientific research and comprehensive technical services; education, culture, arts and radio, film and television; health, sports and social welfare; township economic organizations (township enterprises) management; finance and insurance; other services

Fig. 3 Rural labor resources and employed persons in Ganzhou District from 2011 to 2020

Table 2 Distribution proportion of rural labor employment by industry in Ganzhou District from 2011 to 2020 /%

Tab. 2 Distribution proportion of rural labor employment by industry in Ganzhou District from 2011 to 2020

Industry type	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Primary industry	54.26	52.49	52.71	52.75	53.28	52.66	54.22	58.24	57.31	56.22
Crop farming	46.08	44.54	43.89	43.57	44.11	43.61	44.93	48.58	47.85	46.50
Forestry	1.07	0.93	1.03	0.90	1.02	0.79	0.71	1.40	1.70	1.61
Animal husbandry	7.06	7.00	7.74	8.26	8.12	8.23	8.56	8.24	7.74	8.08
Fishery	0.05	0.03	0.05	0.02	0.02	0.02	0.03	0.03	0.02	0.03
Secondary industry	46.89	47.56	47.48	47.54	47.61	47.97	47.75	46.60	46.07	46.17
Industry	5.03	4.76	4.45	4.35	4.24	4.28	4.24	3.74	3.42	3.51
Construction	11.86	12.80	13.03	13.19	13.37	13.69	13.50	12.86	12.66	12.65
Tertiary industry	28.85	29.95	29.81	29.71	29.11	29.36	28.03	25.16	26.62	27.61
Transportation, storage and postal services	5.73	5.79	4.66	4.56	4.53	4.55	4.41	3.62	3.28	3.32
Information transmission, computer services and software	0.58	0.52	0.52	0.51	0.49	0.49	0.52	0.50	0.54	0.55

Industry type	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wholesale and retail trade	4.14	4.24	4.03	3.99	4.01	4.12	4.06	3.62	3.84	3.90
Accommodation and catering	2.03	2.38	2.69	2.71	2.64	2.71	2.67	2.13	2.29	2.20
Scientific research, technical services and integrated technical services	0.02	0.02	0.03	0.03	0.04	0.03	0.03	0.02	0.05	0.06
Education, culture, arts, radio, film and television	0.21	0.22	0.24	0.24	0.26	0.25	0.25	0.12	0.18	0.19

Industry type	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Health, sports and social welfare	0.16	0.16	0.22	0.21	0.23	0.23	0.25	0.20	0.25	0.26
Township economic organization (multi-township) management	0.06	0.06	0.11	0.56	0.67	0.48	0.58	0.55	0.43	0.26
Financial and insurance services	0.32	0.26	0.35	0.31	0.49	0.33	0.50	0.43	0.70	0.52
Other services	15.40	16.31	16.96	16.58	15.76	16.19	14.75	13.97	15.05	16.35
Ganzhou District laborers employed outside the district	12.35	11.95	12.73	11.92	11.09	10.94	10.07	8.99	10.37	10.38

It is characterized by being higher than industry. The proportion of Ganzhou District's laborers employed outside the district is between 8.99% and 12.73%, a relatively low level, indicating that rural labor in Ganzhou District is mainly employed locally.

To clarify the degree of transformation in the rural labor employment structure of Ganzhou District, the transformation indices of employment structure among the three industries, among detailed sectors, and between local and outside-district employment were calculated respectively. As shown in Table 3, from 2011 to 2020, the total transformation indices of rural labor among the three industries, among detailed sectors, and between local and outside-district employment were 3.97, 5.97 and 1.42, respectively, indicating that the overall degree of transformation in the rural labor employment structure was not high, and that it mainly occurred within industries and between agriculture and non-agriculture. By dimension, the transformation index among the three industries rose from 1.02 in 2011–2015 to 2.95 in 2015–2020, indicating that labor mobility among the three industries strengthened; the index among detailed sectors remained at a high level throughout, showing that adjustment of the intra-industry employment structure was continuously active; the local–outside-district index decreased from 0.91 to 0.51, reflecting weakened cross-regional labor mobility and an increasing tendency for employment to become localized.

2.1.2 Spatiotemporal pattern

To analyze the spatiotemporal transfer pattern of the rural labor employment structure in Ganzhou District, the proportions of employed persons in the three industries in each township in 2011, 2015 and 2020 were calculated respectively, and then a transfer-pattern mulberry diagram was generated based on Origin software. As shown in Figure 4, the trend of labor transfer from the primary industry to the secondary and tertiary industries is obvious. In addition to the agriculture-dominated type, typical transformation patterns formed include the non-agricultural industry rising type and the balanced three-industry structure type. The agriculture-dominated type includes Ganzun Town, J alkaline Town, Mingyong Town, San 阡 Town, Shajing Town, Wujiang Town, Xiaoman Town and Chang' an Town; the proportion employed in the primary industry was always higher than 40% and showed an upward trend, while the proportions in the secondary and tertiary industries were limited. These townships rely on oasis agriculture as the economic pillar, and the transformation impetus is relatively insufficient. The non-agricultural industry rising type covers Anyang Township, Daman Town, Longqu Township, Xindun Town, Huazhai Township, Jing' an Township and Ping Shanhu Township; the proportion in the primary industry declined significantly, while the proportion in the secondary or tertiary industry rose. These townships mainly rely on advantages such as ecological tourism, urban-area services or agricultural product processing to promote the transfer of labor toward non-agricultural industries. The balanced three-industry structure

type is represented by Dangzhai Town, Liangjiadun Town and Shangqin Town; the proportions of the primary, secondary and tertiary industries are balanced, each accounting for 20%-40%, and multi-year changes

Table 3 Transformation index of rural labor employment structure in Ganzhou District from 2011 to 2020

Tab. 3 Transformation index of rural labor employment structure in Ganzhou District from 2011 to 2020

Year	Among the three industries	Among detailed sectors	Between local and outside-district employment
2011–2015	1.02	3.34	0.91
2015–2020	2.95	2.63	0.51
2011–2020	3.97	5.97	1.42

- (a) Anyang Township (b) Daman Town (c) Dangzhai Town
 (b) Ganjun Town (e) Huazhai Township (f) Jianzha Town
 (c) Jing' an Township (h) Liangjiadun Town (i) Longqu Township
 (d) Mingyong Town (k) Pingshanhu Township (l) San' na Town
 (e) Shajing Town (n) Shangqin Town (o) Wujiang Town
 (f) Xiaoman Town (q) Xindun Town (r) Chang' an Town

Fig. 4 Transfer pattern of distribution proportion of rural labor force employed population in Ganzhou District from 2011 to 2020

The situation is stable, presenting a diversified and coordinated development pattern. In summary, the foundational position of oasis agriculture in Ganzhou District remains stable, but water-resource pressure and ecological constraints have prompted the labor force to continue spilling over into non-agricultural sectors. The specific direction of transformation is significantly influenced by location, policy, and resource endowments.

To further reveal the spatiotemporal transformation characteristics of the employment structure of the rural labor force in Ganzhou District, the employment-structure transformation index for 2011–2015 and 2015–2020 was calculated. Combined with GIS spatial visualization, and through summation, the overall transformation level for 2011–2020 was obtained, as shown in Fig. 5.

- (a) Inter-industry among the three sectors, 2011–2015
 (b) Inter-industry among the three sectors, 2015–2020
 (c) Inter-industry among the three sectors, 2011–2020
 (d) Inter-industry among detailed sectors, 2011–2015

- (e) Inter-industry among detailed sectors, 2015–2020
- (f) Inter-industry among detailed sectors, 2011–2020
- (g) Local-out-migration, 2011–2015
- (h) Local-out-migration, 2015–2020
- (i) Local-out-migration, 2011–2020

Legend: township boundary; employment structure transformation index; [0, 5]; (5, 15]; (15, 45]

Fig. 5 Transformation index of rural labor employment structure in Ganzhou District from 2011 to 2020

...indicates that the pattern of employment structure transformation is highly correlated with the geographic location of the core area of the oasis, the peripheral area, and the desert–mountain transition belt. Among the three industries, the transformation index in the core area is generally low, with the labor force mainly concentrated in agriculture and animal husbandry. In the later period, although there was a shift toward rural tourism, commercial and trade services, and other industries, the process was slow. The transformation index in the peripheral area showed a coexistence of low, medium, and high levels; transformation was relatively pronounced in Jiuquan Town and Sanjian Town, and the structure tended to be diversified. The transformation index in the transition belt was generally relatively high; most of the labor force consisted of seasonal migrant workers, with strong mobility. Among fine-grained categories, the core area was still dominated by traditional planting and breeding, supplemented by facility agriculture, agricultural-product processing, and logistics, and the overall transformation was limited. In the peripheral area, transformation was intense in the early stage; small-scale manufacturing and retail services developed rapidly, and the employment structure tended to diversify. In the later stage, the transformation level in Jiandian Town, Dangzhai Town, and other places fell back. In the transition belt, the degree of transformation was mainly medium to high, with Huazhai Township and Pingchuan Lake Township being particularly prominent; the labor force shifted toward eco-tourism, construction, and outbound services, and category conversion was intense, reflecting adaptive choices under water-resource constraints. For local and migrant employment, the overall labor-force transformation index was not high. From 2011 to 2015, both banks of the Heihe River, Dangzhai Township, Huazhai Township, and other places were affected by restrictions on cultivated-land expansion and insufficient local employment momentum, so migrant work was significant. From 2015 to 2020, driven by the rural revitalization policy, local non-agricultural employment accelerated, the trend of migration slowed, and an employment model characterized by return flows took shape. Overall, the transformation of the rural labor-force employment structure in Ganzhou District shows a spatiotemporal pattern of “slow in the core area, diversified in the peripheral area, and intense in the transition belt.” This pattern not only reflects the constraints im-

posed by the natural conditions of the arid-zone oasis on employment paths, but also embodies the evolutionary trend of the labor force shifting from subsistence-oriented to development-oriented under the drive of policy and the market.

2.2 Economic effects of the transformation of the rural labor-force employment structure

2.2.1 Differences in economic income among different employment industries

To analyze the relationship between rural labor-force employment and economic development, based on the income data and the ratio of personnel distribution in rural labor-force employment industries in Ganzhou District in 2011, 2015, and 2020, the per capita income of each employment industry can be obtained. As shown in Table 4, from 2011 to 2020, the overall economic effects ranked from high to low as animal husbandry, industry, fishery, forestry, service industry, construction, and planting. From the perspective of change trends, the per capita income of non-agricultural industries such as services, construction, and industry continued to grow. Within agriculture, only animal husbandry grew steadily; although the benefits of planting increased, its later momentum was insufficient and its absolute level was relatively low, while forestry and fishery showed a “rise first and then fall” pattern, with insufficient development stability. It can be seen that the rural economic structure is being adjusted and optimized, and the economic pulling effect of non-agricultural industries on the labor force is increasingly strengthening.

2.2.2 Impact of employment structure transformation on economic development

To further explore the impact of rural employment structure transformation on economic development, the QAP regression analysis method was used to test the impact of differences in township employment structure transformation on the variation distance of farmers’ per capita net income. As shown in Table 5, the impact of the transformation of the rural labor-force employment structure on farmers’ per capita net income shows different stage effects. From 2011 to 2015, the transformation of forestry and service industries became the main driving force for income growth, while the transformation of planting showed a significantly negative correlation, indicating that the transfer of planting labor during this period failed to be effectively converted into income improvement. From 2015 to 2020, construction transformation became the only significant positive influencing factor, reflecting the pulling effect of infrastructure construction and urbanization on income. At the same time, the driving effect of the service industry turned negative, indicating a stage-based conversion of driving momentum. Over the whole study period, the transformation of traditional agricultural sectors showed a sustained income-increasing effect; in particular, planting, forestry, and animal husbandry all showed significant positive correla-

tions, indicating that within the agricultural sector...

Table 4 Economic effect of rural labor force employment industry in Ganzhou District from 2011 to 2020

Employment industry	Per capita income / yuan • person ⁻¹	2011	2015	2020	Average
Planting		18665	32080	36531	29092
Forestry		50317	66670	46027	54338
Animal husbandry		81429	101283	133906	105539
Fishery		66158	113800	92250	90736
Industry		59827	93923	126619	93456
Construction		24982	31403	53395	36593
Service industry		25090	46847	64945	45627

Table 5 Impact of the transformation of the rural labor force employment structure in Ganzhou District on the per capita net income of farmers

Variable	Standardized regression coefficient: 2011-2015	Standardized regression coefficient: 2015-2020	Standardized regression coefficient: 2011-2020
Planting transformation difference matrix	-0.2233**	0.0006	0.2249*
Forestry transformation difference matrix	0.4094***	0.0228	0.3143**
Animal husbandry transformation difference matrix	-0.1224	0.0371	0.2449***

Variable	Standardized regression coefficient: 2011- 2015	Standardized regression coefficient: 2015- 2020	Standardized regression coefficient: 2011- 2020
Fishery trans- formation difference matrix	-0.0794	0.1542	-0.0658
Industry transforma- tion difference matrix	0.0004	0.1205	0.0915
Construction transforma- tion difference matrix	-0.0358	0.2383*	-0.1142*
Service industry transforma- tion difference matrix	0.3196**	-0.0801	-0.0293
Out- migration transforma- tion difference matrix	-0.1051	-0.0231	0.0013
R^2	0.3310	0.3200	0.3520
P value	0.0000	0.0000	0.0000

Note: R^2 is the proportion of the variance of the dependent variable explained by the independent variables; , , **and** indicate significance at the 10%, 5%, and 1% levels, respectively.

employment adjustment helps income growth in the long run; however, the long-term effect of the construction industry turns significantly negative, implying that it is difficult to sustain income support by relying solely on the expansion of this sector. In addition, although the effects of transformation in fisheries, industry, and out-migration do not pass the significance test, it can be seen that the effect brought about by fisheries transformation is insufficiently stable; industrial transformation is consistently of positive significance for income growth; and out-migration shows a pattern of short-term suppression and long-

term mitigation, reflecting that labor outflow exerts pressure on income in the initial stage, but its impact turns from negative to positive over time. Overall, optimization of the local employment structure is the key factor affecting changes in income.

3 Discussion

3.1 Mechanism of Employment-Structure Transformation in Oasis Villages in Arid Areas

Against the backdrop of climate change and intensified human activities, oases in arid areas face multiple challenges such as water-resource scarcity and ecological degradation

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, and their rural territorial systems are undergoing a profound transformation driven by rigid water-resource constraints. As a core manifestation of this systemic transformation, employment-structure transformation is, in essence, a compound outcome of the interaction among water-resource constraints, ecological feedback, livelihood adjustment, and economic response. First, water-resource constraints are the direct driving force of employment transformation. Water resources in the oasis of arid Ganzhou District are scarce, while agricultural irrigation accounts for 80%–90% of total water use, leading to intense competition among production, ecological, and domestic water use

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. Once development intensity exceeds the carrying-capacity threshold, it directly triggers agricultural shrinkage, labor surplus, and ecological degradation, thereby forcing the transformation of the employment structure

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. Second, ecological vulnerability is the spatial mapping and feedback of resource constraints. Excessive cultivation and groundwater overexploitation lead to problems such as soil salinization and vegetation degradation

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. This not only directly weakens agricultural output capacity and employment capacity, but also further squeezes agricultural production space by increasing ecological-governance costs, thereby amplifying employment pressure caused by resource constraints. Third, employment transformation is an adaptive adjustment of the livelihood system. Under the above resource and ecological pressures, the transfer of labor from agriculture to secondary and tertiary industries has become an inevitable trend

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, and differentiated spatial response patterns have formed in geographical units such as the oasis core area, the marginal area, and the desert-mountain transition zone. Finally, economic effects are a test of transformation outcomes and sustainability. Employment-structure transformation drives the optimization of the regional economic structure, but its economic impact is complex: the contribution of transformation in different industries to economic development may be positive or negative, long-term or short-term, which determines the sustainability of the transformation path. In summary, the formation mechanism of employment-structure transformation in oasis villages in arid Ganzhou District is a compound process triggered by rigid water-resource constraints, strengthened through ecological feedback, adjusted through livelihood adaptability, and ultimately manifested as economic response and spatial differentiation.

3.2 Regulation Pathways for the Employment Structure of Oasis Villages in Arid Areas

With the further advancement of the rural revitalization strategy and the acceleration of agricultural and rural modernization, oasis villages in arid Ganzhou District need to explore pathways for optimizing labor-resource allocation and regulating the employment structure. Based on the empirical results for Ganzhou District, it is recommended that differentiated guidance strategies be implemented by zone. In the oasis core area, while stabilizing the irrigated agricultural foundation, efforts should actively promote the extension of industrial chains and the integrated development of the primary, secondary, and tertiary industries, and guide labor to gradually shift toward high-value-added non-agricultural industries such as agricultural-product processing, cold-chain logistics, and rural tourism. In the oasis marginal area, priority should be given to developing industries such as ecological animal husbandry, facility agriculture, and characteristic industries, so as to promote the expansion of labor from traditional crop farming into local non-agricultural employment channels. In the desert-mountain transition zone, labor export should be moderately guided; ecological compensation and employment-support policies should be improved to alleviate the employment impacts brought by ecological measures such as “returning cultivated land to forests and grasslands” ; and a benign circulation mechanism of migrant work and return-home entrepreneurship should be actively cultivated. In addition, training in farmers’ occupational skills should be strengthened, especially in high-efficiency fields such as precision agriculture, rural tourism, and rural e-commerce, so as to enhance their employment capacity for transformation toward non-agricultural industries. At the same time, infrastructure construction in transportation and communications, as well as the popularization and application of digital technologies, should be strengthened to drive county-wide economic and social development, gradually narrow the development gap between the core area and marginal areas, and form a new pattern of rural employment development that is coordinated overall and orderly by zone.

3.3 Research Innovation and Limitations

Taking Ganzhou District as an example, this study systematically analyzes the employment-structure transformation of rural labor in oasis villages in arid areas and its economic effects, and has certain innovations. Theoretically, based on the perspective of structuralist relations, it constructs an integrated analytical framework and reveals the internal linkage mechanism between labor mobility and income; in terms of scale, it depicts the spatiotemporal differentiation characteristics of employment-structure transformation at the township level, making up for the insufficiency of research at the meso level. The results show that the employment structure of rural labor in oasis villages in arid Ganzhou District exhibits a significant path dependence of “agricultural lock-in,” with transformation intensity showing a hierarchical difference of “within-industry > between-industry > between-territory,” and displaying gradient patterns along the oasis core area, marginal area, and desert-mountain transition zone. Compared with existing studies, while confirming the trend of non-agricultural transformation

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, this paper further reveals the particularity and complexity of the transformation path of oases in arid areas. It finds that the employment-structure transformation of rural labor in oasis villages has not rapidly moved toward “non-agriculturalization,” but instead tends toward fine-grained adjustment within the agricultural industry, thereby deepening the understanding of the gradual and endogenous nature of transformation in ecologically fragile areas. In addition, the study identifies the phenomenon that “traditional agricultural sectors show sustained income-increasing effects during the transformation process,” which breaks through the economic-growth logic of “only non-agriculturalization,” indicating that under ecological constraints, the internal optimization of oasis agriculture in arid areas and non-agricultural transformation are of equal importance.

However, this study still has some limitations. First, constrained by the availability of township-level statistical data, the period covered by the study is relatively limited, which may to some extent affect the robustness of the conclusions. Second, because of limitations in the research space, this study has not quantitatively characterized the internal mechanisms of employment-structure transformation, nor has it explored in depth the impacts of farmers’ decision-making behavior and “Heihe River water allocation.” In addition, because a labor-flow network among townships has not yet been constructed, it is difficult for the study to fully reveal the spatial interaction effects between the core area and the marginal area. Future research could use big data on population migration and survey data tracking farm households to further analyze the driving mechanisms through which micro-level behavior affects employment transformation, thereby improving the systematic nature and predictive capacity of the research.

4 Conclusion

- (1) From the perspective of the overall trend, the scale of rural labor employment is stable, and the employment structure presents the characteristic of “primary industry > tertiary industry > secondary industry,” with planting and animal husbandry being the main forms of employment. The overall transformation index of the employment structure is not high; transformation mainly occurs between detailed occupational categories rather than among the three industries, while the local employment trend has strengthened and cross-regional mobility has weakened.
- (2) From the perspective of the spatiotemporal pattern, township labor has shown an obvious trend of transfer from the primary industry to the secondary and tertiary industries. Except for agriculture-dominated types, employment-transition modes characterized by non-agricultural upgrading and a balanced three-industry structure have formed. Among them, transformation in the core oasis area is slow, and labor is mainly concentrated in traditional agriculture and animal husbandry; the marginal oasis area is accelerating its transfer toward the secondary and tertiary industries, forming a diversified employment pattern; and in the desert-oasis transition belt, occupational category conversion is intense and the transformation index is relatively high.
- (3) From the perspective of economic effects, per capita income across different employment sectors decreases in the following order: animal husbandry, industry, fishery, forestry, services, construction, and planting. The economic pull effect of non-agricultural industries on labor is becoming increasingly stronger. The impact of employment-structure transformation on income has a phased effect: in the early stage, transformation toward forestry and services significantly increases income; in the later stage, the role of transformation toward construction becomes prominent; and over the long term, internal restructuring of agriculture shows a sustained positive effect. Among these, optimization of the local employment structure is the key to income improvement.
- (4) From the perspective of the transformation mechanism, the transformation of the rural employment structure in arid-zone oases is triggered by rigid water-resource constraints, strengthened through ecological feedback, and ultimately manifested as a coupled process of economic response and spatial differentiation through livelihood-adaptability adjustment. In the future, the oasis core area should promote extension of the industrial chain and integrated development of the three industries; the oasis marginal area should focus on developing ecological animal husbandry, facility agriculture, and specialty industries; and the desert-mountain transition belt should actively cultivate a virtuous circulation mechanism linking migrant work and return-home entrepreneurship.

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Transformation pattern of rural labor employment structure in oasis areas of arid regions and its economic effects: A case study of Ganzhou District

HUANG Jing¹, XUE Dongqian², HAN Chen¹, XU Jiaxiu¹

(1. School of Environment and Life Sciences, Weinan Normal University, Weinan 714099, Shaanxi, China; 2. School of Geographical Sciences and Tourism,

Shaanxi Normal University, Xi' an 710119, Shaanxi, China)

Abstract: The transformation of rural labor employment structure contributes to the sustainable development of agriculture and rural areas in arid oasis regions. Taking Ganzhou District, a typical oasis in the middle reaches of the Heihe River, as a case study, this study applies the structural transformation index and quadratic assignment procedure regression analysis to examine the pattern of rural labor employment structure transformation in arid oasis areas and its economic effects from 2011 to 2020, while exploring the mechanism and regulatory paths of such transformation. The main conclusions are as follows: (1) The rural labor employment structure has a stable “132” pattern with a generally low transformation degree. Its transformation is dominated by refined adjustments within industries, accompanied by a strengthened trend of local employment. (2) Township labor forces have developed two typical transformation models—the nonagricultural industry upgrading model and the balanced tertiary industry structure model. Spatially, the transformation progresses slowly in the oasis core area; the employment structure is diversified in the marginal area; and the industrial category conversion is drastic in the desert-oasis transition zone. (3) Nonagricultural industries exert an increasingly strong economic effect on the labor force, and the impact of employment structure transformation on income exhibits phased characteristics, where the forestry and service industry transformation serves as the main driver in the early stage; the role of construction industry transformation becomes prominent in the later stage; and in the long run, it relies on the sustained positive effect of internal structural adjustments in agriculture. Among these factors, the optimization of local employment structure is the key to boosting income growth. (4) The transformation of rural employment structures in arid oasis areas is a complex process. It is triggered by the rigid constraint of water resources, reinforced by ecological feedback, realized through livelihood adaptation adjustments, and ultimately manifested in economic responses and spatial differentiation. Based on this, a zonal regulatory path is proposed as follows: “promote the integration of primary, secondary, and tertiary industries in the core area, focus on the development of nonagricultural industries in the marginal area, and foster a virtuous cycle mechanism of migrant work and return-home entrepreneurship in the transition zone”. The findings can provide a theoretical basis and practical reference for the rational allocation of rural labor resources and the optimization of employment structure in arid oasis areas.

Keywords: oasis rural areas; labor force employment; structural transformation; economic effects; quadratic assignment procedure

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

Source: ChinaXiv. Machine translation. Verify with the original.