Effects of Conservation Tillage on Water Storage, Moisture Conservation, and Yield in Dryland Wheat Fields in Longzhong: Postprint

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Abstract

To investigate the effects of conservation tillage on water storage and moisture conservation as well as yield formation in rainfed wheat fields on the Longzhong Loess Plateau. Based on a continuous 5-year field experiment, the effects of different tillage practices (conventional tillage T, straw mulching TS, no-till NT, and no-till with straw mulching NTS) on moisture storage rate during the fallow period, water use efficiency, dry matter accumulation and translocation of spring wheat, yield, and agronomic traits were analyzed in rainfed wheat fields on the Longzhong Loess Plateau during one tillage cycle from August 2019 to August 2020. The results showed that: (1) Compared with treatment T, the NTS treatment increased topsoil bulk density and water content, increased soil water storage at sowing and harvest stages in rainfed wheat fields, improved water use efficiency by 48.18%, and increased moisture storage rate during the fallow period by 5.70%; (2) The NTS treatment significantly increased the leaf area index of spring wheat and delayed leaf senescence; compared with TS and NT treatments, post-anthesis dry matter accumulation under NTS treatment increased by 67.38% and 32.14%, respectively, and post-anthesis dry matter contribution rate increased by 12.47% and 6.61%, respectively; (3) The NTS treatment optimized yield components and significantly increased spring wheat yield, reaching 3243.30 kg hm-2, which was 49.32% higher than that of conventional tillage (T); the NTS treatment improved the population structure of spring wheat, significantly increased root dry weight, plant height, and biomass of spring wheat, and decreased the root-to-shoot ratio; correlation analysis indicated that the improvements in water use efficiency, leaf area index, and root dry weight were important factors promoting wheat yield increase. Under the conditions of this experiment, no-till with straw mulching is the optimal tillage practice for achieving water storage and moisture conservation as well as water-saving and yield increase in rainfed wheat fields on the Longzhong Loess Plateau, and is worthy of promotion and application in this region.

Full Text

Effects of Conservation Tillage on Water Storage, Moisture Conservation, and Yield of Dry-land Wheat Fields in Central Gansu

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Abstract

This study aimed to explore the effects of conservation tillage on water storage, moisture conservation, and yield formation in dry-land wheat fields in the Loess Plateau of central Gansu province. Based on five consecutive years of field experiments, we analyzed the impacts of different tillage measures [traditional tillage (T), straw mulching (TS), no tillage (NT), and no tillage with straw mulching (NTS)] on the moisture-storage rate during the leisure period, water-use efficiency, dry matter accumulation and transport, yield, and agronomic characteristics of spring wheat during one complete farming cycle from August 2019 to August 2020. The results showed that: (1) Compared with traditional tillage (T), the NTS treatment significantly increased soil bulk density and water content in the plow layer, enhanced soil water storage during both sowing and harvest periods, improved water-use efficiency by 48.18%, and increased the leisure-period moisture-storage rate by 5.70%. (2) The NTS treatment significantly increased the leaf area index and delayed leaf senescence in spring wheat. Compared with TS and NT treatments, post-anthesis dry matter accumulation under NTS increased by 67.38% and 32.14%, respectively, while the contribution rate of post-anthesis dry matter increased by 12.47% and 6.61%, respectively. (3) The NTS treatment optimized yield components and significantly increased spring wheat yield to 3243.30 $kg \cdot hm^{-2}$, which was 49.32% higher than that under traditional tillage (T). Additionally, NTS improved the population structure of spring wheat, significantly increased root dry weight, plant height, and biomass, and reduced the root-shoot ratio. Correlation analysis indicated that improvements in water-use efficiency, leaf area index, and root dry weight were important factors contributing to wheat yield increase. Under the conditions of this experiment, no tillage with straw mulching represents the optimal tillage practice for achieving water storage, moisture conservation, and water-saving yield increases in dry-land wheat fields of the Loess Plateau in central Gansu, and is worthy of promotion and application in this region.

Keywords: Loess Plateau in central Gansu Province; dry-land wheat fields; conservation tillage; spring wheat; water use efficiency; yield; dry matter accumulation and transportation

Introduction

Changes in land use patterns and tillage systems directly affect farmland ecosystems. Rational tillage practices can coordinate the relationships among water, nutrients, air, and heat in farmland ecosystems, optimize soil structure, and promote crop growth and yield formation. The semi-arid region of the Loess Plateau in central Gansu is an important wheat (*Triticum aestivum*) production area in Gansu Province. However, this region is located in the inland northwest of China, characterized by low rainfall, high evaporation, and annual precipitation of only 300–500 mm. Precipitation shows dramatic inter-annual fluctuations and uneven seasonal distribution, with drought occurring in nine out of ten years, making it a typical representative of dryland agriculture on the Loess Plateau. Additionally, long-term traditional tillage practices have reduced soil water and nutrient retention capacity, intensified water and soil erosion, deteriorated the farmland ecological environment, and decreased crop yields, which severely restricts agricultural economic development in this region. Studies have shown that conservation tillage measures, represented by no-tillage, are important water-saving and efficiency-enhancing practices that provide significant ecological benefits in improving farmland soil quality, enhancing soil water and nutrient retention capacity, and controlling water and soil erosion. These measures represent effective pathways to alleviate water resource shortages and improve crop yield and water-use efficiency for sustainable agricultural development in China' s arid and semi-arid regions. Therefore, under the special geographical and climatic conditions of the semi-arid region of the Loess Plateau in central Gansu, investigating the effects of conservation tillage measures on improving the farmland ecological environment, increasing crop yield and water-use efficiency, and achieving water-saving yield increases is of great significance.

Currently, conservation tillage has become one of the important technologies for sustainable agriculture in semi-arid regions. Numerous studies have been conducted in recent years both domestically and internationally. Compared with traditional tillage, no-tillage demonstrates good moisture retention effects and can significantly improve water storage and water-use efficiency in winter wheat. Research by Huang et al. showed that no-tillage with mulching and subsoiling with mulching can improve soil fertility, increase post-anthesis dry matter accumulation in wheat, and promote yield formation. However, other studies have indicated that conservation tillage has no significant effect on crop yield or even causes yield reductions. Most current research on the effects of conservation tillage on yield has focused on soil nutrient and water conditions, but few have addressed the key factors of crop yield formation—namely, the relationships among crop growth characteristics, water utilization, and yield. Moreover, under the specific geographical and climatic conditions of the semi-arid region of the Loess Plateau in central Gansu, the effects of conservation tillage on water utilization and yield formation in spring wheat remain unclear.

Therefore, based on the Dryland Farming Experimental Station in the Loess

Plateau of central Gansu, this study investigated the effects of different tillage measures on soil bulk density and water content, water consumption and water-use efficiency during the spring wheat growth period, and comprehensively analyzed the relationships among agronomic traits, dry matter accumulation, and yield formation in spring wheat. The objective was to clarify the effects of conservation tillage on water-use efficiency and yield in spring wheat, providing a theoretical basis for the promotion and application of conservation tillage and sustainable agricultural development in the semi-arid region of the Loess Plateau in central Gansu.

1. Materials and Methods

1.1 Study Area Overview The experiment was conducted at the Dryland Farming Experimental Station of Gansu Agricultural University in Anjiapo Village, Anding District, Dingxi City, Gansu Province (35°64 N, 104°64 E). This region belongs to a typical semi-arid rain-fed farming area, with an average annual temperature of 6.4 °C, annual evaporation of 2000 mm, frost-free period of approximately 140 d, and average annual precipitation of 302.9 mm. The average precipitation during the experimental period was 409.5 mm, which was 5.15% higher than the multi-year average (388.4 mm), indicating a normal water year. The soil texture in the experimental area is loessal soil, with soil nutrient content and geomorphological characteristics representative of dryland farming areas in the Loess Plateau of central Gansu. The physical and chemical properties of the topsoil (0–20 cm) before the experiment are shown in Table 1.

Analysis of multi-year monthly rainfall in this region (Fig. 1) shows uneven seasonal distribution of rainfall that does not coincide with the critical water demand periods of crop growth. Approximately 65%-70% of annual rainfall occurs between July and September, while rainfall during the sowing and seedling stages (March to May) accounts for only 18%-21% of annual precipitation. Winter and spring are dry with little rainfall, resulting in severe seasonal drought.

1.2 Experimental Design The experimental plots were established in 2016 and have been continuously monitored for nearly five years. The spring wheat variety "Ganchun 27" was selected as the test crop. This variety exhibits strong drought resistance and lodging resistance, wide adaptability, and has been widely promoted in semi-arid areas of central Gansu. Spring wheat was sown in late March 2020 and harvested in late July 2020. The experiment used traditional tillage (T) as the control, with three additional treatments: straw mulching (TS), no tillage (NT), and no tillage with straw mulching (NTS). Each treatment was replicated three times, with each plot measuring 6 m × 4 m. The seeding rate was 150 $kg \cdot hm^{-2}$. To avoid marginal effects, isolation zones were established between plots. Based on survey of local farmers' fertilization practices, the fertilization level for this experiment was determined as: urea 225 $kg \cdot hm^{-2}$ and calcium superphosphate (P_2O_5 16%) 150 $kg \cdot hm^{-2}$, with all phosphorus fertilizer and 70% of nitrogen fertilizer applied as base fertilizer, and the remaining 30% of nitrogen fertilizer top-dressed at the jointing stage. According to irrigation experiments conducted by the research group in this region, 150 mm of irrigation was applied at the jointing stage of spring wheat to ensure adequate water during growth. Irrigation water was collected rainwater from water cellars, delivered to experimental plots via plastic hoses, with water consumption measured using a water meter with 0.001 m^3 precision. Other field management practices were consistent with local conventional farming. Detailed descriptions of different tillage treatments are provided in Table 2.

1.3 Measurement Methods

1.3.1 Spring Wheat Dry Matter Accumulation and Transport At the flowering and maturity stages of spring wheat, 20 representative plants were randomly collected from each plot. The aboveground parts were brought back to the laboratory and separated into leaves, stems, and spikes, which were placed in envelopes and dried in a constant-temperature oven at 105 °C for 0.5 h, then at 80 °C to constant weight. The dry mass of each plant part was measured to calculate dry matter accumulation and transport in vegetative organs. The specific calculation formulas were as follows:

- Pre-anthesis dry matter transport amount ($kg \cdot hm^{-2}$) = dry matter mass of vegetative organs at flowering stage − dry matter mass of vegetative organs at maturity stage
- Pre-anthesis dry matter transport rate (%) = (pre-anthesis dry matter transport amount / dry matter mass of vegetative organs at flowering stage) × 100
- Pre-anthesis dry matter contribution rate (%) = (pre-anthesis dry matter transport amount / dry matter mass of grains at maturity stage) × 100
- Post-anthesis dry matter accumulation amount ($kg \cdot hm^{-2}$) = dry matter mass of grains at maturity stage − pre-anthesis dry matter transport amount
- Post-anthesis dry matter contribution rate (%) = (post-anthesis dry matter accumulation amount / dry matter mass of grains at maturity stage) × 100
- Grain harvest index (%) = (dry matter mass of grains at maturity stage / total plant biomass at maturity stage) × 100

1.3.2 Water Consumption and Water-Use Efficiency During Spring Wheat Growth Period Soil bulk density in the 0–20 cm, 20–40 cm, 40–60 cm, 60–80 cm, and 80–100 cm layers was measured using the ring knife method before sowing and at maturity. Soil water content was measured using the drying method, with three repetitions per treatment. The specific calculation formulas were as follows:

- Soil water storage (mm) = Σ(soil water content × soil bulk density × layer thickness)

- Soil water storage change (mm) = soil water storage at sowing stage − soil water storage at harvest stage
- Total water consumption (ET, mm) = precipitation during growth period (P) + irrigation amount (I) + soil water storage change (ΔW) − groundwater utilization (G) − runoff (R)

As the experimental site was dryland with low precipitation, relatively flat terrain, and low groundwater level, surface runoff and deep soil water effects were not considered. Therefore, ET = P + I + ΔW.

- Water-use efficiency (WUE, $kg \cdot hm^{-2} \cdot mm^{-1}$) = grain yield (Y, $kg \cdot hm^{-2}$) / total water consumption during growth period (ET, mm)
- Leisure-period soil moisture-storage rate (%) = (soil water storage at the end of leisure period − soil water storage at the beginning of leisure period) / total precipitation during leisure period × 100

In this study, the leisure period was from August 2019 to March 2020.

1.3.3 Agronomic Trait Measurement Methods During the grain-filling stage of spring wheat, root sampling was performed using a 10 cm diameter root auger at 10 cm depth intervals to 40 cm depth, with three repetitions for all treatments. Roots were washed with a 0.25 mm sieve, impurities were removed, and roots were dried at 80 °C to constant weight to determine root dry weight. The root-shoot ratio was calculated as: root-shoot ratio = underground biomass / aboveground biomass. At the jointing, flowering, grain-filling, and maturity stages of spring wheat, 20 representative plants were collected from each plot to measure leaf area using a LI-3000 leaf area meter. Leaf area index (LAI) was calculated as: LAI = total leaf area per plant / land area per plant.

1.3.4 Grain Yield and Yield Components At maturity, three 40 cm × 40 cm quadrats were randomly selected from the central area of each plot (avoiding marginal effects) to count effective panicles per unit area and grains per panicle (from 20 random panicles). Aboveground parts within the quadrats were harvested, air-dried in mesh bags, threshed, and weighed to obtain grain weight, which was converted to yield per hectare and effective panicles per hectare. One thousand grains were randomly selected and weighed to determine 1000-grain weight.

1.4 Data Processing SPSS 24.0 software was used for statistical analysis, and SigmaPlot 12.5 software was used for graphing. One-way ANOVA was used to test significant differences in water-use efficiency, dry matter accumulation and transport, agronomic traits, and yield among treatments. Pearson correlation analysis was used to describe relationships among agronomic traits and yield. Significance level was set at $P = 0.05$.

2. Results

2.1 Effects of Different Tillage Measures on Water Storage and Moisture Conservation in Dry-land Wheat Fields Changes in soil bulk density and water content under different tillage measures are shown in Fig. 2. Soil bulk density and water content in the 0–40 cm plow layer at both pre-sowing and post-harvest stages followed the order: NTS > NT > TS > T. Compared with treatment T, the NTS treatment increased bulk density by 2.67% and water content by 2.54% at pre-sowing, and increased bulk density by 3.05% and water content by 1.64% at post-harvest.

The effects of different tillage measures on spring wheat water-use efficiency and water consumption are presented in Table 3. Compared with treatment T, the NTS treatment increased pre-sowing and post-harvest soil water storage in the 0–100 cm layer by an average of 27.35 mm and 21.23 mm, respectively, improved water-use efficiency by 48.18%, and increased the leisure-period moisture-storage rate by 5.70%. Different tillage measures resulted in total water consumption during the growth period ranging from 412.40 to 418.52 mm, but differences among treatments were not significant.

2.2 Effects of Different Tillage Measures on Leaf Area Index and Dry Matter Accumulation and Transport

2.2.1 Effects on Leaf Area Index During Spring Wheat Growth Period As shown in Fig. 3, significant differences in leaf area index among treatments were observed at different growth stages ($P < 0.05$), with all treatments reaching maximum LAI at the flowering stage. From jointing to maturity, LAI under all treatments showed an initial increase followed by a decrease. Traditional tillage (T) peaked at the heading stage, while no-tillage treatments (NT and NTS) peaked at the flowering stage. The decline in LAI from flowering to maturity ranged from 44.74% to 39.20% across treatments, with the smallest decline (39.20%) observed under NTS, indicating that NTS significantly increased LAI and effectively delayed leaf senescence.

2.2.2 Effects on Dry Matter Accumulation and Transport Different tillage treatments significantly affected dry matter accumulation and transport in spring wheat (Table 4). The NTS treatment significantly increased post-anthesis dry matter accumulation and its contribution rate, with significant differences among treatments ($P < 0.05$). Compared with TS and NT treatments, post-anthesis dry matter accumulation under NTS increased by 67.38% and 32.14%, respectively, while the contribution rate increased by 12.47% and 6.61%, respectively. The contribution rate of pre-anthesis dry matter transport to grain was significantly lower than that of post-anthesis dry matter accumulation, indicating that post-anthesis dry matter accumulation is the primary period for grain dry matter formation.

2.3 Effects of Different Tillage Measures on Yield and Agronomic Traits

2.3.1 Effects on Yield and Yield Components Different tillage treatments significantly affected spring wheat yield and its components (Table 5). The NTS treatment significantly increased spring wheat yield to 3243.30 kg · hm^{-2}, which was 49.32% higher than that under conventional tillage (T). The NTS treatment also improved population structure and optimized yield components. Compared with treatment T, 1000-grain weight, effective panicles per hectare, and grains per panicle under NTS increased by 15.25%, 16.70%, and 11.46%, respectively. Path analysis between yield and its components (Table 6) revealed that effective panicles per hectare and 1000-grain weight contributed most to yield increase, with path coefficients of 0.992 and 0.955, respectively. Grain harvest index followed the order NTS > NT > TS > T, but differences among treatments were not significant.

2.3.2 Effects on Agronomic Traits Different tillage measures significantly affected spring wheat agronomic traits (Fig. 4). The NTS treatment significantly increased root dry weight, plant height, and biomass, while significantly reducing the root-shoot ratio. Compared with treatment T, root dry weight, plant height, and biomass under NTS increased by 90.91%, 13.74%, and 22.17%, respectively, while root-shoot ratio decreased by 44.07%.

Correlation analysis among spring wheat agronomic traits, yield, and water-use efficiency (Table 7) showed that water-use efficiency ($r = 0.952$), leaf area index ($r = 0.955$), and root dry weight ($r = 0.992$) were extremely significantly positively correlated with yield and yield components ($P < 0.01$), indicating that improvements in these traits were important factors promoting wheat yield increase.

3. Discussion

3.1 Effects of Different Tillage Treatments on Soil Water Content and Water-Use Efficiency Tillage is a major driving factor of soil physical responses, with bulk density and water content being fundamental indicators of soil physical properties. This study showed that the NTS treatment significantly increased soil bulk density and water content in the plow layer (0–40 cm) at both pre-sowing and post-harvest stages. The NTS treatment showed the lowest change in bulk density and the highest change in water content between pre-sowing and post-harvest stages, indicating that after five years of no-tillage treatment, soil bulk density had reached a relatively stable state and was no longer increasing continuously. This is consistent with the findings of Luo et al., because the experimental soil is loessal soil with low organic matter content, poor cohesion, mostly silt structure, and weak water and nutrient retention capacity. Under traditional tillage, the plow layer soil is loose and prone to water evaporation. The NTS treatment retained root stubble and increased soil organic matter content. After years of no-tillage treatment, it effectively reduced disturbance to surface soil, promoted the formation of large soil aggregates, improved aggregate stability, effectively reduced water evaporation and infiltration, played a role in water collection and moisture conservation, increased soil water content, and enhanced soil water storage capacity.

This study also found that the NTS treatment significantly increased the leisure-period moisture-storage rate and soil water storage before sowing and after harvest, with more significant effects on pre-sowing soil water storage. This is consistent with the findings of Ding et al., because traditional tillage with "three plowings and two harrowings" causes substantial evaporation of soil water during the leisure period, reducing soil water content before sowing. Under no-tillage treatment, the soil is not disturbed and root stubble is retained, reducing surface runoff and ineffective evaporation of water from the plow layer, promoting water accumulation during the leisure period, and increasing the moisture-storage rate and pre-sowing soil water storage. Therefore, the NTS treatment has significant water storage and moisture conservation effects, can receive and store more rainwater, and meets the water needs for wheat growth at sowing, achieving the water-saving effect of "using autumn rain for spring growth."

3.2 Effects of Different Tillage Measures on Leaf Area Index and Dry Matter Accumulation and Transport Reducing soil water evaporation and improving crop water-use efficiency are important aspects of dryland agriculture research. This study found that the NTS treatment significantly increased water-use efficiency in spring wheat, consistent with previous research results. This is because the semi-arid region of the Loess Plateau in central Gansu is characterized by low rainfall and high evaporation. Straw mulching can effectively reduce evaporation of surface soil water, while no-tillage can improve soil structure, promote soil aggregate formation, and enhance soil water storage capacity. The NTS treatment combines the advantages of both, has good water retention and evaporation suppression effects, can reduce ineffective evaporation of soil water, meet the water demand of spring wheat during critical growth periods, promote wheat yield increase, and consequently improve water-use efficiency to achieve the effect of water-saving and yield increase.

This study also found that the NTS treatment significantly increased the leaf area index and effectively delayed the decline in leaf area index after anthesis. The increase in leaf area index also improved the canopy structure of spring wheat, enhanced light interception by wheat leaves, promoted photosynthesis in wheat populations, and consequently increased post-anthesis dry matter accumulation. This is because the NTS treatment significantly improved soil water content and water-use efficiency during wheat growth, overcoming water limitations during critical growth periods and promoting wheat growth. It increased leaf area index and water content in leaves, thereby promoting the accumulation of photosynthetic products in wheat leaves. Additionally, the NTS treatment increased the amount of organic matter returned to the soil through root stubble and litter, improved soil organic matter content, improved soil structure and aeration, provided sufficient nutrients for crop growth, and consequently promoted nutrient accumulation in wheat grains and increased grain dry weight.

3.3 Effects of Different Treatments on Spring Wheat Yield and Agronomic Traits Increasing crop yield is the focus of agricultural production, and tillage measures can significantly affect crop growth and yield formation by regulating the soil environment. This study found that the NTS treatment significantly increased spring wheat yield and optimized yield components. Path analysis between yield and its components revealed that effective panicles per hectare and 1000-grain weight contributed most to yield increase, which is consistent with the findings of Han et al. This is because in the semi-arid rain-fed farming region of the Loess Plateau in central Gansu where spring drought is prominent, water stress at sowing is a key factor affecting crop emergence and survival. Straw mulching treatments, especially NTS, stored substantial water during the leisure period, significantly increased soil water content at sowing, ensured higher survival and emergence rates, and guaranteed normal growth of wheat seedlings. The NTS treatment provided good water and nutrient conditions, promoted wheat growth, enabled wheat roots to produce more effective tillers, ensured more effective panicles, and consequently increased effective panicles per hectare. Additionally, the NTS treatment significantly increased leaf area index, promoted the accumulation and transport of photosynthetic products in grains, increased 1000-grain weight, and consequently promoted wheat yield formation.

Establishing a rational population structure is an effective way to increase crop yield. Root dry weight, root-shoot ratio, leaf area index, plant height, and biomass are important indicators reflecting crop water and nutrient utilization, photosynthetic performance, and dry matter accumulation, which are important factors affecting crop yield formation. This study showed that the NTS treatment significantly increased root dry weight, plant height, and biomass, and significantly reduced the root-shoot ratio, consistent with previous research results. Correlation analysis between agronomic traits and yield showed that water-use efficiency, leaf area index, and root dry weight were significantly positively correlated with yield and yield components, indicating that improvements in these traits were important reasons for promoting wheat yield increase. This is because the NTS treatment effectively improved plow layer soil structure, promoted root growth and deep distribution, enabling roots to fully absorb soil water and nutrients for aboveground utilization, laying the foundation for yield formation. The NTS treatment increased plant height and biomass and reduced the root-shoot ratio, indicating that it effectively improved the canopy structure of spring wheat, enabling the aboveground parts to obtain a larger proportion of dry matter allocation, promoting more photosynthetic assimilates to transfer to grains and aboveground parts, thereby achieving crop yield increase.

4. Conclusion

Based on the analysis of soil water storage and moisture conservation effects, dry matter accumulation and transport, and yield of dry-land wheat fields under conservation tillage in the Loess Plateau of central Gansu, this study reached the following conclusions:

1. Compared with traditional tillage, the no-tillage with straw mulching (NTS) practice significantly increased soil water storage in the 0–100 cm layer, water-use efficiency, and leisure-period moisture-storage rate, demonstrating excellent water storage and moisture conservation effects.
2. The NTS treatment significantly increased the leaf area index of spring wheat, delayed leaf senescence, and increased post-anthesis dry matter accumulation and contribution rate, laying the foundation for high wheat yield.
3. The NTS treatment not only optimized wheat yield components but also improved population agronomic traits, with increased water-use efficiency, leaf area index, and root dry weight being important factors for achieving wheat yield increase.

Therefore, under the conditions of this experiment, no-tillage with straw mulching is the optimal tillage practice that balances water storage, moisture conservation, and water-saving yield increase in dry-land wheat fields of the Loess Plateau in central Gansu, providing guidance for local spring wheat production and the promotion of conservation tillage in this region.

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Figures

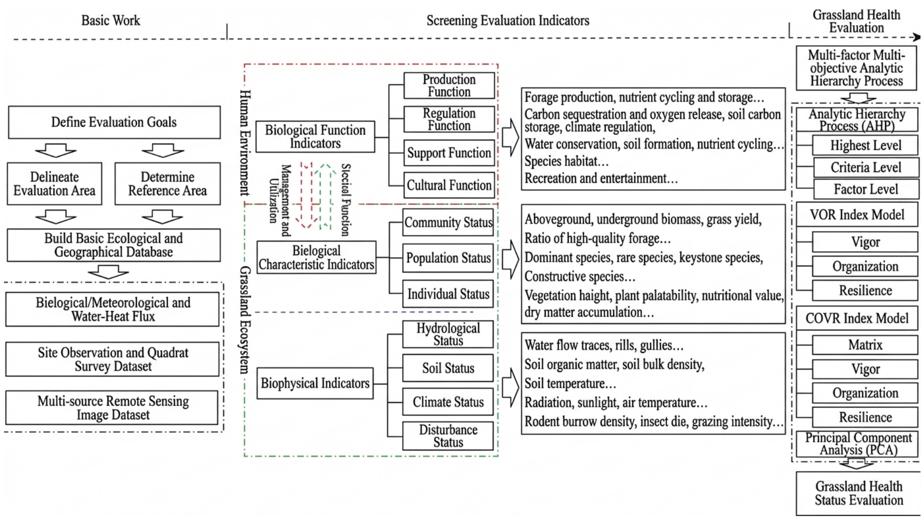

Figure 1: Figure 1

Source: ChinaXiv —Machine translation. Verify with original.

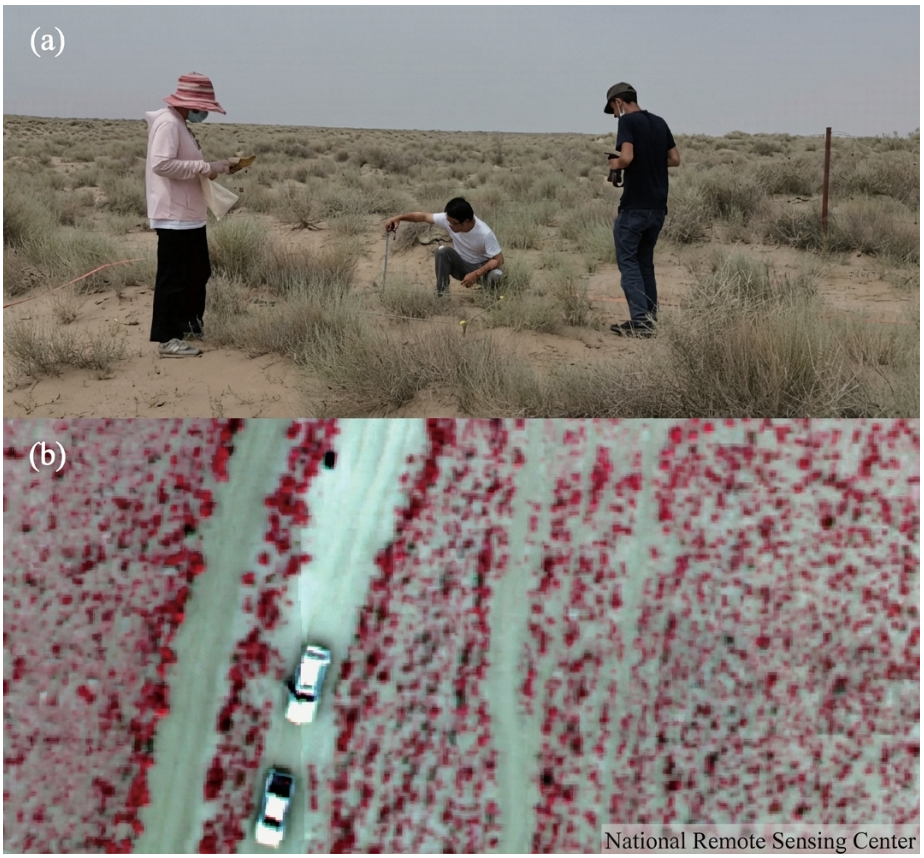

Figure 2: Figure 2

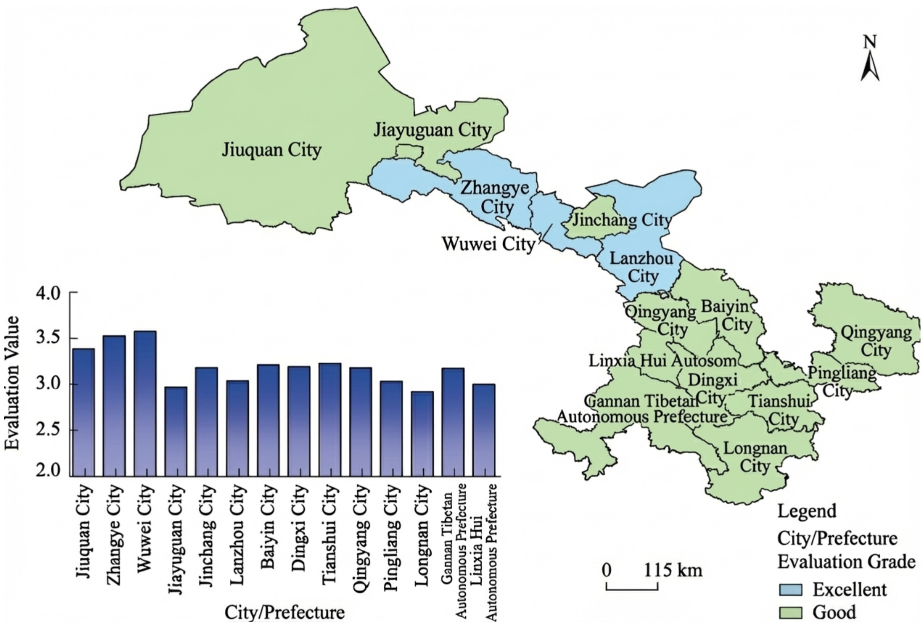

Figure 3: Figure 3

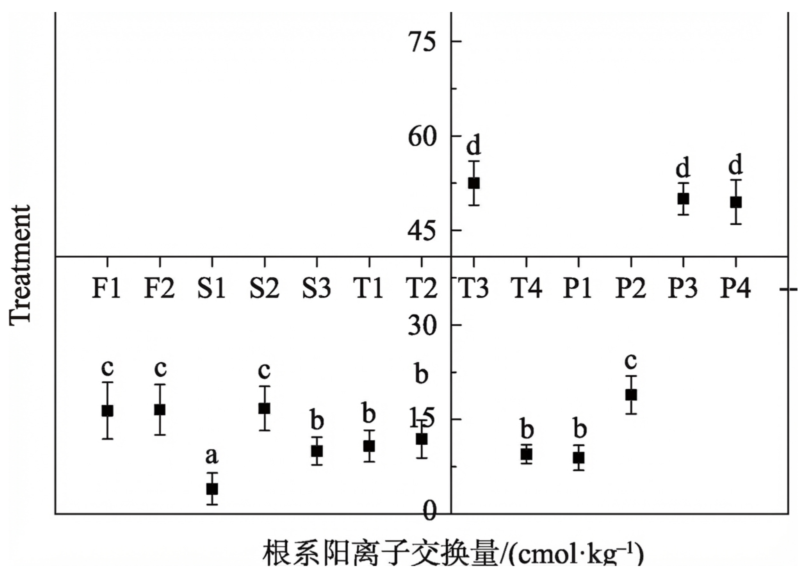

Figure 4: Figure 4