Quantitative Assessment of Climate Quality Based on Multiple Indicators: A Case Study of Red Goji Berry in Eastern Hexi - Postprint

Authors: Guo Xiaoqin

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Abstract

Quantitative evaluation methods constitute the key to scientifically assessing the climate quality of agricultural products. By employing the entropy weight method and fuzzy comprehensive evaluation approach, a quantitative climate quality evaluation model is constructed based on a multi-coupled indicator system. Using red goji berries in the eastern Hexi Corridor as a case study, indicators including light, temperature, and water during the growth period are adopted as evaluation criteria to establish a suitability evaluation model; threshold indicators of major meteorological disasters are hierarchically measured to establish an extreme disaster impact evaluation model, thereby realizing a comprehensive climate quality evaluation model that integrates meteorological evaluation and origin evaluation. Through operational verification, this method can serve as a basis for quantitative evaluation of climate quality for goji berries. Additionally, it provides a reference for quantitative assessment of climate quality for similar agricultural products.

Full Text

Quantitative Evaluation of Climate Quality Based on Multiple Indicators: A Case Study on Lycium chinense Growth in East Hexi Corridor

GUO Xiao-qin
(Wuwei Meteorological Bureau, Wuwei 733000, Gansu, China)

Abstract

Quantitative evaluation methodology is the key to scientifically assessing the climate quality of agricultural products. Based on a multiple coupling index system, this paper establishes a quantitative evaluation model for climate quality using the entropy weight valuation method and fuzzy comprehensive evaluation method. Indicators of sunshine, temperature, water, etc., during the growth period of Lycium chinense in east Hexi Corridor were used to evaluate suitable and extreme disastrous meteorological conditions. The evaluation model of extreme disaster impact was established by grading the main meteorological disaster threshold indexes. The comprehensive evaluation model of climate quality was established by combining meteorological evaluation and production area evaluation. This method could be used as the basis for quantitatively evaluating climate quality for L. chinense growth. At the same time, this method could also provide a reference for the quantitative assessment of climatic quality for the growth of similar agricultural products.

Keywords: index coupling; climate quality assessment; climate conditions; extreme disaster; Lycium chinense; Hexi Corridor

1 Materials and Methods

1.1 Study Area and Data Sources

The study area is located in Wuwei City, Gansu Province (38.10°N, 102.47°E, altitude 1592.1 m), in the eastern part of the Hexi Corridor. This region has a typical temperate continental climate, with abundant sunlight, large diurnal temperature variations, and minimal precipitation. The area experiences 1282.4 hours of sunshine during the main growing season, with average temperatures ranging from 15-25°C. Precipitation is approximately 118.5 mm, concentrated mainly in July–August. The frost-free period lasts 150 days, and the active accumulated temperature 10°C is 2840.1°C.

Meteorological data from 2016–2017 were used as the primary dataset, including daily observations of temperature, precipitation, sunshine hours, wind speed, and relative humidity from the Wuwei National Basic Meteorological Station. The data quality was controlled following national meteorological standards, with missing values interpolated using linear regression methods.

1.2 Research Methods

1.2.1 Evaluation Index System Construction Based on the growth characteristics of Lycium chinense and relevant agricultural meteorological research, a multi-level evaluation index system was constructed comprising two main components: suitable meteorological conditions and extreme weather effects.

Suitable Meteorological Conditions Index (ME): This index evaluates the favorability of meteorological factors during the growth period, including: - Temperature suitability (R -R /°C) - Precipitation suitability (T -T /mm) - Sunshine suitability (hours) - Relative humidity suitability (%)

Extreme Weather Effects Index (EWA): This index quantifies the impact of adverse meteorological events, including: - High temperature damage (days threshold) - Low temperature damage (days   threshold) - Strong wind damage (wind speed   threshold) - Drought damage (precipitation   threshold)

The comprehensive evaluation model is expressed as:

where ME represents the meteorological evaluation index for growth period *i*, SMC is the suitable meteorological conditions score, and EWA is the extreme weather effects score.

The final comprehensive evaluation (CE) combines meteorological evaluation with origin evaluation:

$$\mathbf{CE = A \times ME + B \times OE}$$

where A and B are weight coefficients determined by expert consultation and analytic hierarchy process (AHP). In this study, $A = 0.9$ and $B = 0.1$.

The evaluation results are classified into four grades: - **Excellent:** CE   90 - **Good:** 80   CE $<$ 90 - **Medium:** 70   CE $<$ 80 - **Poor:** CE $<$ 70

1.2.2 Entropy Weight Method The entropy weight method was employed to determine objective weights for each indicator, avoiding subjective bias. The calculation steps include: 1. Data standardization and normalization 2. Entropy value calculation for each indicator 3. Weight determination based on entropy values 4. Comprehensive score calculation using linear weighting

This method ensures that indicators with greater variability and information content receive higher weights in the evaluation system.

2 Results and Analysis

2.1 Climate Quality Evaluation Model

2.1.1 Meteorological Evaluation Sub-model The meteorological evaluation sub-model assesses climate suitability during three key growth stages: - **Germination to flowering stage (April–May):** Temperature and soil moisture are critical - **Flowering to fruiting stage (June–July):** Sunshine and temperature suitability dominate - **Fruiting to maturity stage (August-September):** Precipitation and temperature difference suitability become important

The model calculates daily suitability scores which are accumulated across the growth period. The entropy weight method automatically assigns higher weights to temperature and sunshine indicators, reflecting their dominant role in Lycium chinense quality formation.

2.1.2 Extreme Weather Threshold Design Based on historical disaster data and crop physiological thresholds, the following critical values were established:

TABLE 1 Threshold Design and Evaluation Results of Suitable Meteorological Conditions During Crop Growth Period

Indicator	Threshold Range	Weight	Impact on Quality
Temperature	15–25°C (optimal)	0.32	High
Precipitation	100–150 mm (seasonal)	0.18	Medium
Sunshine	>7 h/day	0.35	High
Relative Humidity	40–65%	0.15	Medium

TABLE 2 Threshold Design and Evaluation Results of Extreme Disastrous Influence During Crop Growth Period

Disaster Type	Light	Moderate	Severe	Extreme
High Temperature (°C)	30	33	36	40
Low Temperature (°C)	5	0	-3	-5
Strong Wind (m/s)	13.9	17.2	20.8	24.5
Drought (consecutive days mm)	15	20	25	30

The 2016–2017 evaluation results show: - **2016:** CE = 85.3 (Good grade), with deductions mainly from high temperature damage in July and early frost in September - **2017:** CE = 91.7 (Excellent grade), benefiting from optimal temperature and precipitation distribution

The model demonstrates that meteorological evaluation accounts for approximately 90% of the comprehensive score, while origin evaluation (soil conditions, geographical certification) contributes 10%, aligning with the dominant role of climate in determining medicinal herb quality.

3 Discussion

The quantitative evaluation method based on multi-indicator coupling provides an objective, reproducible framework for climate quality assessment. The entropy weight method effectively captures the relative importance of different meteorological factors without subjective interference. The fuzzy comprehensive evaluation handles the inherent uncertainty and gradual transitions in climate suitability classifications.

This approach is particularly suitable for specialty agricultural products like Lycium chinense where climate strongly influences active compound accumulation.

The model can be adapted for other crops by adjusting growth period parameters and threshold values. Future improvements should incorporate: - Higher-resolution spatial data from meteorological grids - Physiological process-based crop growth models - Market price feedback to validate quality assessments

The method provides scientific support for climate resource utilization, agricultural planning, and geographic indication certification for Lycium chinense production in the Hexi Corridor region.

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