

Study on Ecological Parameters of Typical Shrubs in the Tianlaochi Watershed, Upper Heihe River (Postprint)

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Abstract

The Qilian Mountains Nature Reserve is a critical water source conservation area in the Hexi region, where shrubland, as one of the principal vegetation types, plays a pivotal role in water source conservation. This study examined two typical subalpine shrub species in the Tianlaochi watershed of the upper Heihe River. Based on field observations from 2014 and 2015 and ArcGIS 10.1 analytical capabilities, variations in ecological parameters (leaf area, Leaf Area Index, and Specific Leaf Area) during the growing season were characterized. Concurrently, the spatial distribution of shrub Leaf Area Index in the study area was estimated by integrating LiDAR data at 0.5 m × 0.5 m resolution with Geoeye-1 imagery. Results indicate that Specific Leaf Area fluctuated within a certain range during the growing season, while leaf area and Leaf Area Index exhibited substantial variations. The most pronounced increase occurred in June and July, stabilization was reached in August, and leaf senescence commenced in September. Additionally, substantial spatial heterogeneity in watershed shrub Leaf Area Index was observed along the elevation gradient due to varying hydrothermal conditions. With 3400 m elevation as the inflection point, Leaf Area Index showed an increasing trend in the 3200-3400 m zone and a decreasing trend in the 3400-3750 m zone.

Full Text

Preamble

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Study Area

The study was conducted in the Tianlaochi catchment, located in the upper reaches of the Heihe River. The Heihe River basin serves as a critical water conservation area for the Heihe, Shiyang, and Shule rivers in northwestern China. The catchment covers an area of 6.5×10^4 hm², with elevations ranging from 2600 m to 3400 m. The dominant shrub species in this region include *Dasiphora fruticosa* (distributed between 2600–3400 m) and *Caragana jubata* (found at 2300–2800 m). The area is characterized by distinct hydrothermal gradients along the elevation zones, with precipitation and temperature being the primary limiting factors for vegetation growth.

Data Collection and Methods

Field investigations were carried out from May to September during 2014 and 2015. We established 71 sample plots of 1 m \times 1 m to measure leaf area and biomass. Boundary delineation and spatial analysis were performed using ArcGIS 10.1. High-resolution remote sensing data were obtained from airborne LiDAR (Light Detection and Ranging) with a spatial resolution of 0.5 m \times 0.5 m and GeoEye-1 satellite imagery. These datasets were used to retrieve the spatial distribution of shrub leaf area index across the catchment. The specific leaf area was calculated using standard gravimetric methods, and all statistical analyses were conducted in Excel.

Results

Temporal Dynamics of Leaf Parameters

The specific leaf area exhibited fluctuations throughout the growing period, with notable variations between species and elevation zones. Leaf area and leaf area index showed significant changes over time, with a marked increase occurring in June and July. The growth tended to stabilize by August, and leaf fall began in September. The relationship between aboveground biomass and leaf area index was strongly positive, indicating that biomass accumulation correlates closely with canopy development [Figure 5: see original paper].

Spatial Distribution Patterns

The spatial distribution of leaf area index varied considerably along the elevation gradient. The leaf area index increased with elevation from 3200 m to 3400 m, but decreased with further elevation gain from 3400 m to 3750 m. This pattern reflects the combined influence of precipitation and temperature on vegetation productivity. The retrieved leaf area index values ranged from 0 to 4.16, with a mean value of 2.56 across the study area [Figure 7: see original paper].

Model Validation

Comparison between measured and simulated leaf area index values showed good agreement, with the simulation results closely following the 1:1 line [Figure 6: see original paper]. The coefficient of determination (r^2) indicated that the remote sensing retrieval method captured 85% of the variation in field-measured leaf area index. The root mean square error was 0.56 for calibration plots and 2.86 for validation plots, demonstrating the reliability of the LiDAR-based retrieval approach.

Discussion

The observed elevation-dependent pattern in leaf area index reflects the trade-offs between water availability and temperature stress in this alpine environment. The 3200–3400 m zone appears to represent an optimal range where hydrothermal conditions maximize shrub productivity. Above 3400 m, low temperatures become the limiting factor, while below 3200 m, water limitation constrains growth. These findings are consistent with previous studies on alpine shrub ecosystems in the Qilian Mountains [5, 6, 7].

The integration of LiDAR and high-resolution optical imagery proved effective for mapping shrub leaf area index at fine spatial scales. This approach overcomes the limitations of field-based measurements and provides spatially continuous data required for distributed eco-hydrological modeling. The retrieved parameters will serve as essential inputs for subsequent modeling of water and energy fluxes in the Tianlaochi catchment.

Conclusion

This study quantified the temporal dynamics and spatial distribution of key ecological parameters for dominant shrub species in the Tianlaochi catchment. The leaf area index showed clear seasonal patterns and elevation-dependent variation, driven primarily by precipitation and temperature gradients. The remote sensing retrieval method demonstrated satisfactory accuracy and provides a robust framework for upscaling field measurements to the catchment scale. These results will support ongoing ecological restoration efforts and hydrological modeling initiatives in the upper Heihe River basin.

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