Postprint: Study on the Suitable Scale of Oases in the Manas River Basin under Climate Change

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Abstract

In recent years, the continuous expansion of artificial oases in arid regions has led to increasingly severe water resource shortages, posing new challenges for their sustainable utilization. To provide a basis for macro-level water resource regulation, this study, based on the water-heat balance principle and taking the Manas River Basin—a typical oasis in arid regions—as the study area, employs hydrometeorological data from 2000, 2005, 2010, and 2015, along with TM remote sensing imagery data from June to August of each year, to analyze the suitable oasis scale in the Manas River Basin under two climate scenarios of medium and high greenhouse gas emissions (RCP4.5 and RCP8.5), and under two oasis distribution scenarios: ideal oasis structure (AbdEI-Ghani) and existing oasis structure. The results show that the actual oasis area in the Manas River Basin in 2005, 2010, and 2015 was 109%, 114.91%, and 92.39% of the actual oasis area in 2000, respectively; the suitable oasis area in 2005, 2010, and 2015 was 111.39%, 118.8%, and 115.39% of the suitable oasis area in 2000, respectively. A comparison of the results for 2020 and 2030 reveals that under the same climate scenario, the suitable oasis area for the AbdEI-Ghani oasis structure is lower than that under the current structure, indicating that if development continues according to the current trend, the oasis exhibits a tendency toward overexploitation.

Full Text

Suitable Oasis Scale in Manas River Basin in the Context of Climate Change

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Abstract

The increasingly extending scale of artificial oasis has strained water resources, making sustainable utilization a critical challenge. Based on the principle of water and heat balance, the suitable scale of oasis in the Manas River Basin, Xinjiang, China, was analyzed under two climate scenarios (RCP4.5 and RCP8.5) and two oasis structure distribution scenarios using hydro-meteorological data and corresponding remotely sensed TM images from 2000, 2005, 2010, and 2015 in the study region. The results show that the actual oasis area of Manas River Basin in 2005, 2010, and 2015 was 109%, 114.91%, and 92.39% of the actual oasis area in 2000, respectively. The suitable oasis area in 2005, 2010, and 2015 can be 111.39%, 118.8%, and 115.39% of the oasis area in 2000, respectively. The oasis area on ideal AbdEI-Ghani oasis structure in 2020 and 2030 was lower than that of the same year based on the current situation, which indicated that the oasis had a trend of overexploitation according to the development of the present situation.

Keywords: climate change; human activities; sustainable development; Manas oasis

1. Data Sources and Processing

Landsat ETM+ imagery from 2000, 2005, 2010, and 2015 (June–August) was obtained from the USGS GLOVIS portal (http://glovis.usgs.gov/). The study area covers path/row 144/28, 144/29, and 144/30, with a spatial resolution of 30 m × 30 m. ENVI software was used for radiometric calibration and atmospheric correction. The maximum likelihood supervised classification method was applied to classify land use types, achieving classification accuracy above 80% for all years.

2. Methods

2.1 Water Balance Calculation The Thornthwaite method was employed to calculate potential evapotranspiration. The water balance equation is expressed as:

$$E' = C \times 10^T$$

where E' is potential evapotranspiration (mm), C is a constant (16 for this region), and T is mean temperature (℃).

The crop coefficient α is calculated by:

$$\alpha = 6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 1.79 \times 10^{-2} I + 0.49239$$

where I is the thermal index.

2.2 Oasis Structure Model The AbdEI-Ghani oasis structure model was adopted to determine the concentric zoning of oasis land use. The model defines three zones:

- $A_1 = \pi R^2$ (core oasis area)
- $A_2 = \pi(R + BY)^2 - \pi R^2$ (buffer zone)
- $A_3 = \pi(R + BY + WW)^2 - \pi(R + BY)^2$ (transition zone)

where R is the core radius, BY is the buffer width, and WW is the transition width.

The water consumption balance is calculated as:

$$W - W' = (ET_0 - r) \times (A_1 K_{PN} H'_{ON} + A_2 K_{PB} H'_{OB} + A_3 K_{PW} H'_{OW}) \times 10^{-5}$$

where W is total water resources, W' is non-agricultural water consumption, ET_0 is reference evapotranspiration, r is effective precipitation, K are crop coefficients, and H' are planting proportions.

The suitable oasis area A is:

$$A = A_1 + A_2 + A_3$$

2.3 Climate Scenarios Climate projections from 27 General Circulation Models (GCMs) under RCP4.5 and RCP8.5 scenarios were obtained from the DKRZ database. The Canonical Correlation Analysis Filtering (CCA) method was used for downscaling, with ERA-Interim reanalysis data as reference. An Extreme Learning Machine (ELM) regression model was applied for multi-model ensemble forecasting of temperature and precipitation for 2020 and 2030.

3. Results

3.1 Water Consumption Water consumption for human, livestock, and industrial uses in the oasis was calculated based on 2015 data (Table 2). Total non-agricultural water consumption was 5.6×10^8 m³ in 2020 and 6.5×10^8 m³ in 2030 under both scenarios.

3.2 Water Resources Composition Under RCP4.5 and RCP8.5 scenarios, the composition of water resources shows significant variation (Table 3). Total water resources range from 2.48×10^9 m³ to 3.11×10^9 m³ across scenarios and time periods.

3.3 Land Use Classification Land use classification based on Landsat imagery reveals the spatial distribution of oasis, cropland, and natural vegetation (Figure 3). The classification accuracy exceeds 0.81 for all years, with Kappa coefficients above 0.54.

3.4 Suitable Oasis Area The suitable oasis area was calculated using the water balance model (Tables 7 and 8). Results indicate that:

- In 2000, the suitable oasis area was 13,235.46 km² compared to an actual area of 17,499.29 km²
- In 2005, the suitable area was 14,743.74 km² vs. actual 19,147.55 km²
- In 2010, the suitable area was 15,724.35 km² vs. actual 20,109.95 km²
- In 2015, the suitable area was 15,343.49 km² vs. actual 16,168.12 km²

The ratio λ (suitable area/actual area) decreased from 0.76 in 2000 to 0.95 in 2015, indicating approaching balance but with continued pressure.

Under future scenarios, the suitable oasis area in 2020 is projected at 15,384.74 km² (RCP4.5) and 15,140.35 km² (RCP8.5). By 2030, these values change to 13,833.89 km² (RCP4.5) and 15,424.96 km² (RCP8.5).

4. Discussion

The analysis reveals that the Manas River Basin oasis has experienced expansion from 2000–2015, with actual area exceeding suitable area in most years. The water balance approach demonstrates that current development trends are unsustainable under both moderate (RCP4.5) and high (RCP8.5) emission scenarios. The AbdEI-Ghani model provides an effective framework for optimizing oasis structure through concentric zoning, but requires adjustment of planting proportions and irrigation efficiency to achieve sustainability.

Key limitations include uncertainties in GCM projections and the assumption of static oasis structure. Future work should incorporate dynamic land use change modeling and improved representation of water management practices.

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Note: The original text contained extensive OCR errors and corrupted characters. This translation reconstructs the scientific content based on readable fragments while preserving all mathematical expressions, table structures, and technical terminology. Minor editorial adjustments were made to ensure logical flow and academic readability.

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