Supplementary Materials

Study area and methods

Research area

The study area includes five mountain regions (Minshan Mountains: MS; Qionglai Mountains: QL; Daxiangling Mountains: DXL; Xiaoxiangling Mountain: XXL; Liangshan Mountains: LS) located within the distribution range of giant pandas in Sichuan Province, China (101°51′–105°27′E, 28°12′–33°34′N), covering a total area of 2.0272 million hm^2. The administrative regions in the study area include 11 cities (autonomous prefectures), 37 counties (districts), and 138 townships (Figure 1). In total, 1 387 pandas live in the area, accounting for 74.4% of the entire wild panda population. The main vegetation types are broad-leaved forest (37.06%) and coniferous forest (34.82%). There are seven genera and 32 species of bamboo identified as staple food, including *Bashania fangiana* (20.92%) and *Fargesia denudata* (18.51%), covering an area of 1.9255 million hm^2 (State Forestry Administration, 2015).

Data collection and pre-processing

Giant panda occurrence data

Data on giant panda population size and occurrence were obtained from the Fourth National Survey (2011) of Giant Pandas (State Forestry Administration, 2015). During the survey, standardized giant panda survey techniques were followed. In brief, live pandas, feces, and other signs (e.g., dens, footprints, claw marks, food traces, corpses) were recorded along with the GPS location and other relevant data. To reduce the influence of double counting on accuracy, duplicated occurrence sites were eliminated in post-survey process. According to the survey results, giant pandas were isolated in 18 populations across the study range. For this study, we selected six populations based on size, including subpopulations with fewer than 15 individuals, as this is the threshold for an extinction risk >50% (Kong et al., 2021; State Forestry Administration, 2015). The subpopulations included DXL-A-1, LS-A-3, LS-A-4, MS-A-2, MS-A-3, and XXL-B-1 (Figure 1A).

Climate data

Climate data were acquired from the China Meteorological Data Sharing Service System (http://data.cma.cn/). Data included monthly mean air temperature and monthly precipitation for 2001–2011, measured from 30 meteorological stations covering all five mountains in the study area. Given on the longitude, latitude, and elevation of the meteorological stations, we used ArcGIS v10.6 and the Kriging method to interpolate spatial distributions of precipitation and temperature. Seasonal average precipitation and temperature were calculated as total annual precipitation and temperature, respectively.

Vegetation data

Information on the distribution of different vegetation types was obtained from the vegetation map of the study area (scale of 1:1 000 000) provided by the Data Sharing Infrastructure of Earth System Science (http://www.geodata.cn). We obtained vegetation maps for 2001 and 2011, which were reclassified into nine vegetation types, including broad-leaved forest, coniferous forest, coniferous and broad-leaved mixed forest, shrub, grassland, wetland, cultivated land, town, and bare land. The NDVI shows good correlation with vegetation coverage and biomass and is commonly used to estimate vegetation coverage from remote sensing images (Li et al., 2016; Yang et al., 2015). We obtained the NDVI from January 2001 to December 2011 (16-day Global 250 m product, MOD13Q1), provided by the United States Geological Survey (USGS) (https://earthexplorer.usgs.gov/). The NDVI data were preprocessed by geometric correction, radiometric correction, and atmospheric correction, then further processed for data format and projection conversion, image stitching, and image clipping using ENVI v5.1 and ArcGIS v10.6. The obtained raster data had a spatial resolution consistent with the climate data.

Methods

Panda-vegetation coverage and panda-climate factor analysis

Using NDVI to approximate vegetation coverage, we used the pixel dichotomy model, (Eq. 1),

$$F_C=(NDVI-NDVI_{NV})/(NDVI_V-NDVI_{NV}) \qquad (1)$$

where $NDVI_V$ is the NDVI value of the vegetation pixels and $NDVI_{NV}$ is the NDVI value of the non-vegetation pixels.

$$NDVI_{NV}=(F_{CMAX}*NDVI_{MIN}-F_{CMIN}*NDVI_{MAX})/(F_{CMAX}-F_{CMIN})$$

$$NDVI_V=((1-F_{CMIN})*NDVI_{MAX}-(1-F_{CMAX})*NDVI_{MIN})/(F_{CMAX}-F_{CMIN})$$

Using integral direct calculation, vegetation coverage with bare soil and non-vegetation region is close to 0 (approximate VVC_{MIN}=0%), and the area with high vegetation coverage (approximate FVC_{MAX}=100%) (Rundquist, 2002; Li et al., 2016). The equation 1 is changed to equation 4:

$$F_C=(NDVI-NDVI_{MIN})/(NDVI_{MAX}-NDVI_{MIN}) \qquad (2)$$

where FVC is the vegetation coverage and $NDVI_{MAX}$ and $NDVI_{MIN}$ are the maximum (95%) and minimum (5%) values within a confidence interval, respectively. According to the relevant Soil Erosion Classification Standard issued by the Ministry of Water Resources in 2008, vegetation coverage was divided into five grades: $0<F_C\leq0.3$, low vegetation coverage; $0.3<F_C\leq0.45$, lower vegetation coverage; $0.45<F_C\leq0.60$, medium vegetation coverage; $0.6<F_C\leq0.75$, higher vegetation coverage; $0.75<F_C\leq1$, high vegetation coverage (Liu & Yue, 2016). The relationship between panda location sites and vegetation coverage was obtained via overlay analysis (State Forestry Administration, 2015). Otherwise, to analyze the correlation between panda locations and climate factors, we performed multiple linear regression analysis using the altitude of panda sites and the annual mean precipitation and temperature that had been interpolated. All analyses were performed using ENVI v5.3.1, ArcGIS v10.6, and SPSS v26.

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