The calculation process and results of constraint conditions in the research area.

The area of each land use type in the research area must follow certain rules during the development process, such as the protection policies for arable land and forest land, which means that there is a minimum area requirement for arable land and forest land. On the other hand, there are upper limits on the built-up areas of cities, and excessive expansion of cities is not allowed. Therefore, based on these policy requirements and the results of Markov chain prediction and grey prediction models, we have imposed constraints on the area and patch quantity of various land uses.

Table S1 The constraint conditions of the study area

Constraint Factors	Constraint Function	Instructions
Total area const.	$\sum_{i=1}^{7} n_i X_i = A_{total}$	The total area of the research area remains unchanged, and the sum of the areas of each land use type should be equal to the total area of the research area.
Area const. for Crop land	$A_{c,\,2030} \leq n_c X_c \leq A_{c,\,base}$	The proportion of arable land in the research area continues to decline, and this trend is difficult to reverse. With the advancement of urbanization and industrialization, arable land will be further occupied. To balance regional food security needs and farmland protection policies, the upper limit of farmland area is set for the base year (2020), and the lower limit of farmland retention is planned for 2030 (the natural development year). Markov chain prediction.
Area const. for Forest land	$A_{n,base} \leq \mathrm{n}_f \mathrm{X}_f$	With the implementation of multiple forest protection policies such as the Grain for Green Project in China, the protection of forest resources is also receiving increasing attention. Therefore, the forest area should be greater than or equal to the forest area in the base year (2020).
Area const. for Grass land	$A_{g,2030} \leq \mathrm{n_g X_g} \leq A_{g,base}$	The grassland area has shown a significant decrease in recent years. In order to maintain landscape diversity and preserve space for urban development, the Markov chain prediction of the 2030 area is set as the lower limit.

Area const. for Water	$A_{w,2030} \leq n_w X_w \leq A_{w,base}$	From 2010 to 2020, the water area showed a trend of first increasing and then decreasing. Therefore, the water area in 2020 was set as the upper limit, and the area predicted by Markov chain in 2030 was set as the lower limit.
Area const. for Built land	$0.95 \times A_{b,base} \leq n_b X_b \leq 1.05 \times A_{b,2030}$	From 2010 to 2020, the construction land area grew rapidly, mainly from the conversion of arable land and grassland. To curb the pressure of rapid urban expansion on the ecological environment, a Markov chain prediction of 105% of the construction land area by 2030 is set as the upper limit, and 95% of the construction land area by 2020 is set as the lower limit.
Patch const.	$0.9 \times n_{i,base} \leq n_i$	The number of patches for each land use type cannot be less than the number of patches in the reference year.

The description of Integrating NP and MPS into GMOP

We treat land-use area and patch metrics as joint decision variables. Let A_k denote the area of land-use type k and N_k the number of patches for type k. Mean patch size is $\mathrm{MPS}_k = A_k/N_k$. The multi-objective problem is formulated as:

maximize $B_{\mathrm{econ}}(\mathbf{A})$ (economic benefit)

maximize $B_{\mathrm{eco}}(\mathbf{A})$ (ecological benefit)

minimize $\sum_{k\in\mathcal{E}} N_k$ (fragmentation of ecological land types $\mathcal{E} = \{$cropland, forest, grassland$\}$)

– maximize $\sum_{k\in\mathcal{E}} \mathrm{MPS}_k = \sum_{k\in\mathcal{E}} A_k/N_k$ (patch cohesion)

subject to:

(i) $\sum_k A_k = A_{\mathrm{total}},\ A_k \in \left[A_k^{\min}, A_k^{\max}\right]$

(ii) $N_k \in [N_k^{\min}, N_k^{\max}]$, integer;

(iii) tolerance bands: $A_k \in A_k^{\mathrm{base}}\,(1 \pm 0.05),\ N_k \in N_k^{\mathrm{base}}\,(1 \pm 0.10)$.

The objectives are normalized and combined by a gray multi-objective programming (GMOP) scheme with gray constraints to accommodate parameter uncertainty.