Table S1. Multi-scenario land-use conversion constraint matrix

	ND						UD						CP						EP					
	C	F	G	W	B	U	C	F	G	W	B	U	C	F	G	W	B	U	C	F	G	W	B	U
C	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	1	1	1	0	0	0
F	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	0	0
G	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	0	0
W	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	1	0	0	0	1	1	1	0	1
B	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0
U	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1

Note: Rows indicate source (from) classes and columns indicate target (to) classes. C, F, G, W, B, U denote Cropland, Forestland, Grassland, Water bodies, Built-up land, and Unused land, respectively.

S1 Data source: Permanent Basic Farmland (PBF) boundaries were verified via the Ministry of Natural Resources' online platform, with vector basemaps provided by the competent local natural-resources authorities; Ecological Conservation Redline (ERL) delineations were obtained from the National Earth System Science Data Center; and Urban Development Boundaries (UDB) were determined from approvals and public disclosures of territorial spatial plans issued by the Tibet Autonomous Region and its prefecture-level authorities. All vector datasets were reprojected to the WGS 84 coordinate system, aligned to the land use rasters for the corresponding years, and mask-extracted to generate hard-constraint layers for the PLUS model.

S1 Source (online): Ministry of Natural Resources (China) — Permanent Basic Farmland (PBF) Online Inquiry Platform: https://yncx.mnr.gov.cn/yn/#/home; National Earth System Science Data Center (geodata.cn): https://www.geodata.cn/; Tibet Autonomous Region Department of Natural Resources: https://zrzyt.xizang.gov.cn/.

Table S2. Neighborhood factor weights

Land use type	Cropland	Forestland	Grassland	Water bodies	Built-up land	Unused land
Weight	0.47	0.53	1	0.24	0.45	0.1

Table S3. Water yield module's biophysical table

Lulc code	LULC_Name	root_depth	Kc	LULC_veg
1	Cropland	2100	1.07	1

2	Forest	5200	0.77	1
3	Grassland	2300	0.6	1
4	Water	100	0.64	0
5	Impervious	100	1	0

Note: Root_depth is the maximum rooting depth for the land-cover type (typically in mm), Kc is the dimensionless crop coefficient that scales reference evapotranspiration to actual evapotranspiration for that cover, and LULC_veg indicates whether the land cover is vegetated (1) or non-vegetated (0). In addition, the module was run with a Z constant of 15.

S3 Data source: The parameter priors in Table S3 were primarily taken from the compilation for the Tibet region by (Yang et al., 2024). We then localized them using station records from the Tibet Autonomous Region Meteorological Administration (2000-2020 precipitation, temperature, and reference evapotranspiration) and discharge statistics from the Tibet Autonomous Region Department of Water Resources. Specifically, we revised the K coefficient and rooting depth according to local vegetation and cropping types, and tuned the Z parameter to a best-fit value.

S3 Source (online): Xizang Autonomous Region Meteorological Administration: http://xz.cma.gov.cn/; Xizang Autonomous Region Department of Water Resources: https://slt.xizang.gov.cn/

Table S4. Habitat quality module's threats table

Lucode	Max_Dist	Weight	Threat	Decay
1	4	0.6	Cropland	linear
2	8	0.8	Rural settlements	exponential
3	6	1	Townland	exponential
4	3	0.6	Other construction land	linear

Table S5. Habitat quality module's sensitivity table

Lucode	LULC_Name	Habitat	Cropland	Rural settlements	Townland	Other construction land
1	Cropland	0.3	0.3	0.7	0.5	0.6
2	Forest	1	0.7	0.8	0.8	0.65
3	Grassland	0.7	0.55	0.6	0.65	0.4
4	Water	0.9	0.3	0.65	0.75	0.6
5	Construction	0	0	0	0	0

S4 and S5 Data source: Values in Table S4 (threat parameters: Max_Dist, Weight, Decay, and land-cover Habitat) and Table S5 (sensitivities of each land-cover class to Cropland, Rural settlements, Townland, and Other construction land) were anchored to the published ranges reported (Jin et al., 2022; Xia et al., 2022; Gu et al., 2019; Du et al., 2024 and Wang et al., 2022). Under the constraint of preserving the relative strengths among land-cover classes, we then applied a ±20% grid-based tuning with an expert consistency check, using the latest local land-use map and protected-area configuration as context, to ensure monotonic habitat-quality decay around construction land and highest suitability for forest and water. Final values and their sources are listed in Tables S4-S5.

Table S6. Carbon storage module's carbon_pools table

lucode	LULC_Name	C_above	C_below	C_soil	C_dead
1	Cropland	11.84	33.15	74.91	1
2	Forest	44.25	12.83	76.3	5.2
3	Grassland	5.35	15	71	10
4	Water	0.09	0	0	0
5	Construction	28.55	13.42	0	0

Note: C_above, C_below, C_soil, and C_dead denote the carbon densities (Mg C/ha) of the four carbon pools—aboveground biomass (trunks, branches, leaves), belowground biomass (roots and other live tissues), soil organic carbon (SOC), and dead organic matter (litter and deadwood).

S6 Data source: Parameters in Table S6 were anchored to the publicly available data reported by (Yang et al. 2024) and the InVEST User's Guide (Sharp et al., 2016), and then localized using evidence from (Yang et al. 2022)'s studies on the Tibetan Plateau.

Table S7. Soil retention module's biophysical table

description	lucode	Usle_c	Usle_p
Cropland	1	0.15	0.15
Forest	2	0.04	1
Grassland	3	0.1	1
Water	4	0	0
Impervious	5	0	0

Note: Usle_c is the USLE cover-management factor (dimensionless, 0-1) representing vegetation/ground-cover effects on erosion risk, and Usle_p is the USLE support-practice factor (dimensionless, 0-1) representing erosion-control.

S7 Data source: USLE factors (C and P) in Table S7 were anchored to the published ranges reported by (Ghosh et al. 2025; Ebabu et al. 2022), with additional guidance from the InVEST User's Guide (Sharp et al., 2016). While preserving the relative strengths among land-cover classes, we applied a ±20% grid-based tuning using Tibet local databases, the current land-use pattern in Nyingchi, and expert consistency checks: cropland C ≈ 0.15 and P ≈ 0.15 (representing strong soil-conservation practices); forest and grassland were assigned low C values (lowest for forest); and water and non-erodible impervious surfaces were set to C = 0 and P = 0. Final values and sources are listed in Table S7.

Table S8. Nutrient delivery ratio module's biophysical table

description	lucode	load_n	load_p	eff_n	eff_p	crit_len_p	crit_len_n	proportion_subsurface_n
Cropland	1	18.5	2.1	0.8	0.9	150	150	0.3
Forest	2	1.2	0.1	0.95	0.9	150	150	0.5
Grassland	3	5	0.8	0.9	0.9	150	150	0.4
Water	4	0.001	0.001	0.02	0.4	150	150	0
Construction	5	20	3	0.3	0.4	150	150	0.2

Note: load_n and load_p are nutrient loadings for each LULC class (kg ha^{-1} yr^{-1}), eff_n and eff_p are the maximum nutrient retention efficiencies (0-1), crit_len_n and crit_len_p are the retention lengths (m) after which maximum efficiency is reached, and proportion_subsurface_n is the fraction of total nitrogen routed to subsurface flow (0-1).

S8 Data source: Values in Table S8 were anchored to the published dataset by (Sadgui et al. 2024), with (Liu et al. 2024) providing guidance for localization. While preserving the relative ordering among land-cover classes, we applied minor adjustments informed by the latest land-use map of Nyingchi and its plateau-city context to improve agreement with local conditions. Final values and their sources are indicated in Table 8 and its footnotes.

Table S9. Food production module's Crop fertilization rates table

Crop_name	Nitrogen_rate	Phosphorus_rate	Potassium_rate
barley	65	30	30
maize	70	30	30
potato	105	40	105
wheat	45	20	25

Note: In the Food production module, we select representative high-yield crops in Nyingchi (e.g., hulless barley, wheat, maize, and potato) for calculation, and calibrate results using multi-year data from the China Statistical Yearbook.

S9 Data source: Crop types in Table S9 were localized from the China Statistical Yearbook 2000, 2010 and 2020 for Tibet. Parameter values followed the InVEST User's Guide (Sharp et al., 2016). Model outputs were then calibrated against the Yearbook's sown area and yield statistics for the corresponding years to ensure consistency in orders of magnitude and composition.

S9 Source (online): China Statistical Yearbook (multiple editions). National Bureau of Statistics of China. Available at: https://www.stats.gov.cn/sj/ndsj/

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