Supporting Information

Construction of an Early Warning System Based on a Fuzzy Matter-Element Model for Diagnosing the Health of Alpine Grassland: A Case Study of Henan County, Qinghai, China

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Table S1 The weights and steps of each evaluation factor

$$A-B=\begin{bmatrix} 1 & 4 & 3 \\ \frac{1}{4} & 1 & 2 \\ \frac{1}{3} & \frac{1}{2} & 1 \end{bmatrix} \quad B_1-C=\begin{bmatrix} 1 & 2 & 5 & 3 & \frac{1}{2} & \frac{1}{4} \\ \frac{1}{2} & 1 & 3 & 2 & \frac{1}{2} & \frac{1}{5} \\ \frac{1}{5} & \frac{1}{3} & 1 & \frac{1}{2} & \frac{1}{3} & \frac{1}{7} \\ \frac{1}{3} & \frac{1}{4} & 2 & 1 & \frac{1}{2} & \frac{1}{4} \\ 2 & 2 & 3 & 2 & 1 & \frac{1}{3} \\ 4 & 5 & 7 & 4 & 3 & 1 \end{bmatrix} \quad B_2-C=\begin{bmatrix} 1 & 7 & 5 & 3 & 2 & 3 \\ \frac{1}{7} & 1 & \frac{1}{3} & \frac{1}{5} & \frac{1}{5} & \frac{1}{3} \\ \frac{1}{5} & 3 & 1 & \frac{1}{3} & \frac{1}{3} & \frac{1}{2} \\ \frac{1}{3} & 5 & 3 & 1 & 2 & 3 \\ \frac{1}{2} & 5 & 3 & \frac{1}{2} & 1 & 2 \\ \frac{1}{3} & 3 & 2 & \frac{1}{3} & \frac{1}{2} & 1 \end{bmatrix} \quad B_3-C=\begin{bmatrix} 1 & \frac{1}{3} & 3 \\ 3 & 1 & 5 \\ \frac{1}{3} & \frac{1}{5} & 1 \end{bmatrix}$$

Table S2 Mean random consistency index $R.I.$ values

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58	1.59

Table S3 Thresholds values (S_i) of individual indicators C_i (U_{ij}) used in calculating the level of warning

	Indicators	No warning	Light warning	Threatened warning	Dangerous warning	Collapsed warning
		$<S_4$	S_4-S_3	S_3-S_2	S_2-S_1	$\geq S_1$
C_1	Alopecia proportions (%)	<10	10-15	15-20	20-25	≥25
C_2	Thickness of the turf layer (cm)	>12	10-12	8-10	6-8	≤6
C_3	Aboveground biomass (g/m^2)	>100	86-100	71-85	55-70	≤ 55
C_4	Vegetation coverage (%)	>90	81-90	71-80	61-70	≤60
C_5	Dominant height (cm)	>10	7-10	5-7	3-5	≤3
C_6	Plant diversity (species/0.25 m^2)	>15	10-15	8-10	6-8	≤6
C_7	Total carbon (g/Kg)	>40	40-30	30-20	20-10	≤10
C_8	Available phosphorus (mg/Kg)	>20	20-15	15-10	10-5	≤5
C_9	Total nitrogen (g/Kg)	>10	7-10	5-7	3-5	≤3
C_{10}	Available potassium (mg/Kg)	>166	166-133	133-100	100-67	≤67
C_{11}	Moisture (%)	>40	40-30	30-20	20-10	≤10
C_{12}	Slope (°)	≤5	5-15	15-25	25-35	>35
C_{13}	Grazing intensity (sheep-unit /hm^2.a)	≤0.9	0.9-1.2	1.2-1.5	1.5-1.8	>1.8
C_{14}	Forage production (RMB/hm^2)	>50	40-50	30-40	20-30	≤20
C_{15}	Fine forage ratio (%)	>75	56-75	46-55	36-45	≤36

Note: S_i-The thresholds values of individual indicators, i from 1-4; U_{ij}-The true values of the individual indicators C_i, i from 1-15, j from 1-8.

Table S4 The formula used to standardize U_{ij} to X_{ij} based on the level of warning judged from

Level of Warning	formula
No warning	$X_{ij} = 2 + 2 \times (U_{ij} - S_4)/S_4 \quad (U_{ij} < S_4)$
Light warning	$X_{ij} = 4 + 2 \times (U_{ij} - S_3)/(S_3 - S_4) \quad (S_4 < U_{ij} < S_3)$
Medium warning	$X_{ij} = 6 + 2 \times (U_{ij} - S_2)/(S_2 - S_3) \quad (S_3 < U_{ij} < S_2)$
Serious warning	$X_{ij} = 8 + 2 \times (U_{ij} - S_1)/(S_1 - S_2) \quad (S_2 < U_{ij} < S_1)$
Giant warning	$X_{ij} = 8 + 2 \times (U_{ij} - S_1)/S_1 \quad (S_1 \leq U_{ij})$

Note: U_{ij}-The true values of the individual indicators C_i, i from 1-15, j from 1-8; X_{ij} -The standardized values of U_{ij}; If $X_{ij}<0$, the value is 0; if $X_{ij}>10$, the value is 10.

Table S5 Test of the consistency of the indicators' weights

Single ranking	A−B	B-B_1	B-B_2	B-B_3
λ_{max}	3.006	6.194	6.247	3.065
C. I	0.036	0.039	0.049	0.032
R. I	0.520	1.260	1.260	0.520
C. R	0.069	0.031	0.039	0.062
Consistency	Yes	Yes	Yes	Yes