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Supplement of

Alpine wetland degradation reshapes the balance between hydrolytic and reductive soil nitrogen cycling enzyme potentials on the Qinghai–Tibetan Plateau

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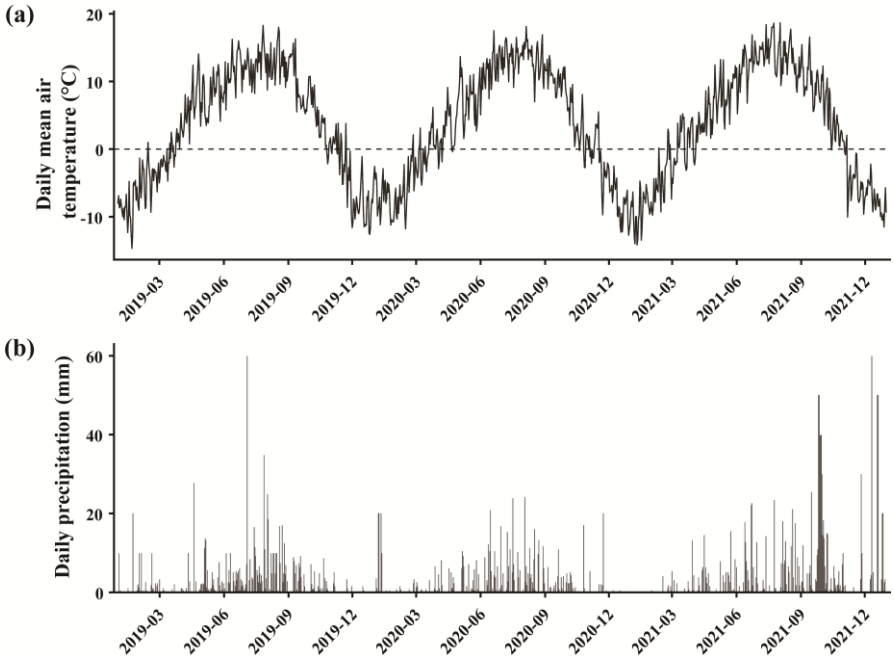


Figure. S1. Climatic conditions in the study area from 2019 to 2021. (a) Daily mean air temperature; (b) daily precipitation.

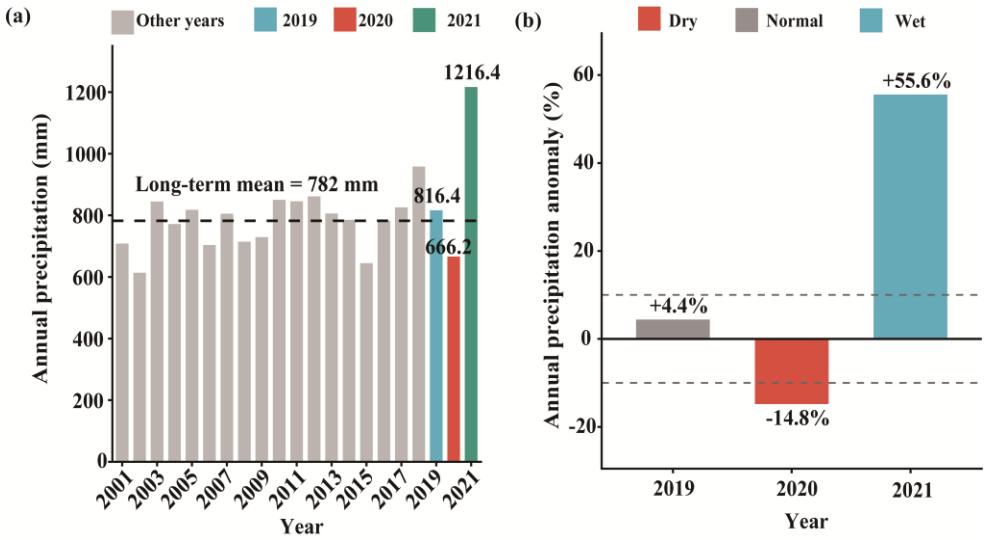


Figure S2. Interannual variation in annual precipitation and precipitation anomalies at the Gahai Wetland. Annual precipitation during 2001–2021. The horizontal dashed line indicates the long-term mean annual precipitation (782 mm) calculated from the 1991–2020 climatological normal (a). Annual precipitation anomalies for 2019–2021 relative to the long-term mean annual precipitation (b). Dashed horizontal lines in panel indicate the ±10% thresholds used to distinguish dry, normal, and wet conditions.

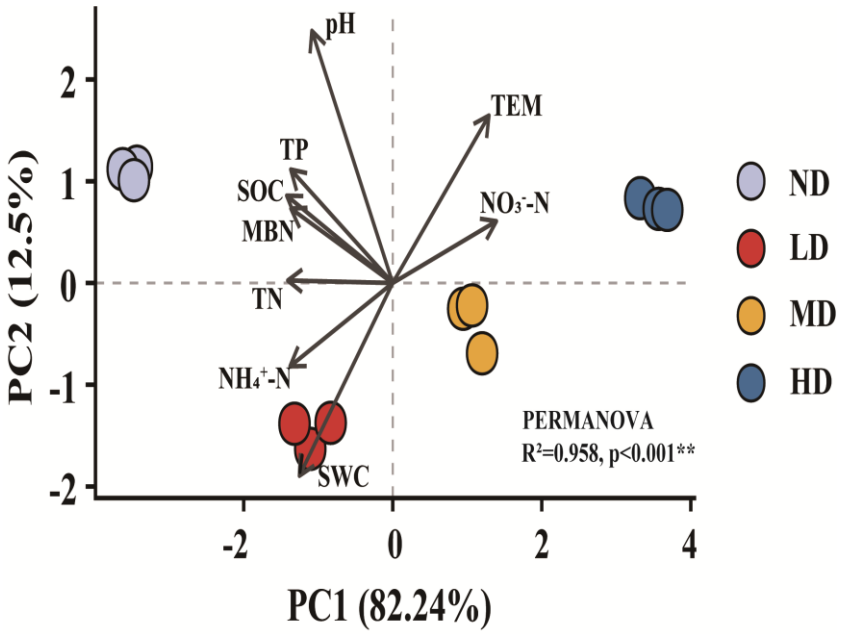


Figure. S3. Principal component analysis (PCA) of soil physicochemical properties across four alpine wetland degradation stages. ND, non-degraded; LD, lightly degraded; MD, moderately degraded; HD, heavily degraded. Each point represents an independent sampling plot (n = 3 per degradation stage), and arrows indicate the directions and relative associations of soil properties with the principal component axes.

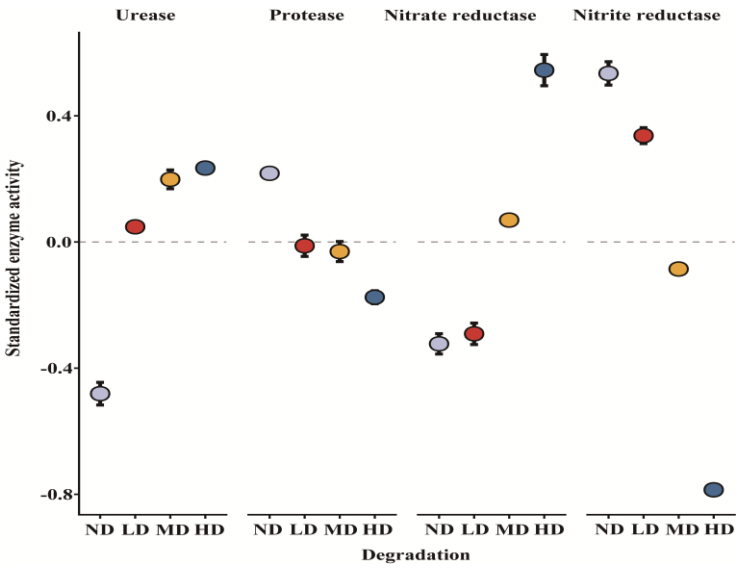


Figure S4. Standardized responses of potential N-cycling enzyme activities to wetland degradation. Enzyme activities were individually standardized within each enzyme assay using z-scores to enable direct comparisons among enzymes spanning different ranges of absolute activity. Data points represent means, and error bars indicate standard errors (SE). ND, non-degraded; LD, lightly degraded; MD, moderately degraded; HD, heavily degraded.

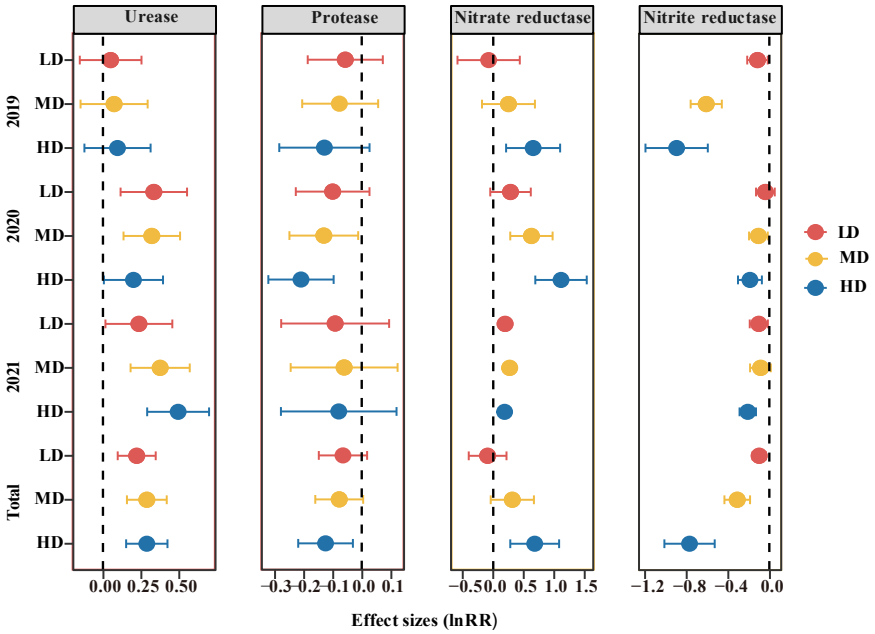


Figure S5. The interannual effect of soil N-cycling enzyme activity of degraded wetlands on that of undegraded wetlands from 2019 to 2021. urease (URE), protease (PRO), nitrate reductase (NR), and nitrite reductase (NIR). ND, non-degraded; LD, lightly degraded; MD, moderately degraded; HD, heavily degraded.

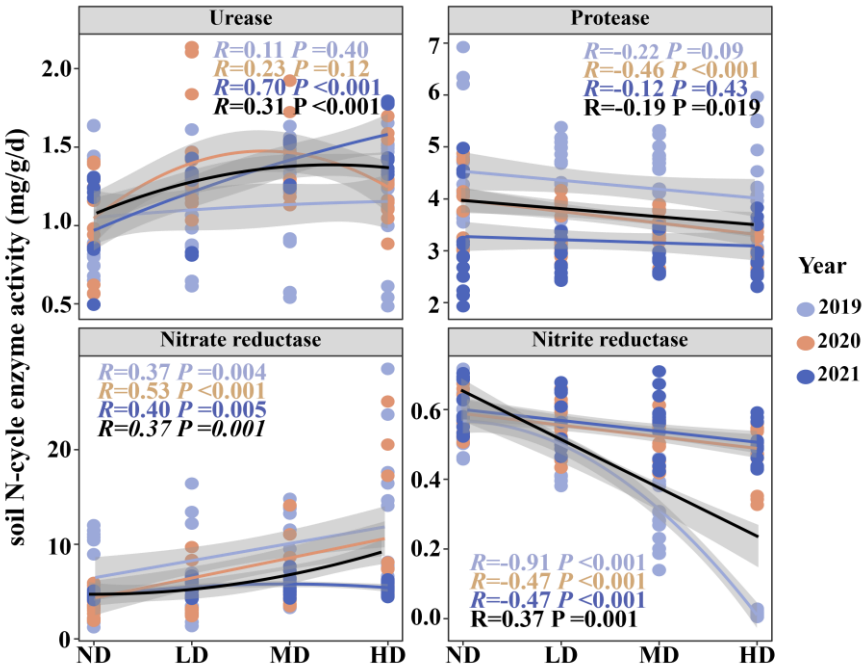


Figure S6. Response of soil N-cycle enzyme activity to wet meadow degradation from 2019 to 2021. The three colored lines represent the fitted lines for 2019, 2020, and 2021, and black represents the total fit. ND, non-degraded; LD, lightly degraded; MD, moderately degraded; HD, heavily degraded.

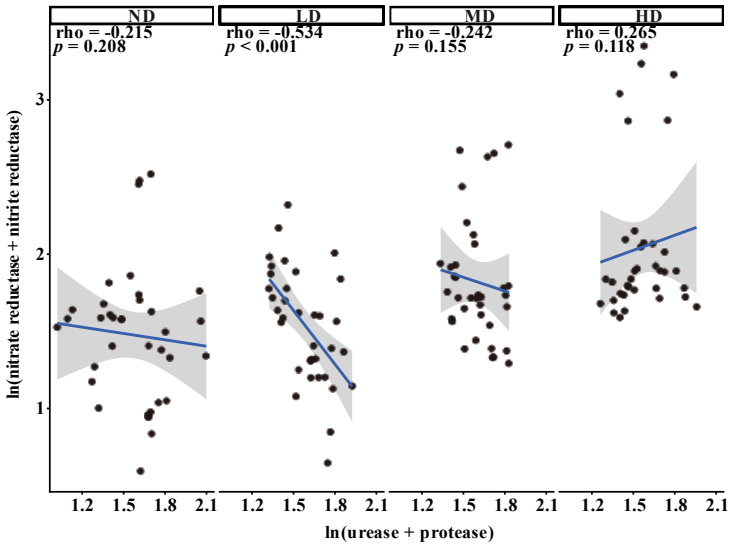


Figure S7. Relationships between ln(urease + protease) and ln(nitrate reductase + nitrite reductase) across different wetland degradation levels. The fitted lines indicate the relationships between nitrogen-mineralizing and nitrogen-reducing enzyme activities within each degradation stage. ND, non-degraded; LD, lightly degraded; MD, moderately degraded; HD, heavily degraded.

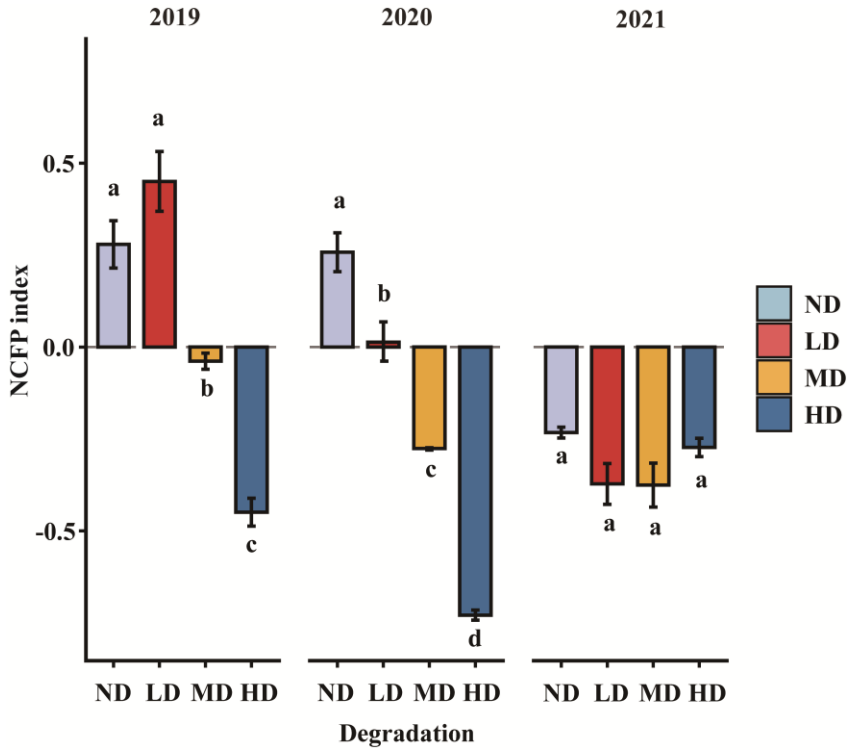


Figure S8. Interannual variation in the hydrolytic-to-reductive potential enzyme activity ratio across four alpine wetland degradation stages from 2019 to 2021. Bars represent mean ± SE among three independent plots. The dashed line at zero corresponds to a raw ratio of 1. Annual precipitation was 816.4, 666.2, and 1216.4 mm in 2019, 2020, and 2021, respectively. Different lowercase letters indicate significant differences among degradation stages within each year. ND, non-degraded; LD, lightly degraded; MD, moderately degraded; HD, heavily degraded.

Table S1. Vegetation characteristics of the four wetland degradation levels in the study area.

Degradation	Altitude (m)	Groundwater level (cm)	Cover (%)	Height (cm)	Aboveground biomass (g cm^{-2})	Dominant species
ND	3477	20-40	96.25±5.32a	16.71±2.98a	355.90±174.64a	*Kobresia tibetica*+*Potentilla anserine*+ *Poa annua*
LD	3478	40-70	86.34±7.36b	13.02±2.24b	293.02±143.93b	*Carex* sp.+*Potentilla anserine*+*Artemisia frigida Willd* +*Kobresia capilifolia*
MD	3484	>70	45.33±13.34c	7.43±0.97c	185.73±134.90c	*Artemisia frigida Willd* +*Artemisia sacrorum*.var. + *Kobresia capilifolia*
HD	3486	>100	Severe rodent damage resulted in sparse vegetation, with only little *Artemisia frigida*.and *Polygonum viviparum*			

Note: ND, non-degraded; LD, lightly degraded; MD, moderately degraded; HD, heavily degraded. The different letters above the table represent significant differences among the treatments at $P<0.05$. Values are Means ± Se.