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Freeze-thaw-driven nitrogen conversion dominates the annual budget of gross nitrogen turnover in semi-arid steppe of Inner Mongolia

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Continental semi-arid steppe covers vast regions, but little is known on nitrogen turnover in the soil of these ecosystems. We monitored a full annual cycle of gross nitrogen turnover, net nitrogen turnover and microbial biomass dynamics in soils of winter cold semi-arid steppe of Inner Mongolia (PR China) both at ungrazed and wintergrazed plots. Four distinct seasons with characteristic patterns of N turnover could be distinguished: (1) growing season with counter rotating cycles of microbial growth and gross ammonification, (2) transition to winter with a sharp decline in microbial biomass (approx. 85%) in conjunction with a peak of gross nitrification, (3) winter with constantly frozen soil and low rates of gross N turnover but build up of microbial biomass, (4) spring freeze thaw period: peaks of gross ammonification, nitrification and soil nitrate concentrations at highest values of soil moisture. Winter-grazing reduced microbial N turnover during the spring freeze thaw period via reduced wintertime water retention and hence, lower microbial activity. Overall, net rates of N turnover did not provide insight into patterns, temporal dynamics and magnitude of gross N turnover. Cumulative annual gross N turnover was in the range of ca. 250 – 420 kg N ha-1 year-1 for the uppermost 10 cm of the soil, and N turnover in freeze-thaw periods dominated this annual budget. Our study shows the importance of soil moisture and microbial biomass turnover as major drivers of N fluxes in the investigated ecosystem. Furthermore, it highlights the need to investigate gross N turnover in winter- and freeze-thaw periods.