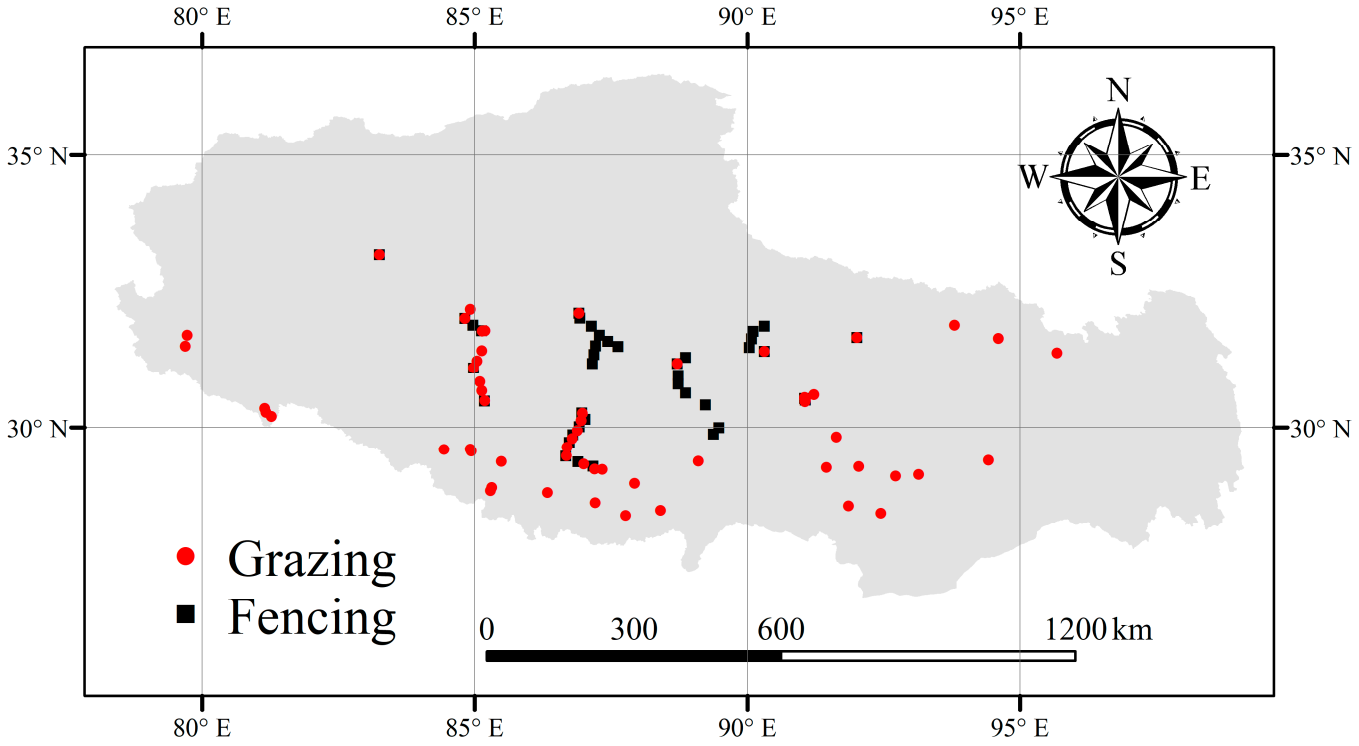


**Figure S1.** Sampling sites

**Table S1** Random forest algorithm parameters of soil $NH_4^+$-N, $NO_3^-$-N and AP. (unit, mg $kg^{-1}$)

| Scene | Soil depth (cm) | Variable | $R^2$ | Mean square errors | *ntree* | *mtry* | *n* |
|---|---|---|---|---|---|---|---|
| Fencing | 0–10 | $NH_4^+$-N | 0.92 | 1.62 | 956 | 3 | 220 |
| | | $NO_3^-$-N | 0.78 | 13.39 | 785 | 1 | 240 |
| | | AP | 0.79 | 9.49 | 702 | 2 | 246 |
| | 10–20 | $NH_4^+$-N | 0.80 | 0.90 | 986 | 3 | 140 |
| | | $NO_3^-$-N | 0.90 | 5.04 | 992 | 1 | 160 |
| | | AP | 0.78 | 13.17 | 923 | 1 | 160 |
| Grazing | 0–10 | $NH_4^+$-N | 0.92 | 2.90 | 978 | 2 | 250 |
| | | $NO_3^-$-N | 0.92 | 10.36 | 981 | 3 | 240 |
| | | AP | 0.83 | 7.86 | 963 | 1 | 260 |
| | 10–20 | $NH_4^+$-N | 0.91 | 1.71 | 975 | 2 | 210 |
| | | $NO_3^-$-N | 0.93 | 6.02 | 993 | 4 | 210 |
| | | AP | 0.86 | 7.33 | 967 | 3 | 227 |

$NH_4^+$-N, ammonium nitrogen; $NO_3^-$-N: nitrate nitrogen; AP: available phosphorus.

**Table S2** Multiple linear regression parameters of soil $NH_4^+$-N, $NO_3^-$-N and AP. (unit, mg $kg^{-1}$)

| Scene | Soil depth (cm) | Variable | Intercept | Temperature | Precipitation | Radiation | NDVI | $R^2$ | *n* |
|---|---|---|---|---|---|---|---|---|---|
| Fencing | 0–10 | $NH_4^+$-N | 37.56 | –1.16 | –0.02 | –0.03 | | 0.29 | 220 |
| | | $NO_3^-$-N | 38.27 | –0.63 | –0.02 | –0.03 | | 0.08 | 240 |
| | | AP | 27.59 | –0.07 | –0.03 | –0.02 | | 0.05 | 246 |
| | 10–20 | $NH_4^+$-N | 7.99 | –0.43 | –0.03 | 0.00 | | 0.13 | 140 |
| | | $NO_3^-$-N | 22.93 | 0.34 | 0.01 | –0.03 | | 0.02 | 160 |
| | | AP | 143.75 | –0.39 | 0.09 | –0.20 | | 0.54 | 160 |
| Grazing | 0–10 | $NH_4^+$-N | –13.80 | –0.38 | 0.00 | 0.02 | 0.00 | 0.44 | 250 |
| | | $NO_3^-$-N | –23.97 | 0.05 | 0.06 | 0.04 | 0.00 | 0.20 | 240 |
| | | AP | 23.62 | 0.41 | 0.02 | –0.03 | 0.00 | 0.09 | 260 |
| | 10–20 | $NH_4^+$-N | –12.31 | –0.50 | –0.01 | 0.03 | 0.00 | 0.37 | 210 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $NO_3^-$-N | 1.68 | –0.49 | 0.07 | 0.01 | 0.00 | 0.10 | 210 |
| AP | 83.21 | 0.35 | 0.17 | –0.13 | 0.00 | 0.54 | 227 |

$NH_4^+$-N, ammonium nitrogen; $NO_3^-$-N: nitrate nitrogen; AP: available phosphorus.

**Table S3** Recursive regression tree parameters of soil $NH_4^+$-N, $NO_3^-$-N and AP. (unit, mg $kg^{-1}$)

| Scene | Soil depth (cm) | Variable | $R^2$ | *n* |
|---|---|---|---|---|
| Fencing | 0–10 | $NH_4^+$-N | 0.74 | 220 |
| | | $NO_3^-$-N | 0.35 | 240 |
| | | AP | 0.35 | 246 |
| | 10–20 | $NH_4^+$-N | 0.25 | 140 |
| | | $NO_3^-$-N | 0.31 | 160 |
| | | AP | 0.74 | 160 |
| Grazing | 0–10 | $NH_4^+$-N | 0.59 | 250 |
| | | $NO_3^-$-N | 0.65 | 240 |
| | | AP | 0.40 | 260 |
| | 10–20 | $NH_4^+$-N | 0.59 | 210 |
| | | $NO_3^-$-N | 0.34 | 210 |
| | | AP | 0.45 | 227 |

$NH_4^+$-N, ammonium nitrogen; $NO_3^-$-N: nitrate nitrogen; AP: available phosphorus.

**Table S4** Generalized boosted regression parameters of soil $NH_4^+$-N, $NO_3^-$-N and AP. (unit, mg $kg^{-1}$)

| Scene | Soil depth (cm) | Variable | Tree Nos | mean train error | mean cv error | *n* |
|---|---|---|---|---|---|---|
| Fencing | 0–10 | $NH_4^+$-N | 990 | 3.92 | 8.26 | 220 |
| | | $NO_3^-$-N | 989 | 21.99 | 34.36 | 240 |
| | | AP | 968 | 14.03 | 21.09 | 246 |
| | 10–20 | $NH_4^+$-N | 892 | 0.96 | 3.80 | 140 |
| | | $NO_3^-$-N | 989 | 9.92 | 21.96 | 160 |
| | | AP | 912 | 14.31 | 42.22 | 160 |
| Grazing | 0–10 | $NH_4^+$-N | 980 | 5.52 | 10.35 | 250 |
| | | $NO_3^-$-N | 994 | 25.64 | 54.05 | 240 |
| | | AP | 984 | 15.02 | 37.45 | 260 |
| | 10–20 | $NH_4^+$-N | 976 | 2.95 | 5.07 | 210 |
| | | $NO_3^-$-N | 992 | 16.21 | 38.48 | 210 |
| | | AP | 964 | 11.35 | 21.66 | 227 |

$NH_4^+$-N, ammonium nitrogen; $NO_3^-$-N: nitrate nitrogen; AP: available phosphorus.

**Table S5** Support vector machine parameters of soil $NH_4^+$-N, $NO_3^-$-N and AP. (unit, mg $kg^{-1}$)

| Scene | Soil depth (cm) | Variable | Mean residuals | Mean decision values | Support vector Nos | *n* |
|---|---|---|---|---|---|---|
| Fencing | 0–10 | $NH_4^+$-N | 0.81 | –0.18 | 136 | 220 |
| | | $NO_3^-$-N | 1.18 | –0.15 | 193 | 240 |
| | | AP | 1.46 | –0.22 | 188 | 246 |
| | 10–20 | $NH_4^+$-N | 0.40 | –0.19 | 86 | 140 |
| | | $NO_3^-$-N | 1.35 | –0.19 | 115 | 160 |
| | | AP | 0.90 | –0.12 | 112 | 160 |
| Grazing | 0–10 | $NH_4^+$-N | 0.55 | –0.09 | 153 | 250 |
| | | $NO_3^-$-N | 2.21 | –0.20 | 186 | 240 |

| | | | | | |
|---|---|---|---|---|---|
| | AP | 0.97 | –0.14 | 206 | 260 |
| 10–20 | $NH_4^+$-N | 0.74 | –0.17 | 118 | 210 |
| | $NO_3^-$-N | 2.33 | –0.25 | 161 | 210 |
| | AP | 0.82 | –0.11 | 181 | 227 |

$NH_4^+$-N, ammonium nitrogen; $NO_3^-$-N: nitrate nitrogen; AP: available phosphorus.

**Table S6** Artificial neural network (ANN), generalized linear regression (GLR), conditional inference tree (CIT) and eXtreme gradient boosting (eXGB) errors of soil $NH_4^+$-N, $NO_3^-$-N and AP. (unit, mg $kg^{-1}$)

| Scene | Soil depth (cm) | Variable | ANN | GLR | CIT | eXGB | *n* |
|---|---|---|---|---|---|---|---|
| Fencing | 0–10 | $NH_4^+$-N | 203.89 | 239.94 | 206.46 | 139.60 | 220 |
| | | $NO_3^-$-N | 332.26 | 347.9 | 317.09 | 404.12 | 240 |
| | | AP | 277.37 | 290.49 | 290.49 | 328.34 | 246 |
| | 10–20 | $NH_4^+$-N | 65.37 | 65.56 | 65.56 | 45.25 | 140 |
| | | $NO_3^-$-N | 199.15 | 212.94 | 212.94 | 166.87 | 160 |
| | | AP | 183.08 | 188.33 | 140.00 | 225.46 | 160 |
| Grazing | 0–10 | $NH_4^+$-N | 256.98 | 279.74 | 237.92 | 214.25 | 250 |
| | | $NO_3^-$-N | 549.04 | 686.16 | 500.65 | 439.63 | 240 |
| | | AP | 398.36 | 403.71 | 403.71 | 439.77 | 260 |
| | 10–20 | $NH_4^+$-N | 173.76 | 188.29 | 128.56 | 95.91 | 210 |
| | | $NO_3^-$-N | 411.00 | 452.53 | 397.57 | 305.89 | 210 |
| | | AP | 314.72 | 323.36 | 225.16 | 363.51 | 227 |

$NH_4^+$-N, ammonium nitrogen; $NO_3^-$-N: nitrate nitrogen; AP: available phosphorus.