附表1 采样点主要地化环境参数

Table 1 GPS location and geochemical parameters of the sampled soils

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 样品 | 经度（E) | 纬度（N) | pH | EC（μS/cm) | Sr 含量（μg/g) |
| L01-01 | 123°06′00.17″ | 43°52′50.09″ | 7.18 | 104.6 | 273 |
| L01-02 | 123°06′24.89″ | 43°53′50.78″ | 6.70 | 79.0 | 267 |
| L01-03 | 123°01′50.10″ | 43°54′07.14″ | 7.48 | 78.7 | 246 |
| L01-16 | 123°03′41.10″ | 43°54′39.90″ | 8.55 | 774.0 | 330 |
| L02-09 | 122°58′57.10″ | 43°55′01.19″ | 8.97 | 1021 | 349 |
| L02-10 | 123°02′19.00″ | 43°55′01.57″ | 7.68 | 163.9 | 224 |
| L02-12 | 122°57′42.16″ | 43°55′22.97″ | 7.48 | 101.5 | 208 |
| L02-16 | 123°00′55.08″ | 43°55′23.62″ | 8.02 | 140.0 | 257 |
| L03-01 | 123°07′29.11″ | 43°55′39.99″ | 7.54 | 95.6 | 230 |
| L03-10 | 122°59′26.07″ | 43°55′53.00″ | 7.76 | 34.8 | 241 |
| L03-13 | 123°02′50.68″ | 43°55′53.61″ | 6.61 | 60.7 | 228 |
| L03-14 | 123°12′48.37″ | 43°56′14.04″ | 7.60 | 113.0 | 264 |
| L03-15 | 122°58′05.28″ | 43°56′19.90″ | 7.35 | 79.3 | 260 |
| L03-16 | 123°01′28.33″ | 43°56′24.27″ | 7.61 | 158.2 | 249 |
| L04-01 | 123°00′02.41″ | 43°56′49.51″ | 7.34 | 18.6 | 254 |
| L04-02 | 123°03′18.29″ | 43°56′56.06″ | 7.42 | 46.8 | 240 |
| L04-03 | 123°13′16.40″ | 43°57′08.61″ | 7.13 | 37.4 | 215 |
| L04-05 | 122°58′39.24″ | 43°57′15.34″ | 7.25 | 75.2 | 264 |
| L04-06 | 123°05′10.21″ | 43°57′26.54″ | 7.25 | 68.8 | 246 |
| L04-07 | 122°50′43.49″ | 43°57′31.97″ | 7.86 | 34.7 | 288 |
| L04-08 | 123°00′31.72″ | 43°57′46.24″ | 7.68 | 126.0 | 362 |
| L04-10 | 122°49′15.55″ | 43°57′55.73″ | 7.99 | 60.9 | 237 |
| L04-11 | 123°13′51.94″ | 43°58′04.69″ | 7.87 | 67.2 | 239 |
| L04-13 | 122°59′16.10″ | 43°58′09.41″ | 7.33 | 51.4 | 234 |
| L04-14 | 123°02′29.73″ | 43°58′16.61″ | 7.50 | 20.2 | 221 |
| L04-15 | 122°51′16.04″ | 43°58′21.25″ | 7.66 | 49.4 | 252 |
| L04-16 | 123°05′47.62″ | 43°58′27.81″ | 7.61 | 55.0 | 265 |
| L05-01 | 123°12′35.11″ | 43°58′33.68″ | 7.71 | 168.2 | 277 |
| L05-02 | 123°01′08.44″ | 43°58′39.69″ | 7.78 | 79.3 | 258 |
| L05-03 | 123°04′23.93″ | 43°58′47.09″ | 7.03 | 20.1 | 221 |
| L05-04 | 122°49′51.85″ | 43°58′49.44″ | 7.70 | 78.3 | 228 |
| L05-05 | 122°45′15.57″ | 43°59′02.71″ | 7.93 | 51.5 | 248 |
| L05-06 | 123°02′57.81″ | 43°59′12.83″ | 8.13 | 50.9 | 236 |
| L05-07 | 123°06′19.00″ | 43°59′18.75″ | 8.33 | 37.6 | 225 |
| L05-08 | 122°51′47.59″ | 43°59′21.21″ | 9.56 | 691.0 | 276 |
| L05-09 | 123°09′33.98″ | 43°59′22.90″ | 7.87 | 69.4 | 244 |
| L05-10 | 122°43′43.30″ | 43°59′34.04″ | 8.00 | 33.9 | 251 |
| L05-11 | 123°01′38.83″ | 43°59′39.81″ | 7.00 | 25.2 | 230 |
| L05-12 | 123°04′56.95″ | 43°59′40.40″ | 8.15 | 38.5 | 231 |
| L08-01 | 122°50′24.78″ | 43°59′44.80″ | 7.99 | 77.3 | 270 |
| L08-02 | 123°08′10.06″ | 43°59′51.12″ | 7.66 | 81.1 | 274 |
| L08-03 | 122°45′39.17″ | 44°00′01.64″ | 7.74 | 87.9 | 283 |
| L08-04 | 123°03′24.93″ | 44°00′07.88″ | 7.69 | 83.7 | 241 |
| L08-05 | 123°06′47.58″ | 44°00′13.28″ | 7.54 | 67.1 | 230 |
| L08-06 | 122°52′20.21″ | 44°00′19.58″ | 7.75 | 98.2 | 245 |
| L08-07 | 122°44′14.61″ | 44°00′31.27″ | 7.82 | 87.5 | 247 |
| L08-08 | 123°02′08.84″ | 44°00′33.82″ | 8.14 | 70.9 | 255 |
| L08-09 | 123°05′21.09″ | 44°00′36.34″ | 9.91 | 81.4 | 328 |
| L08-10 | 122°50′59.84″ | 44°00′39.22″ | 7.90 | 92.0 | 249 |
| L08-11 | 122°46′12.47″ | 44°01′02.08″ | 7.91 | 66.2 | 242 |
| L08-12 | 123°04′01.20″ | 44°01′04.44″ | 7.96 | 97.8 | 277 |
| L08-13 | 122°52′49.96″ | 44°01′07.84″ | 8.03 | 91.2 | 244 |
| L08-14 | 122°44′48.19″ | 44°01′29.50″ | 7.94 | 77.2 | 238 |
| L08-15 | 123°02′36.99″ | 44°01′34.07″ | 8.42 | 124.8 | 369 |
| L08-16 | 122°51′11.79″ | 44°01′36.98″ | 7.83 | 105.1 | 260 |
| L09-02 | 122°46′43.95″ | 44°01′55.99″ | 7.67 | 295.0 | 225 |
| L10-01 | 122°53′17.30″ | 44°02′08.75″ | 7.55 | 133.9 | 254 |
| L10-02 | 122°45′21.55″ | 44°02′24.89″ | 7.30 | 122.4 | 264 |
| L10-04 | 122°52′00.64″ | 44°02′31.47″ | 7.75 | 529.0 | 350 |
| L10-05 | 122°47′20.05″ | 44°02′50.74″ | 7.91 | 82.6 | 281 |
| L10-06 | 122°53′54.74″ | 44°03′03.44″ | 7.78 | 93.0 | 290 |
| L10-07 | 122°45′54.15″ | 44°03′15.65″ | 7.20 | 66.1 | 233 |
| L10-08 | 122°52′27.31″ | 44°03′33.14″ | 7.47 | 75.6 | 233 |
| L10-09 | 122°54′17.88″ | 44°04′02.36″ | 7.45 | 83.0 | 240 |
| L10-10 | 122°51′03.84″ | 44°04′06.49″ | 8.06 | 323 | 304 |
| L10-11 | 122°46′26.03″ | 44°04′12.24″ | 7.84 | 108.7 | 278 |
| L10-12 | 122°52′58.93″ | 44°04′28.47″ | 7.32 | 558 | 311 |
| L10-13 | 122°48′12.13″ | 44°04′45.36″ | 8.15 | 1083 | 303 |
| L10-14 | 122°47′00.97″ | 44°05′09.47″ | 7.92 | 135.7 | 297 |
| L10-15 | 122°48′49.10″ | 44°05′46.18″ | 7.87 | 32.7 | 249 |
| L10-16 | 122°47′28.01″ | 44°06′07.22″ | 7.74 | 158.0 | 258 |

附表2 采样区土壤微生物群落α多样性指数

Table 2 Diversity indices of microbial communities in the sampled soils in the Tongliao area

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 样品 | Total reads | Observed OTUs | Shannon Wiener | Simpson | Equitability | Fisher |
| L01-01 | 19 095 | 1224 | 6.13 | 0.99 | 0.86 | 508.90 |
| L01-02 | 5 130 | 646 | 5.63 | 0.99 | 0.87 | 195.47 |
| L01-03 | 12 867 | 1 153 | 6.28 | 1.00 | 0.89 | 462.63 |
| L01-16 | 18 635 | 480 | 4.52 | 0.96 | 0.73 | 129.62 |
| L02-09 | 7 772 | 356 | 4.97 | 0.99 | 0.85 | 86.95 |
| L02-10 | 22 714 | 813 | 5.08 | 0.98 | 0.76 | 272.03 |
| L02-12 | 16 520 | 1 006 | 5.43 | 0.98 | 0.78 | 374.18 |
| L02-16 | 23 846 | 693 | 5.26 | 0.98 | 0.80 | 215.95 |
| L03-01 | 14 038 | 1 143 | 5.92 | 0.99 | 0.84 | 456.30 |
| L03-10 | 10 499 | 822 | 5.26 | 0.98 | 0.78 | 276.46 |
| L03-13 | 21 527 | 1 175 | 6.01 | 0.99 | 0.85 | 476.71 |
| L03-14 | 16 214 | 1 309 | 6.41 | 1.00 | 0.89 | 567.53 |
| L03-15 | 20 274 | 1 136 | 6.20 | 1.00 | 0.88 | 451.90 |
| L03-16 | 21 783 | 1 084 | 6.12 | 0.99 | 0.88 | 419.91 |
| L04-01 | 19 589 | 1 225 | 6.34 | 1.00 | 0.89 | 509.57 |
| L04-02 | 21 439 | 1 051 | 5.99 | 0.99 | 0.86 | 400.24 |
| L04-03 | 18 103 | 1 018 | 5.89 | 0.99 | 0.85 | 381.05 |
| L04-05 | 22 383 | 940 | 5.35 | 0.98 | 0.78 | 337.53 |
| L04-06 | 20 739 | 927 | 5.32 | 0.98 | 0.78 | 330.53 |
| L04-07 | 22 288 | 761 | 5.29 | 0.98 | 0.80 | 247.06 |
| L04-08 | 17 443 | 798 | 5.59 | 0.99 | 0.84 | 264.72 |
| L04-10 | 10 802 | 732 | 5.13 | 0.98 | 0.78 | 233.58 |
| L04-11 | 14 837 | 837 | 5.07 | 0.97 | 0.75 | 283.92 |
| L04-13 | 13 938 | 733 | 5.28 | 0.98 | 0.80 | 234.04 |
| L04-14 | 11 849 | 1 077 | 5.88 | 0.99 | 0.84 | 415.70 |
| L04-15 | 15 828 | 975 | 5.75 | 0.98 | 0.84 | 356.74 |
| L04-16 | 16 069 | 1 026 | 5.60 | 0.98 | 0.81 | 385.66 |
| L05-01 | 12 838 | 1 099 | 6.00 | 0.99 | 0.86 | 429.01 |
| L05-02 | 16 694 | 936 | 5.22 | 0.97 | 0.76 | 335.37 |
| L05-03 | 18 321 | 880 | 5.07 | 0.97 | 0.75 | 305.78 |
| L05-04 | 13 595 | 916 | 5.20 | 0.97 | 0.76 | 324.65 |
| L05-05 | 13 250 | 1 045 | 5.46 | 0.98 | 0.79 | 396.72 |
| L05-06 | 14 925 | 1 020 | 5.68 | 0.98 | 0.82 | 382.20 |
| L05-07 | 11 953 | 676 | 4.91 | 0.97 | 0.75 | 208.45 |
| L05-08 | 20 677 | 320 | 4.19 | 0.95 | 0.73 | 75.62 |
| L05-09 | 11 143 | 924 | 5.61 | 0.99 | 0.82 | 328.92 |
| L05-10 | 11 225 | 729 | 5.39 | 0.98 | 0.82 | 232.20 |
| L05-11 | 9 688 | 990 | 5.92 | 0.99 | 0.86 | 365.13 |
| L05-12 | 11 511 | 1 013 | 5.60 | 0.98 | 0.81 | 378.18 |
| L08-01 | 10 919 | 930 | 5.79 | 0.99 | 0.85 | 332.14 |
| L08-02 | 10 974 | 1 172 | 6.36 | 1.00 | 0.90 | 474.78 |
| L08-03 | 9 886 | 1 074 | 6.31 | 1.00 | 0.90 | 413.90 |
| L08-04 | 10 853 | 1 042 | 6.20 | 0.99 | 0.89 | 394.96 |
| L08-05 | 10 417 | 884 | 5.50 | 0.98 | 0.81 | 307.85 |
| L08-06 | 9 365 | 978 | 6.01 | 0.99 | 0.87 | 358.41 |
| L08-07 | 8 514 | 804 | 5.73 | 0.99 | 0.86 | 267.63 |
| L08-08 | 7 269 | 660 | 5.46 | 0.99 | 0.84 | 201.49 |
| L08-09 | 13 182 | 314 | 3.63 | 0.91 | 0.63 | 73.78 |
| L08-10 | 7 393 | 624 | 5.24 | 0.97 | 0.81 | 186.16 |
| L08-11 | 6 691 | 848 | 5.90 | 0.99 | 0.87 | 289.44 |
| L08-12 | 6 323 | 719 | 5.69 | 0.99 | 0.86 | 227.64 |
| L08-13 | 5 471 | 866 | 6.05 | 0.99 | 0.89 | 298.58 |
| L08-14 | 5 350 | 818 | 5.83 | 0.99 | 0.87 | 274.49 |
| L08-15 | 6 171 | 464 | 4.74 | 0.95 | 0.77 | 123.80 |
| L08-16 | 6 286 | 945 | 6.11 | 0.99 | 0.89 | 340.24 |
| L09-02 | 5 862 | 490 | 4.69 | 0.96 | 0.76 | 133.30 |
| L10-01 | 28 757 | 1 201 | 6.44 | 1.00 | 0.91 | 493.65 |
| L10-02 | 24 058 | 1 407 | 6.51 | 1.00 | 0.90 | 639.75 |
| L10-04 | 29 995 | 484 | 4.74 | 0.97 | 0.77 | 131.09 |
| L10-05 | 23 459 | 1 139 | 5.79 | 0.99 | 0.82 | 453.79 |
| L10-06 | 22 030 | 1 067 | 5.84 | 0.99 | 0.84 | 409.72 |
| L10-07 | 27 758 | 1 303 | 6.34 | 1.00 | 0.88 | 563.27 |
| L10-08 | 27 758 | 1 158 | 6.13 | 0.99 | 0.87 | 465.81 |
| L10-09 | 16 103 | 1 080 | 5.71 | 0.99 | 0.82 | 417.50 |
| L10-10 | 31 164 | 548 | 4.83 | 0.95 | 0.77 | 155.38 |
| L10-11 | 20 517 | 1 009 | 5.96 | 0.99 | 0.86 | 375.89 |
| L10-12 | 34 521 | 465 | 4.89 | 0.98 | 0.80 | 124.16 |
| L10-13 | 22 916 | 452 | 4.88 | 0.98 | 0.80 | 119.49 |
| L10-14 | 25 535 | 1 244 | 6.34 | 1.00 | 0.89 | 522.37 |
| L10-15 | 21 337 | 1 304 | 6.35 | 1.00 | 0.89 | 563.98 |
| L10-16 | 23 745 | 1 062 | 5.85 | 0.99 | 0.84 | 406.74 |

附表3 采样区71个土壤样品微生物群落功能预测结果

Table 3 The potential microbial functions of 71 soil samples in the Tongliao area

|  |  |  |  |
| --- | --- | --- | --- |
| 功能微生物群落类型 | 相对丰度（%) | | |
|  | 最大值 | 平均值 | 最小值 |
| methanotrophy | 0.22 | 0.00 | 0.00 |
| methanogenesis\_by\_disproportionation\_of\_methyl\_groups | 0.50 | 0.01 | 0.00 |
| methanogenesis\_by\_CO2\_reduction\_with\_H2 | 2.27 | 0.04 | 0.00 |
| hydrogenotrophic\_methanogenesis | 2.27 | 0.04 | 0.00 |
| methanogenesis | 2.27 | 0.04 | 0.00 |
| methanol\_oxidation | 0.31 | 0.02 | 0.00 |
| methylotrophy | 0.31 | 0.02 | 0.00 |
| aerobic\_ammonia\_oxidation | 42.53 | 17.84 | 0.37 |
| aerobic\_nitrite\_oxidation | 1.22 | 0.26 | 0.00 |
| nitrification | 42.72 | 18.10 | 0.44 |
| sulfate\_respiration | 1.25 | 0.08 | 0.00 |
| sulfur\_respiration | 4.12 | 0.08 | 0.00 |
| thiosulfate\_respiration | 0.14 | 0.00 | 0.00 |
| respiration\_of\_sulfur\_compounds | 5.37 | 0.17 | 0.00 |
| chitinolysis | 3.60 | 0.41 | 0.00 |
| knallgas\_bacteria | 0.04 | 0.00 | 0.00 |
| dark\_hydrogen\_oxidation | 2.27 | 0.04 | 0.00 |
| nitrogen\_fixation | 0.15 | 0.02 | 0.00 |
| nitrate\_ammonification | 0.04 | 0.00 | 0.00 |
| nitrite\_ammonification | 0.04 | 0.00 | 0.00 |
| nitrite\_respiration | 0.21 | 0.01 | 0.00 |
| cellulolysis | 0.16 | 0.01 | 0.00 |
| xylanolysis | 0.03 | 0.00 | 0.00 |
| dark\_sulfide\_oxidation | 0.37 | 0.01 | 0.00 |
| dark\_oxidation\_of\_sulfur\_compounds | 0.37 | 0.01 | 0.00 |
| manganese\_oxidation | 0.78 | 0.10 | 0.00 |
| fermentation | 4.12 | 0.50 | 0.00 |
| human\_pathogens\_pneumonia | 0.11 | 0.01 | 0.00 |
| human\_pathogens\_all | 0.17 | 0.02 | 0.00 |
| animal\_parasites\_or\_symbionts | 0.35 | 0.03 | 0.00 |
| aromatic\_hydrocarbon\_degradation | 0.16 | 0.00 | 0.00 |
| aromatic\_compound\_degradation | 0.79 | 0.23 | 0.00 |
| aliphatic\_non\_methane\_hydrocarbon\_degradation | 0.16 | 0.00 | 0.00 |
| hydrocarbon\_degradation | 8.02 | 0.16 | 0.00 |
| iron\_respiration | 4.12 | 0.12 | 0.00 |
| nitrate\_respiration | 2.55 | 0.11 | 0.00 |
| nitrate\_reduction | 8.36 | 2.52 | 0.13 |
| nitrogen\_respiration | 2.55 | 0.11 | 0.00 |
| fumarate\_respiration | 0.04 | 0.00 | 0.00 |
| intracellular\_parasites | 0.11 | 0.00 | 0.00 |
| chlorate\_reducers | 0.05 | 0.00 | 0.00 |
| predatory\_or\_exoparasitic | 2.23 | 0.59 | 0.00 |
| cyanobacteria | 2.07 | 0.09 | 0.00 |
| oxygenic\_photoautotrophy | 2.07 | 0.09 | 0.00 |
| photoautotrophy | 2.07 | 0.09 | 0.00 |
| photoheterotrophy | 0.04 | 0.00 | 0.00 |
| phototrophy | 2.07 | 0.09 | 0.00 |
| plastic\_degradation | 0.08 | 0.00 | 0.00 |
| ureolysis | 0.46 | 0.04 | 0.00 |
| chemoheterotrophy | 25.37 | 11.22 | 1.06 |
| other | 91.84 | 69.64 | 44.48 |

附表4 微生物群落和环境参数相关性的Mantel检验分析结果

Table 4 Mantel tests on the correlation between microbial community and measured environmental variables

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 环境参数 | Pearson (R) | P | Spearman (R) | P |
| pH | 0.397 | <0.001 | 0.303 | <0.001 |
| EC | 0.585 | <0.001 | 0.474 | <0.001 |
| TN | 0.153 | 0.015 | 0.137 | 0.016 |
| TC | -0.007 | 0.493 | -0.011 | 0.544 |
| TH | -0.009 | 0.524 | -0.011 | 0.536 |
| TS | -0.071 | 0.776 | -0.020 | 0.600 |
| C/N | 0.192 | 0.039 | 0.270 | 0.001 |
| C/H | 0.001 | 0.464 | 0.014 | 0.388 |
| TOC | 0.066 | 0.197 | 0.040 | 0.247 |
| Ca | 0.046 | 0.242 | 0.063 | 0.141 |
| Fe | -0.066 | 0.805 | -0.038 | 0.681 |
| K | 0.009 | 0.409 | 0.005 | 0.442 |
| Mg | 0.155 | 0.016 | 0.155 | 0.012 |
| Na | 0.242 | 0.002 | 0.207 | 0.006 |
| As | -0.021 | 0.581 | 0.006 | 0.435 |
| Cd | 0.076 | 0.098 | 0.056 | 0.124 |
| Cr | -0.080 | 0.872 | -0.058 | 0.810 |
| Cu | -0.019 | 0.580 | 0.006 | 0.442 |
| Ga | -0.112 | 0.933 | -0.100 | 0.935 |
| Ge | -0.095 | 0.941 | -0.089 | 0.940 |
| Mn | -0.101 | 0.913 | -0.081 | 0.877 |
| Ni | -0.050 | 0.731 | -0.011 | 0.535 |
| P | -0.026 | 0.521 | -0.022 | 0.606 |
| Pb | -0.078 | 0.868 | -0.088 | 0.912 |
| Se | 0.020 | 0.355 | 0.035 | 0.294 |
| Sr | 0.538 | <0.001 | 0.494 | <0.001 |
| Zn | -0.112 | 0.955 | -0.070 | 0.839 |

附表5 空间因子与微生物群落结构的相关性

Table 5 Pearson correlations between the geographic distance and microbial community

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | PCNM1 | | PCNM19 | |
| Pearson (R) | P | Pearson (R) | P |
| 整体 | 0.132 | <0.001 | 0.274 | <0.001 |
| 门水平 | 0.272 | <0.001 | 0.142 | <0.005 |
| 纲水平 | 0.276 | <0.001 | 0.176 | <0.005 |
| 有氧氨氧化 | 0.134 | <0.001 | 0.229 | <0.001 |
| 硝化作用 | 0.136 | <0.001 | 0.229 | <0.001 |
| 硝酸盐还原 | 0.181 | <0.001 | 0.240 | <0.001 |
| 化能异养 | 0.152 | <0.001 | 0.152 | <0.001 |