*Supplement of*

# Geospatial micro-estimates of slum populations in 129 Global South countries using machine learning and public data

Supplementary Figures S1-S4

Supplementary Tables S1-S5

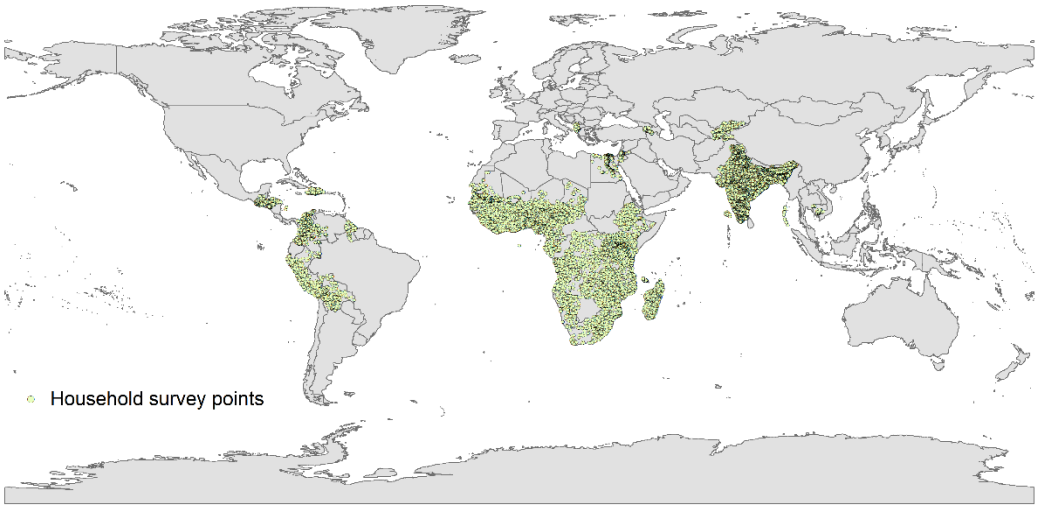


**Figure S1 Locations of household surveys, referred to as clusters, collected from Demographic and Health Surveys conducted in 53 countries of the Global South.** To protect respondent confidentiality, the GPS latitude/longitude coordinates of surveyed households within each cluster are randomly displaced.

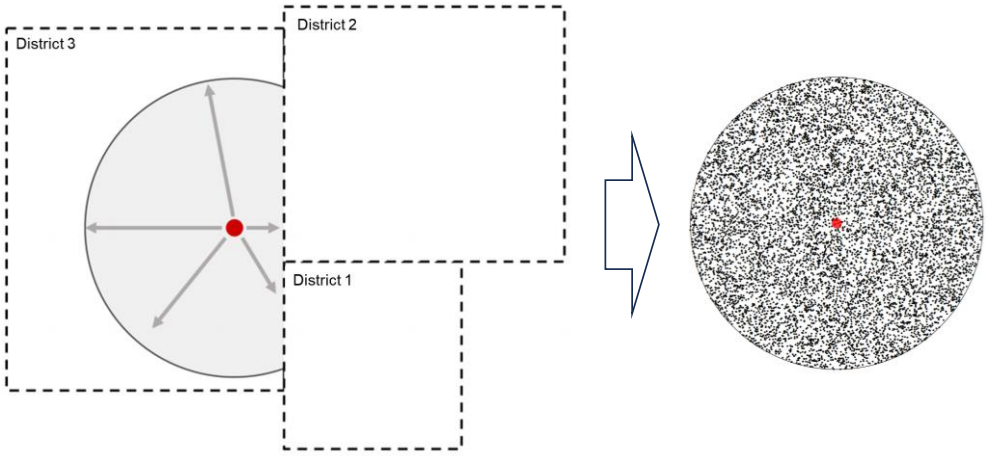


**Figure S2 A illustration of GPS perturbation.** The red point means the GPS coordinates after perturbation. Districts are at the administrative level 3.

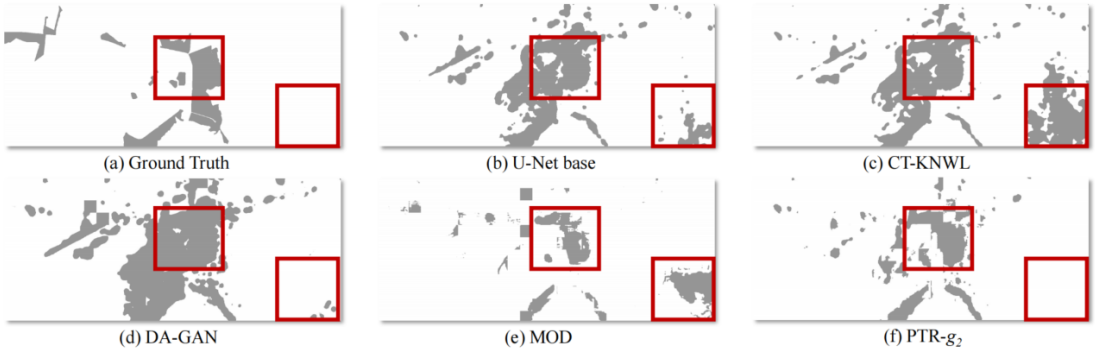


**Figure S3 Examples of the uncertainty in morphological slum delineation using five image segmentation methods (b-f), compared to ground truth (a).** sourced from Li et al., (2023). The existing slum population mapping frameworks heavily relied on slum geometry, exhibiting notable uncertainties.

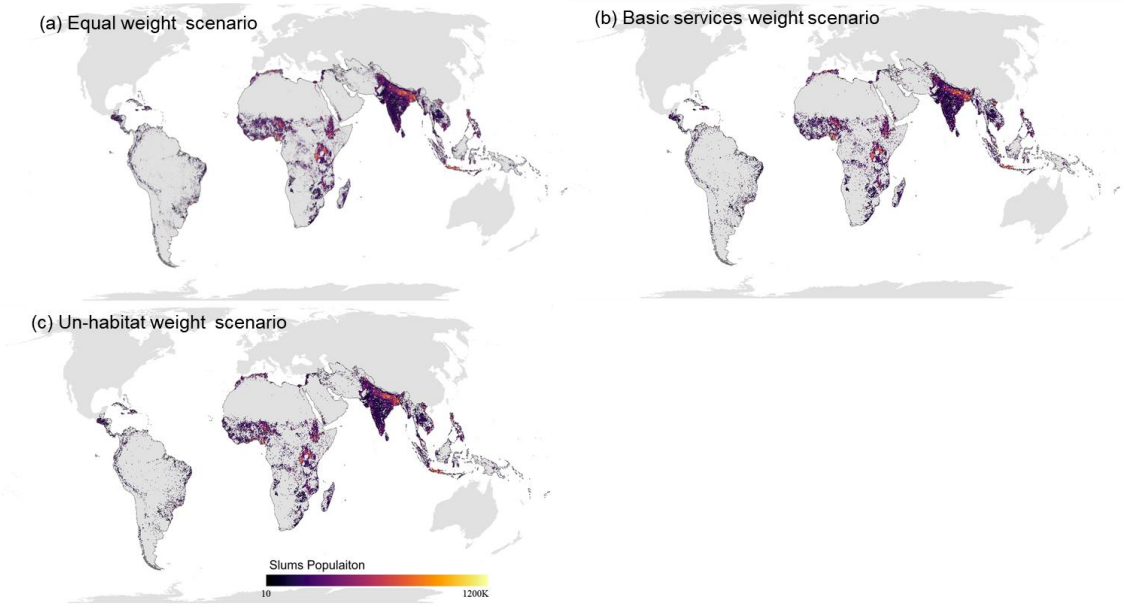


**Figure S4 Maps of the slum population based on three different weighting scenarios of slum indicators.** (a) equal weight scenario, (b) basic services weight scenario and (c) un-habitat weight scenario

**Table S1 Household-based surveys for each country.**

| Number | Country name | Code | Year | Counts | | |
|---|---|---|---|---|---|---|
| | | | | Total | Urban | Rural |
| 1 | Angola | AO | 2015 | 625 | 345 | 280 |
| 2 | Burkina Faso | BF | 2010 | 573 | 176 | 397 |
| 3 | Benin | BJ | 2017 | 555 | 251 | 304 |
| 4 | Burundi | BU | 2016 | 554 | 106 | 448 |
| 5 | D. R. of Congo | CD | 2013 | 536 | 161 | 375 |
| 6 | Côte d'Ivoire | CI | 2012 | 350 | 160 | 190 |
| 7 | Cameroon | CM | 2018 | 430 | 237 | 193 |
| 8 | Egypt | EG | 2018 | 1836 | 977 | 859 |
| 9 | Ethiopia | ET | 2016 | 643 | 202 | 441 |
| 10 | Gabon | GA | 2012 | 336 | 183 | 153 |
| 11 | Ghana | GH | 2014 | 427 | 216 | 211 |
| 12 | The Gambia | GM | 2019 | 280 | 173 | 107 |
| 13 | Guinea | GN | 2018 | 401 | 138 | 263 |
| 14 | Kenya | KE | 2014 | 1594 | 617 | 977 |
| 15 | Comoros | KM | 2012 | 252 | 108 | 144 |
| 16 | Liberia | LB | 2019 | 325 | 120 | 205 |
| 17 | Lesotho | LS | 2014 | 399 | 118 | 281 |
| 18 | Madagascar | MD | 2021 | 650 | 164 | 486 |
| 19 | Mali | ML | 2018 | 345 | 104 | 241 |
| 20 | Mauritania | MR | 2020 | 1200 | 565 | 635 |
| 21 | Malawi | MW | 2015 | 850 | 173 | 677 |
| 22 | Mozambique | MZ | 2011 | 610 | 256 | 354 |
| 23 | Nigeria | NG | 2018 | 1389 | 576 | 813 |
| 24 | Niger | NI | 2012 | 476 | 130 | 346 |
| 25 | Namibia | NM | 2013 | 550 | 267 | 283 |
| 26 | Rwanda | RW | 2019 | 500 | 112 | 388 |
| 27 | Sierra Leone | SL | 2019 | 576 | 214 | 362 |
| 28 | Senegal | SN | 2019 | 214 | 84 | 130 |
| 29 | Chad | TD | 2014 | 624 | 163 | 461 |
| 30 | Togo | TG | 2013 | 330 | 128 | 202 |
| 31 | U. R. Tanzania | TZ | 2015 | 608 | 180 | 428 |
| 32 | Uganda | UG | 2016 | 696 | 162 | 534 |
| 33 | South Africa | ZA | 2017 | 746 | 464 | 282 |
| 34 | Zambia | ZM | 2018 | 545 | 198 | 347 |
| 35 | Zimbabwe | ZW | 2015 | 400 | 166 | 234 |
| 36 | Bangladesh | BD | 2018 | 672 | 226 | 446 |
| 37 | India | IA | 2020 | 30170 | 7780 | 22390 |
| 38 | Jordan | JO | 2017 | 970 | 769 | 201 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 39 | Cambodia | KH | 2014 | 611 | 188 | 423 |
| 40 | Myanmar | MM | 2015 | 441 | 122 | 319 |
| 41 | Nepal | NP | 2016 | 383 | 243 | 140 |
| 42 | Philippines | PH | 2017 | 1250 | 444 | 806 |
| 43 | Pakistan | PK | 2017 | 561 | 282 | 279 |
| 44 | Tajikistan | TJ | 2017 | 366 | 166 | 200 |
| 45 | Timor Leste | TL | 2016 | 455 | 129 | 326 |
| 46 | Bolivia | BO | 2008 | 998 | 593 | 405 |
| 47 | Colombia | CO | 2010 | 4868 | 3401 | 1467 |
| 48 | Dominican R. | DR | 2013 | 524 | 364 | 160 |
| 49 | Guatemala | GU | 2015 | 853 | 381 | 472 |
| 50 | Guyana | GY | 2009 | 312 | 87 | 225 |
| 51 | Honduras | HN | 2011 | 1128 | 494 | 634 |
| 52 | Haiti | HT | 2016 | 450 | 152 | 298 |
| 53 | Peru | PE | 2009 | 1131 | 692 | 439 |

**Table S2 Definitions of the 10 slum sub-indicators and their corresponding criteria.**

| | Indicators | Improved | Unimproved |
|---|---|---|---|
| 1 | House made of finished materials (roof, wall and floor) | Finished roof materials typically include metal, wood, cement fiber, ceramic tiles, cement and roofing shingles | Natural or rudimentary roof materials typically include thatch, palm leaf, sod, rustic matting, bamboo, wood planks and cardboard. |
| | | Finished wall materials typically include cement, stone with lime or cement, burnt bricks, cement blocks, covered adobe and wood planks or shingles | Natural or rudimentary wall materials typically include cane, palm, dirt, bamboo or stone with mud, uncovered adobe, plywood, cardboard and reused wood planks. |
| | | Finished floor materials include parquet or polished wood, vinyl or asphalt strips, ceramic tiles, cement and carpet | Natural or rudimentary floor materials include earth, sand, dung, wood planks, palm and bamboo |
| 2 | House with a sufficient living room | no more than 3 people sharing one sleeping room | more than 3 people sharing one sleeping room |
| 3 | Household using safely managed drinking water | Piped water into dwelling<br>Piped water to yard/plot<br>Public tap or standpipe<br>Tubewell or borehole<br>Protected dug well<br>Protected spring<br>Rainwater | Unprotected spring<br>Unprotected dug well<br>Tanker-truck<br>Cart with small tank/drum<br>Surface water<br>Bottled water |
| 4 | Household with access to water availability for continuous two weeks | Yes, not interrupted for a full day | No, interrupted for a full day or more |
| 5 | Household with access to drinking water located within a round trip of 30 minutes | <30, on premises | >30, don't know |
| 6 | Household using safely managed sanitation toilets | Flush toilet<br>Piped sewer system<br>Septic tank<br>Flush/pour flush to pit latrine<br>Ventilated improved pit latrine (VIP)<br>Pit latrine with slab<br>Composting toilet | Flush/pour flush to elsewhere<br>Pit latrine without slab<br>Bucket<br>Hanging toilet or hanging latrine<br>Shared sanitation<br>No facilities or bush or field |
| 7 | Household using safely managed hand-washing facility with water. | Observed, fixed place | Not observed: no permission to see<br>not observed: not in dwelling |
| 8 | Household using safely managed hand-washing facility with soap or detergent | Yes | No |

| | | | |
|---|---|---|---|
| 9 | Household with access to electricity | Yes | No |
| 10 | Household with clean cooking fuels | Electricity, Natural gas, Biogas, LPG | Cardboard/paper<br>charcoal<br>other<br>petroleum/kerosene<br>wood<br>straw/shrubs/grass |

**Table S3 Regional models categorized by income levels and geographical locations.**

| | Regional models | Countries with available training labels | Countries with unavailable training labels |
|---|---|---|---|
| Africa | Low income& west of Africa countries Model | Burkina Faso; Chad; Democratic Republic of the Congo; The Gambia; Liberia; Mali; Niger; Sierra Leone; Togo | Central African Republic; Guinea-Bissau |
| | Low income& east of Africa countries Model | Burundi; Ethiopia; Madagascar; Malawi; Mozambique; Rwanda; Uganda | Eritrea; Somalia; Sudan |
| | Lower-middle income& west of Africa countries Model | Angola; Benin; Cameroon; Cote d'Ivoire; Ghana; Guinea; Mauritania; Nigeria; Senegal | Algeria; Cabo Verde; The Republic of the Congo; Morocco; Sao Tome and Principe; Tunisia; Western Sahara |
| | Lower-middle income& East of Africa countries Model | Comoros; Egypt; Kenya; Lesotho; the United Republic of Tanzania; Zambia; Zimbabwe | Djibouti; Swaziland（Eswatini） |
| | Upper-middle income countries Model | Gabon; Namibia; South Africa | Gabon; Namibia; South Africa; |
| Asia | Lower-middle income& west of Asia countries Model | Bangladesh; India; Jordan; Nepal; Pakistan; Tajikistan | Afghanistan; Bahrain; Bhutan; Iran; Iraq; Israel; Kuwait; Lebanon; Maldives; Oman; Qatar; Saudi Arabia; Sri Lanka; Syria; Turkmenistan; United Arab Emirates; West Bank; Yemen |
| | Lower-middle income& east of Asia countries Model | Cambodia; Myanmar (Burma); Philippines; Timor-Leste | Brunei; Fiji; Indonesia; Laos; Malaysia; Marshall Islands; Federated States of Micronesia; Nauru; Papua New Guinea; Singapore; Solomon Islands; Thailand; Vanuatu; Vietnam |
| Latin America | Lower-middle- and low income Model | Guyana; Colombia; Dominican Republic; Guatemala; Peru | Antigua and Barbuda; Barbados; Chile; Panama; St. Kitts and Nevis; The Bahamas; Trinidad and Tobago; Uruguay; French Guiana; Argentina; Belize; Brazil; Costa Rica; Cuba; Dominica; Ecuador; El Salvador; Grenada; Jamaica; Paraguay; St. Lucia; St. Vincent and the Grenadines; Suriname |
| | High- and upper middle- income Model | Bolivia; Haiti; Honduras | Marshall Islands; Federated States of Micronesia |

**Table S4 Optimal Hyperparameters of XGBoost Models for all three weighting scenarios.**

| Model | | | colsample_bytree | gamma | learning_rate | max_depth | n_estimators | subsample |
|---|---|---|---|---|---|---|---|---|
| Low income | West of Africa | Scenario1 | 0.6 | 0 | 0.1 | 3 | 65 | 0.8 |
| | | Scenario2 | 0.6 | 0 | 0.05 | 3 | 100 | 1 |
| | | Scenario3 | 0.6 | 0 | 0.1 | 3 | 81 | 1 |
| | East of Africa | Scenario1 | 1 | 0.2 | 0.05 | 5 | 117 | 0.8 |
| | | Scenario2 | 0.6 | 0 | 0.1 | 3 | 63 | 1 |
| | | Scenario3 | 0.6 | 0 | 0.1 | 3 | 55 | 1 |
| Lower middle income | West of Africa | Scenario1 | 0.6 | 0 | 0.1 | 3 | 94 | 0.8 |
| | | Scenario2 | 0.6 | 0.1 | 0.1 | 3 | 92 | 1 |
| | | Scenario3 | 0.6 | 0 | 0.1 | 3 | 110 | 1 |
| | East of Africa | Scenario1 | 0.6 | 0.1 | 0.1 | 3 | 56 | 0.8 |
| | | Scenario2 | 1.0 | 0 | 0.1 | 3 | 55 | 0.8 |
| | | Scenario3 | 1 | 0.2 | 0.1 | 3 | 63 | 0.8 |
| Upper middle income | Asia | Scenario1 | 1 | 0.3 | 0.1 | 3 | 48 | 1 |
| | | Scenario2 | 0.6 | 0 | 0.1 | 3 | 54 | 1 |
| | | Scenario3 | 1 | 0.3 | 0.05 | 3 | 219 | 0.8 |
| Lower middle income | West of Asia | Scenario1 | 0.8 | 0 | 0.03 | 7 | 228 | 0.8 |
| | | Scenario2 | 0.8 | 0.1 | 0.05 | 6 | 138 | 0.8 |
| | | Scenario3 | 0.8 | 0.2 | 0.05 | 5 | 142 | 1 |
| Lower middle income | East of Asia | Scenario1 | 0.6 | 0 | 0.1 | 3 | 69 | 1 |
| | | Scenario2 | 0.8 | 0 | 0.1 | 3 | 57 | 1 |
| | | Scenario3 | 1 | 0.2 | 0.1 | 3 | 97 | 1 |
| Lower- middle and low income | Latin American | Scenario1 | 0.8 | 0 | 0.1 | 3 | 55 | 1 |
| | | Scenario2 | 1 | 0 | 0.1 | 3 | 51 | 1 |
| | | Scenario3 | 0.6 | 0.3 | 0.1 | 6 | 50 | 1 |
| High and upper middle income | Latin American | Scenario1 | 0.8 | 0.2 | 0.1 | 5 | 93 | 0.8 |
| | | Scenario2 | 1 | 0 | 0.1 | 3 | 102 | 0.8 |
| | | Scenario3 | 0.8 | 0 | 0.1 | 3 | 84 | 1 |

**Table S5 The country-specific model's performance measured by the root mean square error (RMSE) and R squared ($R^2$)**

| Country | RMSE | $R^2$ | Country | RMSE | $R^2$ |
|---|---|---|---|---|---|
| AO | 6.79 | 0.93 | LS | 3.91 | 0.95 |
| BD | 4.68 | 0.83 | MD | 6.62 | 0.87 |
| BF | 5.62 | 0.90 | ML | 5.25 | 0.90 |
| BJ | 6.38 | 0.86 | MM | 4.50 | 0.87 |
| BO | 6.47 | 0.93 | MR | 7.64 | 0.91 |
| BU | 4.63 | 0.87 | MW | 3.95 | 0.89 |
| CD | 3.42 | 0.94 | MZ | 5.98 | 0.90 |
| CI | 7.59 | 0.85 | NG | 5.53 | 0.90 |
| CM | 4.49 | 0.95 | NI | 7.25 | 0.90 |
| CO | 5.98 | 0.88 | NM | 8.14 | 0.86 |
| DR | 3.19 | 0.82 | NP | 5.36 | 0.81 |
| EG | 1.38 | 0.92 | PE | 5.75 | 0.91 |
| ET | 4.10 | 0.97 | PH | 3.07 | 0.90 |
| GA | 3.51 | 0.93 | PK | 7.40 | 0.78 |
| GH | 6.51 | 0.77 | RW | 5.87 | 0.82 |
| GM | 2.88 | 0.95 | SL | 6.21 | 0.82 |
| GN | 5.26 | 0.91 | SN | 7.95 | 0.78 |
| GU | 4.85 | 0.85 | TD | 4.59 | 0.91 |
| GY | 4.35 | 0.92 | TG | 5.63 | 0.91 |
| HN | 5.80 | 0.77 | TJ | 3.68 | 0.81 |
| HT | 5.71 | 0.84 | TL | 6.43 | 0.84 |
| IA | 4.38 | 0.86 | TZ | 7.19 | 0.85 |
| JO | 2.55 | 0.79 | UG | 4.45 | 0.93 |
| KE | 5.98 | 0.89 | ZA | 4.45 | 0.93 |
| KH | 4.83 | 0.94 | ZM | 9.08 | 0.79 |
| KM | 3.52 | 0.81 | ZW | 4.61 | 0.95 |
| LB | 2.99 | 0.92 | | | |

## References:

Li, Z., Xie, Y., Jia, X., Stuart, K., Delaire, C. and Skakun, S., 2023. Point-to-region co-learning for poverty mapping at high resolution using satellite imagery. In *Proceedings of the AAAI Conference on Artificial Intelligence,* 37(12), 14321-14328.