**Supplementary Information**

**Table S1 Woolly wolf presence locations used for species distribution modelling**

|  |  |  |  |
| --- | --- | --- | --- |
| **Study** | **Country** | **No. of Locations** | **Year** |
| Mohammad Kabir et al., 2017 | Pakistan | 73 | 2017 |
| Subba et al., 2016 | Nepal | 20 | 2016 |
| Chetri et al., 2016 | Nepal | 14 | 2016 |
| Deu Bahadur Rana (Thesis) 2018 | Nepal | 125 | 2018 |
| Werhahn et al., 2019 | China | 10 | 2019 |
| Lyngdoh et al., 2021 | India | 3223 | 2021 |
| Reshamwala et al., 2021 | India | 267 | 2021 |
| Habib 2007 | Afghanistan | 37 | 2007 |
| Raza Khan et al., 2019 | Pakistan | 7 | 2019 |

**Table S2 List of all environmental variables acquired along with descriptions for conducting current and future species distribution modeling of woolly wolf**

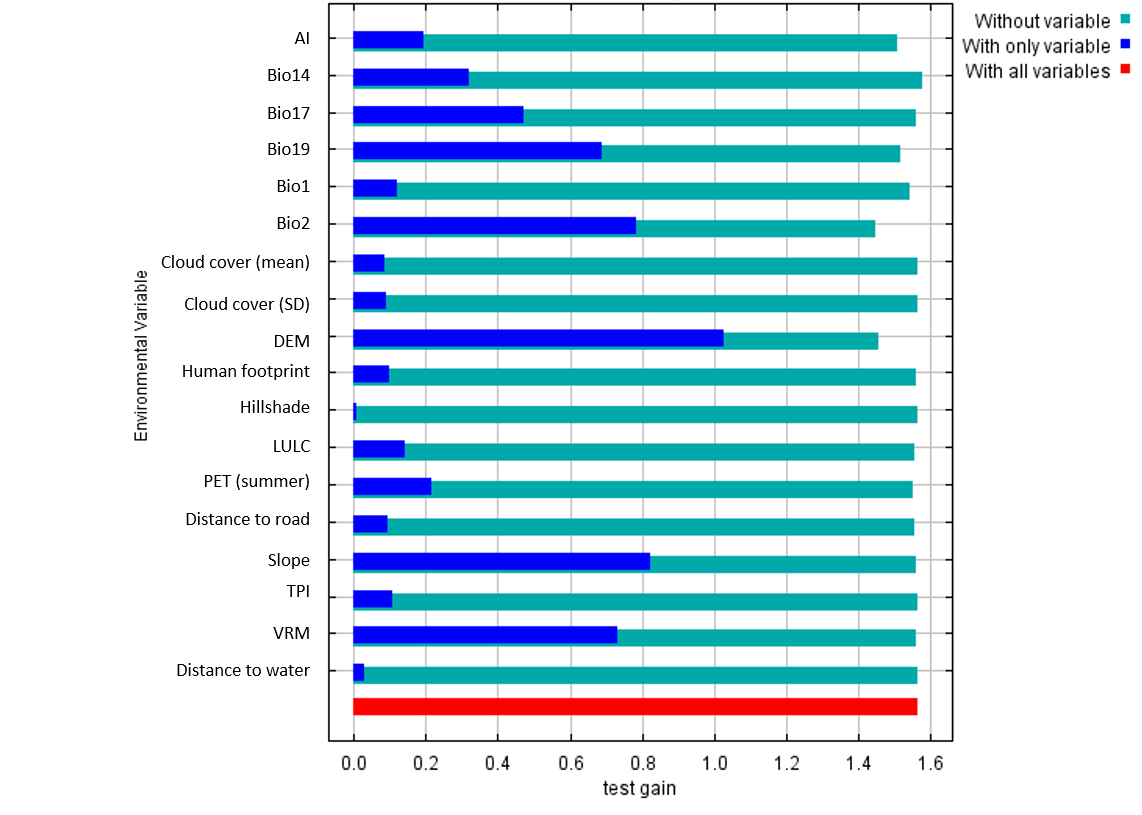
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **Environmental Layer** | **Source** | **Description** | **Type** |
| 1 | **\*** BIO1 = Annual Mean Temperature | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 2 | **\*** BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp)) | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 3 | BIO3 = Isothermality (BIO2/BIO7) (×100) | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 4 | BIO4 = Temperature Seasonality (standard deviation ×100) | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 5 | BIO5 = Max Temperature of Warmest Month | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 6 | BIO6 = Min Temperature of Coldest Month | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 7 | BIO7 = Temperature Annual Range (BIO5-BIO6) | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 8 | BIO8 = Mean Temperature of Wettest Quarter | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 9 | BIO9 = Mean Temperature of Driest Quarter | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 10 | BIO10 = Mean Temperature of Warmest Quarter | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 11 | BIO11 = Mean Temperature of Coldest Quarter | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 12 | BIO12 = Annual Precipitation | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 13 | BIO13 = Precipitation of Wettest Month | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 14 | **\*** BIO14 = Precipitation of Driest Month | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 15 | BIO15 = Precipitation Seasonality (Coefficient of Variation) | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 16 | BIO16 = Precipitation of Wettest Quarter | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 17 | **\*** BIO17 = Precipitation of Driest Quarter | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 18 | BIO18 = Precipitation of Warmest Quarter | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 19 | **\*** BIO19 = Precipitation of Coldest Quarter | <http://www.worldclim.com> | WorldClim data Version 1.4 at 30 seconds, resolution 1 km | Climatic |
| 20 | **\*** Aridity Index (AI) | <https://cgiarcsi.community/2019/01/24/global-aridity-index-and-potential-evapotranspiration-climate-database-v2/> |  | Climatic |
| 21 | **\*** Potential Evapotranspiration  (PET) (Summer) | <https://cgiarcsi.community/2019/01/24/global-aridity-index-and-potential-evapotranspiration-climate-database-v2/> | Mean (April to September) | Climatic |
| 22 | PET (Winter) | <https://cgiarcsi.community/2019/01/24/global-aridity-index-and-potential-evapotranspiration-climate-database-v2/> | Mean (October to March) | Climatic |
| 23 | **\*** Cloud cover (SD) | <https://www.earthenv.org/cloud> |  | Climatic |
| 24 | **\*** Cloud cover (Mean) | <https://www.earthenv.org/cloud> |  | Climatic |
| 25 | Normalized Difference Vegetation Index (NDVI) (Summer) 2010 | <https://lpdaac.usgs.gov> | Mean (April to September), MOD13A2, version 006, resolution 1km at a 16-day interval | Topographical |
| 26 | NDVI (Winter) 2010 | <https://lpdaac.usgs.gov> | Mean (October to March) MOD13A2, version 006, resolution 1km at a 16-day interval | Topographical |
| 27 | **\*** Digital elevation model (DEM) | <https://www2.jpl.nasa.gov/srtm/> | SRTM elevation | Topographical |
| 28 | \* Current global Land Use Land Cover (LULC) | <https://lpdaac.usgs.gov> | SDS Land Cover Type 1, IGBP classification, 18 Land Cover classes reclassified into six broad classes, resolution 500 m | Topographical |
| 29 | **\*** Slope |  | Derived from DEM | Topographical |
| 30 | Aspect |  | Derived from DEM | Topographical |
| 31 | **\*** Topographic position index (TPI) |  | Derived from DEM | Topographical |
| 32 | Terrain ruggedness |  | Derived from DEM | Topographical |
| 33 | **\*** Vector ruggedness measure (VRM) |  | Derived from DEM | Topographical |
| 34 | **\*** Hill shade |  | Derived from DEM | Topographical |
| 35 | **\*** Distance to nearest water source | <https://www.hydrosheds.org/page/gloric>. | Processed from Global River Classification (GloRiC version 1.0) | Topographical |
| 36 | Distance to nearest glaciers | <http://glims.colorado.edu/glacierdata/> | Processed from Global Land Ice Measurements from Space (GLIMS) | Topographical |
| 37 | **\*** Distance to nearest roads | <https://sedac.ciesin.columbia.edu/> | Processed from World road layers | Anthropogenic |
| 38 | **\*** Human Footprint | <https://sedac.ciesin.columbia.edu/> |  | Anthropogenic |
| 39 | Population density | <https://sedac.ciesin.columbia.edu/> |  | Anthropogenic |
| 40 - 58 | RCP 4.5 (2050) | <http://www.worldclim.com> | Version 1.4, downscaled CMIP5 projection at 30 seconds, resolution 1km, MICROC 5 GCM | Future Climatic |
| 59 - 77 | RCP 8.5 (2050) | <http://www.worldclim.com> | Version 1.4, downscaled CMIP5 projection at 30 seconds, resolution 1km, MICROC 5 GCM | Future Climatic |
| 78 - 96 | RCP 4.5 (2070) | <http://www.worldclim.com> | Version 1.4, downscaled CMIP5 projection at 30 seconds, resolution 1km, MICROC 5 GCM | Future Climatic |
| 97 - 115 | RCP 8.5 (2070) | <http://www.worldclim.com> | Version 1.4, downscaled CMIP5 projection at 30 seconds, resolution 1km, MICROC 5 GCM | Future Climatic |
| 116 | Future global LULC A1B scenario (2050) | <http://geosimulation.cn/GlobalLUCCProduct.html> | SDS Land Cover Type 1, IGBP classification, 18 Land Cover classes reclassified into six broad classes, resolution 500 m | Future topographical |

Note: \* Environmental variables with < 0.6 correlation used for analysis of current distribution

CMIP5 = Coupled Model Intercomparison Project Phase 5; RCP = Representative Concentration Pathway; GCM = Global Climatic Model. The current distribution was modelled using first 39 variables and for future projection only climatic and LULC layers were replaced with appropriate future scenarios.

**Table S3: List of Maxent models conducted with various combinations for species distribution modelling of woolly wolf**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sr.no.** | **Models** | **Feature class** | **Regularization multiplier** | **Iterations** | **Bias File** | **Partitioned training set** | **Future scenario (2050)** | **Future scenario (2070)** |
| 1 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | nil | full | nil | nil |
| 2 | 2x2 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | nil | full | nil | nil |
| 3 | 3x3 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | nil | full | nil | nil |
| 4 | 5x5 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | nil | full | nil | nil |
| 5 | 7x7 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | nil | full | nil | nil |
| 6 | 10x10 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | nil | full | nil | nil |
| 7 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 50km | full | nil | nil |
| 8 | 2x2 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 50km | full | nil | nil |
| 9 | 3x3 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 50km | full | nil | nil |
| 10 | 5x5 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 50km | full | nil | nil |
| 11 | 7x7 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 50km | full | nil | nil |
| 12 | 10x10 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 50km | full | nil | nil |
| 13 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 100km | full | nil | nil |
| 14 | 2x2 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 100km | full | nil | nil |
| 15 | 3x3 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 100km | full | nil | nil |
| 16 | 5x5 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 100km | full | nil | nil |
| 17 | 7x7 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 100km | full | nil | nil |
| 18 | 10x10 grid locations + variables | Linear, Quadratic, Hinge | Default | 1 | 100km | full | nil | nil |
| 19 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 0.25 | 1 | 100km | full | nil | nil |
| 20 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 0.5 | 1 | 100km | full | nil | nil |
| 21 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 1 | 1 | 100km | full | nil | nil |
| 22 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 1.5 | 1 | 100km | full | nil | nil |
| 23 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 1 | 100km | full | nil | nil |
| 24 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 1 | nil | nil |
| 25 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 2 | nil | nil |
| 26 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 3 | nil | nil |
| 27 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 4 | nil | nil |
| 28 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 5 | nil | nil |
| 29 | 1x1 grid locations + variables excluding LULC | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 1 | RCP 4.5 | nil |
| 30 | 1x1 grid locations + variables excluding LULC | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 2 | RCP 4.5 | nil |
| 31 | 1x1 grid locations + variables excluding LULC | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 3 | RCP 4.5 | nil |
| 32 | 1x1 grid locations + variables excluding LULC | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 4 | RCP 4.5 | nil |
| 33 | 1x1 grid locations + variables excluding LULC | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 5 | RCP 4.5 | nil |
| 34 | 1x1 grid locations + variables excluding LULC | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 1 | RCP 8.5 | nil |
| 35 | 1x1 grid locations + variables excluding LULC | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 2 | RCP 8.5 | nil |
| 36 | 1x1 grid locations + variables excluding LULC | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 3 | RCP 8.5 | nil |
| 37 | 1x1 grid locations + variables excluding LULC | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 4 | RCP 8.5 | nil |
| 38 | 1x1 grid locations + variables excluding LULC | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 5 | RCP 8.5 | nil |
| 39 | 1x1 grid locations + variables excluding climatic | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 1 | LULC A1b | nil |
| 40 | 1x1 grid locations + variables excluding climatic | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 2 | LULC A1b | nil |
| 41 | 1x1 grid locations + variables excluding climatic | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 3 | LULC A1b | nil |
| 42 | 1x1 grid locations + variables excluding climatic | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 4 | LULC A1b | nil |
| 43 | 1x1 grid locations + variables excluding climatic | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 5 | LULC A1b | nil |
| 44 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 1 | RCP4.5+LULCA1b | nil |
| 45 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 2 | RCP4.5+LULCA1b | nil |
| 46 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 3 | RCP4.5+LULCA1b | nil |
| 47 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 4 | RCP4.5+LULCA1b | nil |
| 48 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 5 | RCP4.5+LULCA1b | nil |
| 49 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 1 | RCP8.5+LULCA1b | nil |
| 50 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 2 | RCP8.5+LULCA1b | nil |
| 51 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 3 | RCP8.5+LULCA1b | nil |
| 52 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 4 | RCP8.5+LULCA1b | nil |
| 53 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 5 | RCP8.5+LULCA1b | RCP4.5+LULCA1b |
| 54 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 1 | nil | RCP4.5+LULCA1b |
| 55 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 2 | nil | RCP4.5+LULCA1b |
| 56 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 3 | nil | RCP4.5+LULCA1b |
| 57 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 4 | nil | RCP4.5+LULCA1b |
| 58 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 5 | nil | RCP8.5+LULCA1b |
| 59 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 1 | nil | RCP8.5+LULCA1b |
| 60 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 2 | nil | RCP8.5+LULCA1b |
| 61 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 3 | nil | RCP8.5+LULCA1b |
| 62 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 4 | nil | RCP8.5+LULCA1b |
| 63 | 1x1 grid locations + variables | Linear, Quadratic, Hinge | 2 | 50 | 100km | set 5 | nil | RCP8.5+LULCA1b |

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**Figure S1: Results of Jackknife test showing percent contribution of each variable.**

**Table S4. Country wise gain/loss of woolly wolf suitable habitat both within (PA) and outside Protected Areas (OPA) in RCP 4.5 for 2050 and 2070 future scenarios with respect to current suitable habitat in three suitability classes**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **rcp45\_2050** | | | **rcp45\_2070** | | |
| **Countries** | **Area** | **Low (%)** | **Medium (%)** | **High (%)** | **Low (%)** | **Medium (%)** | **High (%)** |
| **Mongolia** | **PA** | -0.94 | 24.79 | 191.49 | -0.65 | 17.14 | 112.77 |
|  | **OPA** | -0.88 | 71.80 | 1371.43 | -0.48 | 39.59 | 871.43 |
| **Afghanistan** | **PA** | 13.96 | -9.33 | 22.92 | -9.50 | -25.95 | 159.66 |
|  | **OPA** | -60.03 | 13.51 | 222.35 | -59.63 | -3.37 | 246.02 |
| **Pakistan** | **PA** | 0.48 | 34.81 | -18.93 | 0.72 | 3.12 | -2.47 |
|  | **OPA** | -0.55 | -16.13 | 4.89 | -0.82 | -11.91 | 3.80 |
| **China** | **PA** | -7.23 | 63.42 | 164.48 | -9.05 | 82.88 | 164.82 |
|  | **OPA** | 16377.16 | 7965.98 | 68108.62 | 16318.74 | 8186.01 | 67880.92 |
| **Kyrgyzstan** | **PA** | 32.38 | -38.79 | 140.10 | 40.76 | -28.93 | -2.83 |
|  | **OPA** | -98.43 | -83.72 | -44.62 | -98.38 | -81.21 | -77.04 |
| **Tajikistan** | **PA** | 9.23 | -9.26 | 9.87 | 12.28 | -9.48 | 9.37 |
|  | **OPA** | 11.80 | -7.98 | 1.23 | 26.64 | -13.14 | -1.82 |
| **India** | **PA** | -57.12 | 5.02 | 74.70 | -58.98 | -0.82 | 91.86 |
|  | **OPA** | 403.04 | 677.39 | 73727.27 | 390.14 | 623.66 | 91777.27 |

**Table S5. Country wise gain/loss of woolly wolf suitable habitat both within (PA) and outside Protected Areas (OPA) in RCP 8.5 for 2050 and 2070 future scenarios with respect to current suitable habitat in three suitability classes**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **rcp85\_2050** | | | **rcp85\_2070** | | |
| **Countries** | **Area** | **Low (%)** | **Medium (%)** | **High (%)** | **Low (%)** | **Medium (%)** | **High (%)** |
| **Mongolia** | **PA** | -0.87 | 23.07 | 206.38 | -1.37 | 32.39 | 1706.38 |
|  | **OPA** | -0.60 | 49.23 | 1314.29 | -1.43 | 114.43 | 14742.86 |
| **Afghanistan** | **PA** | 8.89 | -13.45 | 55.35 | -3.14 | -13.02 | 76.92 |
|  | **OPA** | -62.14 | 10.67 | 233.82 | -57.86 | -0.31 | 235.55 |
| **Pakistan** | **PA** | 0.00 | 39.48 | -20.85 | 0.85 | 9.09 | -5.76 |
|  | **OPA** | -1.29 | -5.24 | 2.09 | -1.43 | -15.26 | 5.03 |
| **China** | **PA** | -10.68 | 99.73 | 172.34 | -11.37 | 102.73 | 222.90 |
|  | **OPA** | 16095.94 | 8782.32 | 78142.46 | 16009.96 | 8715.46 | 96110.46 |
| **Kyrgyzstan** | **PA** | 32.34 | -37.08 | 124.94 | 30.71 | -34.71 | 114.40 |
|  | **OPA** | -98.37 | -83.77 | -50.94 | -98.55 | -81.74 | -52.70 |
| **Tajikistan** | **PA** | 7.78 | -9.65 | 10.77 | -9.80 | -14.64 | 22.01 |
|  | **OPA** | 13.59 | -6.71 | -0.93 | 23.31 | -13.61 | 0.39 |
| **India** | **PA** | -61.67 | 2.76 | 87.19 | -68.63 | -9.50 | 127.87 |
|  | **OPA** | 407.19 | 690.50 | 68772.73 | 361.00 | 735.78 | 83604.55 |