

# Measures of Remoteness: Land Isolation Distance and Population Isolation Distance

**Tim Powell**

*Independent Researcher*

*Oakton, VA, USA*

[Tim@GeoIsolation.com](mailto:Tim@GeoIsolation.com)

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## **Abstract**

The paper presents straightforward measures involving distance that are useful in determining isolation and independence, i.e., freedom from influence. The *Land Isolation Distance* is the distance from a particular island or landmass to the nearest land of equal or greater size. The measure is very versatile: the list of top 25 most isolated lands includes continents, medium-sized islands and tiny islands. The twin measure, *Population Isolation Distance*, is used on population data and the results are similarly versatile: the top 25 list includes major metropolitan areas as well as tiny settlements. These measures are also likely valuable to analysts applying Geographic Information Systems to demographic data and other data sets.

**Keywords:** GIS, isolation, land, population, remote

## **Introduction and Benefits**

Humans throughout history have pondered their isolation, thinking about faraway lands and distant peoples. As travel has become much easier in recent times, more and more of us have the opportunity to visit several different lands and communities. But a key question remains: which lands and peoples are the most isolated? This paper presents quantitative measures that are useful and versatile in answering this question. Also, the two measures discussed are likely valuable to analysts applying Geographic Information Systems to various data sets in other domains.

Isolation implies distance. The *Land Isolation Distance* is the distance from one land – tiny island, large island, continent or landmass – to a land of equal or greater size. This straightforward calculation and its twin measure, *Population Isolation Distance*, have probably been used informally in various studies but no one has systematically applied the measures to land and population data. These twin measures are useful because they capture the concept of isolation and do so in simple calculations.

Alternative measures for analyzing land relationships such as *Nearest Land* and *Nearest Inhabited Land* do not capture the concept of isolation very well. For example, Australia is intuitively isolated from other major lands in Asia and the West; however, there are several tiny islands, including Bird Island, just off the coast of Australia, making the Nearest Land calculation small, incorrectly indicating low isolation. Similarly, the Nearest Inhabited Land measure fails to correctly predict isolation because some of these same islands are inhabited, such as Daydream Island (5 km off the coast<sup>gm</sup>). Another example is the famously isolated island of Tahiti with its smaller sister island of Moorea just 17 km away<sup>gm</sup>. Both of the nearest-land measures just mentioned incorrectly indicate low isolation for Tahiti.

Perhaps an easier way to explain the utility of the twin isolation measures is to examine some Population Isolation Distance examples. Kahuku is a community of less than 3000 persons<sup>1</sup> on the Hawaiian island of Oahu. Although they live on an island in the middle of the Pacific, the citizens of Kahuku probably do not feel very isolated. There are several other larger towns and cities nearby on the island and Kahuku citizens are just one-hour or so by car from Honolulu<sup>gm</sup>, a metropolitan area with a population of almost a million people<sup>1</sup> and where one can purchase almost any product, service or food in the world. In contrast, many of the citizens of Honolulu *do* probably feel isolated. Even though they live in a large city, the influence and excitement of the next nearest larger metro area is San Francisco, over 3800 km away on the mainland of North America<sup>gm</sup>. The Population Isolation Distances are: 5 km for Kahuku<sup>gm</sup> (distance from the village of Laie) and 3800 km for Honolulu<sup>gm</sup>. This example also illustrates a central tenet of population isolation: size matters, i.e., nearness to a smaller population does not make one feel less isolated.

For other examples, consider Farmington, Missouri, population 16,200 and Population Isolation Distance of 95 km (60 miles) from downtown St. Louis<sup>1,gm</sup>, which itself is 421 km (262 miles) away from the nearest larger metro area, Chicago<sup>2,gm</sup>. Or the tiny village (population 523) of Tabiteuea on Tarawa Atoll of Kiribati just 8 km (5 mi) away from the bustling 50,000 person South Tarawa urban area<sup>3,gm</sup>. South Tarawa's nearest larger population is 1870 km away in the Solomon Islands<sup>gm</sup>. In each case, citizens of the smaller communities

probably do not feel isolated while citizens of the larger cities probably do. The versatile Population Isolation Distance measure also works well in oft-cited remote places such as the island of Saint Helena in the middle of the Atlantic between South America and Africa. The calculation is 1880 km as there is nothing but ocean for the total distance between the largest settlement on the island, Half Tree Hollow (population 984) and the city of Tombwa and other coastal communities of Angola<sup>4,5,gm</sup>.

## Methodology

To compute the Land Isolation Distance of a particular land, we need two data sets: land areas and distances. The distances (great circle distances) are between the closest points of the two lands, i.e., from the particular land being analyzed to each of the other lands. The Land Isolation Distance is this distance for the nearest land that is equal to or larger in area.

Land areas vary from the largest landmass, Afro-Eurasia, to the smallest islets. For atolls and other island groups, treat each islet as a separate land in Land Isolation Distance calculations unless there is a causeway or footpath connecting the islet to another islet.

The most efficient algorithm for computing Land Isolation Distance depends on the geographic region and size of the particular land being analyzed and the availability of land area and distance data. One approach suitable for a human analyst (vs. fully automated) is to obtain the land areas for all lands near the land being analyzed, Land Z, and to filter out from this list all the lands with areas smaller than Land Z. If there are no lands “near” that are larger than Land Z, expand the geographic area being considered until there are larger lands. For the remaining lands on the list, examine a map to predict which land is nearest to Land Z and calculate the distance between the two lands (between the nearest points). If another land or lands could possibly be nearer to Land Z, repeat the distance calculation for the other land(s). This step is especially important when working with large distances due to the distortion of the projection of Earth (a sphere) onto a flat map. Always measure distances using a great circle calculation (Google Maps, for example, provides a distance tool that incorporates great circle<sup>gm</sup>). Finally, select the distance to the nearest land of equal or greater size than Land Z; this is the Land Isolation Distance of Land Z.

The definitions and algorithms for computing Population Isolation Distance are similar to those of Land Isolation Distance, using population size instead of land area. The Population Isolation Distance for a particular city or community is the distance to the nearest population of equal or greater number. Instead of the population edges, measure the distance between the two populations from the population centers. Also, use metropolitan area or urban area data where available as other population measures are often limited by arbitrary boundaries.

## Results

The tables below present the top 25 most isolated lands and populations. Note the wide range in land areas in the first table and the wide range in population size in the second table. The existence of a wide range of values is a strong indicator that these calculations are robust and potentially useful for many different applications.

| #  | Island or Landmass                 | Country    | Ocean         | Area      |                           | Country      | Area (sq. km) | Distance (km) |
|----|------------------------------------|------------|---------------|-----------|---------------------------|--------------|---------------|---------------|
|    |                                    |            |               | (sq. km)  | Nearest Larger            |              |               |               |
| 1  | Hawai'i/Hawaiian Islands           | USA        | N. Pacific    | 10,432    | Americas                  | USA          | 42,300,000    | 3,670         |
| 2  | Easter Island                      | Chile      | S. Pacific    | 164       | Isabela Is./Galapagos Is. | Ecuador      | 4,711         | 3,470         |
| 3  | Australia                          | Australia  | Ind., S. Pac. | 7,600,000 | Afro-Eurasia              | Malaysia     | 85,000,000    | 2,790         |
| 4  | Tristan da Cunha/Tristan da C. Is. | UK         | S. Atlantic   | 98        | Saint Helena              | UK           | 121           | 2,430         |
| 5  | Tahiti/Society Islands             | France     | S. Pacific    | 1,069     | Upolu                     | Samoa        | 1,125         | 2,360         |
| 6  | Grande Terre/Kerguelen Islands     | France     | Indian        | 6,617     | Antarctica                | (none)       | 14,000,000    | 1,960         |
| 7  | Kiritimati                         | Kiribati   | N. Pacific    | 389       | Hawai'i/Hawaiian Islands  | USA          | 10,434        | 1,890         |
| 8  | Sand Island/Midway Atoll           | USA        | N. Pacific    | 5         | Ni'ihau/Hawaii            | USA          | 180           | 1,860         |
| 9  | Saint Helena                       | UK         | S. Atlantic   | 121       | Afro-Eurasia              | Angola       | 85,000,000    | 1,855         |
| 10 | *Bouvet Island                     | Norway     | Southern      | 59        | Antarctica                | (none)       | 14,000,000    | 1,760         |
| 11 | *Marion Island/Prince Edward Is.   | S. Africa  | Indian        | 298       | Afro-Eurasia              | S. Africa    | 85,000,000    | 1,730         |
| 12 | Diego Garcia Island/Chagos Arch.   | UK         | Indian        | 27        | Sri Lanka                 | Sri Lanka    | 67,655        | 1,710         |
| 13 | Guam                               | USA        | N. Pacific    | 541       | Manus                     | Papua N.G.   | 1,940         | 1,705         |
| 14 | South Island                       | N. Zealand | S. Pacific    | 145,836   | Australia                 | Australia    | 7,600,000     | 1,650         |
| 15 | *Henderson Island/Pitcairn Islands | UK         | S. Pacific    | 31        | Rapa/Austral Islands      | France       | 39            | 1,630         |
| 16 | Wake Islet/Wake Atoll              | USA        | N. Pacific    | 6         | Majuro/Majuro Atoll       | Marshall Is. | 7             | 1,430         |
| 17 | Nuku Hiva/Marquesas Islands        | France     | S. Pacific    | 339       | Tahiti/Society Islands    | France       | 1,069         | 1,375         |
| 18 | *Ile Amsterdam                     | France     | Indian        | 47        | Grand Terre/Kerguelen Is. | France       | 6,617         | 1,368         |
| 19 | Sao Miguel Island/Azores           | Portugal   | N. Atlantic   | 769       | Afro-Eurasia              | Portugal     | 85,000,000    | 1,367         |
| 20 | *South Georgia Is./S. Georgia Grp. | UK         | S. Atlantic   | 3,718     | East Falkland/Falklands   | UK           | 7,040         | 1,340         |
| 21 | Abemama/Abemama Atoll              | Kiribati   | S. Pacific    | 24        | Kosrae                    | Micronesia   | 110           | 1,310         |
| 22 | Pohnpei/Senyavin Islands           | Micronesia | N. Pacific    | 334       | New Ireland               | Papua N.G.   | 7,405         | 1,305         |
| 23 | Ascension Island                   | UK         | S. Atlantic   | 88        | Saint Helena              | UK           | 121           | 1,290         |
| 24 | Grande Terre/New Caledonia         | France     | S. Pacific    | 16,648    | Australia                 | Australia    | 7,600,000     | 1,270         |
| 25 | Kanton Island                      | Kiribati   | S. Pacific    | 9         | Savai'i                   | Samoa        | 1,718         | 1,180         |

\* Uninhabited

Table 1: Most Isolated Lands [area data<sup>6,7,8,9,10,11,12</sup>, distances<sup>gm</sup>]

| #  | Metro Area or Community         | Country    | Population | Continent  | Nearest Larger              | Country    | Population | Distance (km) |
|----|---------------------------------|------------|------------|------------|-----------------------------|------------|------------|---------------|
| 1  | New York                        | USA        | 23,723,696 | N. America | Tokyo                       | Japan      | 37,832,892 | 10,840        |
| 2  | Sao Paulo                       | Brazil     | 21,242,939 | S. America | Mexico City                 | Mexico     | 21,339,781 | 7,430         |
| 3  | Lagos                           | Nigeria    | 21,000,000 | Africa     | Sao Paulo                   | Brazil     | 21,242,939 | 6,360         |
| 4  | Sydney                          | Australia  | 5,000,500  | Oceania    | Surabaya                    | Indonesia  | 6,484,026  | 4,930         |
| 5  | Karachi                         | Pakistan   | 24,300,000 | Asia       | Guangzhou                   | China      | 25,000,000 | 4,680         |
| 6  | Jakarta                         | Indonesia  | 30,000,000 | Asia       | Shanghai                    | China      | 34,000,000 | 4,440         |
| 7  | Moscow                          | Russia     | 19,000,000 | Asia       | Karachi                     | Pakistan   | 24,300,000 | 4,180         |
| 8  | Honolulu/Hawaii                 | USA        | 953,207    | Oceania    | San Francisco               | USA        | 4,594,060  | 3,850         |
| 9  | Cairo                           | Egypt      | 18,772,000 | Africa     | Karachi                     | Pakistan   | 24,300,000 | 3,560         |
| 10 | Hanga Roa/Easter Island         | Chile      | 3,304      | S. America | Lebu/Bio Bio                | Chile      | 20,838     | 3,530         |
| 11 | McMurdo Station/Antarctica      | USA        | 250        | Antarctica | Oban/Stewart Island         | N. Zealand | 302        | 3,440         |
| 12 | Papeete/Society Islands         | France     | 124,864    | Oceania    | Suva                        | Fiji       | 173,137    | 3,380         |
| 13 | Mexico City                     | Mexico     | 21,339,781 | N. America | New York                    | USA        | 23,723,696 | 3,360         |
| 14 | Lima                            | Peru       | 9,886,647  | S. America | Buenos Aires                | Argentina  | 13,074,000 | 3,130         |
| 15 | Johannesburg                    | S. Africa  | 9,399,000  | Africa     | Kinshasa                    | Dm. Congo  | 11,587,000 | 2,780         |
| 16 | Perth                           | Australia  | 1,728,867  | Oceania    | Melbourne                   | Australia  | 4,650,000  | 2,720         |
| 17 | Mirny Station/Antarctica        | Russia     | 60         | Antarctica | McMurdo Stn./Antarctica     | USA        | 250        | 2,560         |
| 18 | London                          | UK         | 13,879,757 | Europe     | Istanbul                    | Turkey     | 14,804,116 | 2,500         |
| 19 | Los Angeles                     | USA        | 14,237,873 | N. America | Mexico City                 | Mexico     | 21,339,781 | 2,490         |
| 20 | Edinburgh./Tristan da Cunha Is. | UK         | 270        | Africa     | Half Tree Hollow/St. Helena | UK         | 984        | 2,440         |
| 21 | Nairobi                         | Kenya      | 6,650,000  | Africa     | Kinshasa                    | Dm. Congo  | 11,587,000 | 2,420         |
| 22 | Base Station/Kerguelen Islands  | France     | 50         | Antarctica | Mirny Station/Antarctica    | Russia     | 60         | 2,310         |
| 23 | Auckland                        | N. Zealand | 1,507,600  | Oceania    | Sydney                      | Australia  | 5,000,500  | 2,160         |
| 24 | Novolazarevskaya Stn./Antarc.   | Russia     | 30         | Antarctica | Amundsen–Scott Stn./Ant.    | USA        | 75         | 2,146         |
| 25 | Anchorage/Alaska                | USA        | 402,000    | N. America | Vancouver                   | Canada     | 2,460,000  | 2,130         |

Table 2: Most Isolated Populations [population data<sup>1,13,14,15,16,17,18,19,20,21,22,23,24,25</sup>, distances<sup>gm</sup>]

The largest landmass on Earth, Afro-Eurasia, does not have a Land Isolation Distance because by definition there is no nearest larger land. Similarly, Tokyo, the largest metropolitan area, does not have a Population Isolation Distance.

## Discussion

There are several aspects of the twin distance measures that merit further examination and perhaps the most controversial are the calculation formulas themselves. Instead of “nearest equal to or greater than...,” one could create more complex calculations but in the end they seem less useful. For example, an alternative calculation is to take the integral of the land areas encountered traveling in each direction from Land Z and define the

isolation distance as the point where any of the integrals exceeds the area of Land Z. Keeping track of all the integrals makes for a very complex calculation and, arguably, the result is not a better measure of isolation. There are many permutations one can think of and all require many more mathematical operations to compute a result and many more minutes of head scratching to interpret the result. The measure presented in this paper is the best combination of intuitive correlation with isolation and calculation simplicity.

Lastly about the selected calculation is that one could state “the nearest larger than” and in practice the calculations would be the same, i.e., the measures yield the same results. Measurements of land area are imprecise and change slightly over time (e.g., erosion, global warming) and populations are constantly changing so the case of “equal to” does not exist in practice.

The Land Isolation Distance calculations above use total land area, which includes fully enclosed bodies of water. There is room for debate about whether using dry land area would be more accurate but there are very few cases where the dry land measure would yield a significantly different result. For example, the unique island of Gaua in the South Pacific (Republic of Vanuatu) has a very large lake, Lake Letas, relative to the island. Even in this extreme case, the lake is only 5.5% of the total area (19 sq. km of 342 sq. km total<sup>7,26</sup>).

Atolls present challenges to the Land Isolation Distance measure in both interpretation and calculation. Often, reefs connecting islets along an atoll are above the water level at low tide but disappear underwater at high tide – are the islets and reefs all one land? At the other extreme, many large atolls contain islets that are kilometers apart – clearly these islets are not the same land else many island chains would be all one land. To address this large variation with a uniform rule, the Land Isolation Distance calculation treats each islet as a separate land unless there is a causeway or footpath connecting the islet with another islet to make a larger land unit out of the combined islets. This rule is consistent with the broader land isolation concept in that an islet is isolated to the extent it is distant and unconnected from a larger islet or island. Lastly about atolls, it is difficult to find data. Geographic references typically list land area for an atoll in total but not for the individual islets. One can use maps to estimate the land area of a particular islet given the atoll total area but admittedly this can be a tedious process.

Afro-Eurasia (largest landmass) and Tokyo (largest metropolis) are special cases relative to the twin isolation measures but in the end the measures hold up fine. By definition, neither of these “largests” has an isolation distance because there are no larger lands or populations. A central aspect of isolation is the longing for

something larger and perhaps more exciting; in these cases there are not any larger so it is appropriate that neither has an isolation rating.

One difference between Land Isolation Distance and Population Isolation Distance is that the latter uses distances measured from the centers rather than the edges. While it would probably be more accurate to measure population distances between the closest edges, the results would be changing rapidly for many vibrant populations and diminish the utility of the measure. Also, there are no comprehensive sources of edge data for population boundaries (vs. administrative boundaries). Fortunately, the distance from the population center to any edge is typically small compared to the Population Isolation Distance (larger populations tend to have larger Population Isolation Distances) so incorporating this factor, even if one had the time and large data sets required would have little effect on the results.

## Conclusions and Further Study

Using the Land Isolation Distance measure, the top five most isolated lands are: Hawai'i (big island), Easter Island, Australia, Tristan da Cunha and Tahiti. The Population Isolation Distance measure yields these top five most isolated populations: New York, Sao Paulo, Lagos, Sydney and Karachi. Hanga Roa (population 5800) of Easter Island is the 10<sup>th</sup> most isolated population. See Table 1 and Table 2 above for the full lists of top isolated lands and populations.

The twin isolation distance measures are versatile, robust and applicable to a vast range of analyses. The following are examples of potential applications for further study:

- Politics. Voting patterns as a function of population isolation. Patterns of emergence and growth of political factions as a function of the isolation of the faction.
- Demographic analyses. Membership rates and preference for different religious organizations, volunteer organizations and other organizations as function of population isolation. Growth of the local chapters of these same organizations as a function of each chapter's isolation.

- Government policy and law enforcement. Alcoholism, drug use and other individual behaviors as a function of population isolation. Growth and tactics used by gangs as a function of a particular gang's isolation from other gangs.
- Wildlife management. Whether selected animal populations naturally strive to spread out to achieve a target level of isolation.
- Business and economics. Desire for a particular product or service as a function of isolation.

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