Module 201 Slides

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The following images appear in the background of the lecture on “The Global Health Crisis” in the PatentX lecture series. A recording of the lecture itself is available at https://ipxcourses.org/lectures-2/. Removed from their original context, the images will not make much sense. The function of this collection of images is to enable persons who have already watched the lecture to review the material it contains.

Part A: Contours

Dimensions of the Global Health Crisis

1) The threats to human health posed by many diseases are currently increasing.

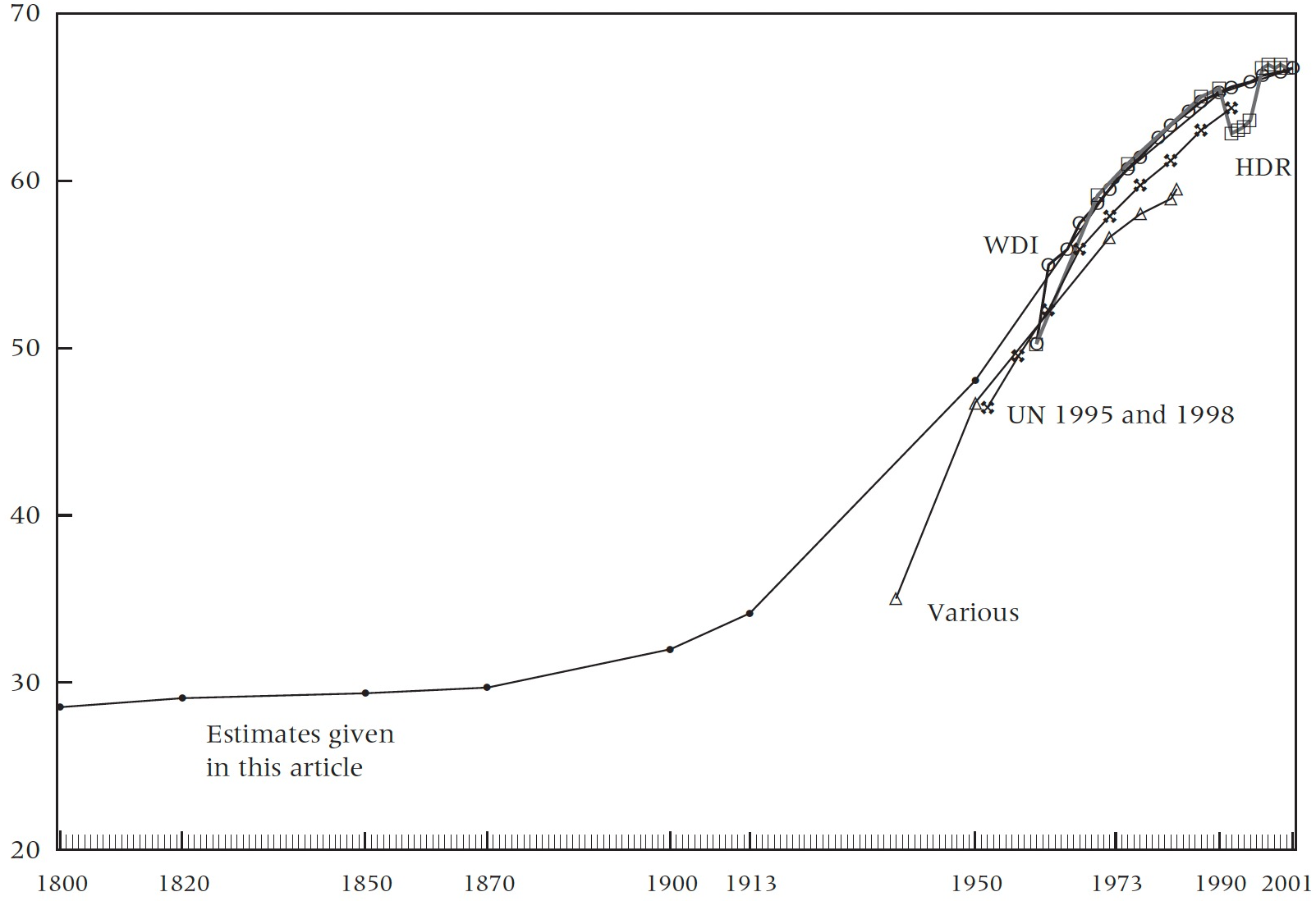
2) The disease burdens borne by low and-middle income countries exceed the burdens borne by upper-income countries – and the threats on the horizon may increase that disparity.

Metrics

- **Life expectancy at birth** = how long a person born at a particular moment in time would live if the conditions affecting health did not change during the person's lifetime
- **Healthy Life Expectancy** = average number of years that a person can expect to live in full health by taking into account years lived in less than full health due to disease or injury
- **Disability Adjusted Life Year (DALY)** = one lost year of healthy life
- **Deaths**
- **Mortality rate** = the percentage of a population that dies from a specific cause during a specified period
- **Incidence** = the occurrence of new cases of disease over a specified period
- **Prevalence** = the proportion of persons in a population who have a particular disease at a specified moment or over a specified period.
- **Age standardization** = a method of adjusting a metric, such as mortality or prevalence, to control for the facts (a) that the age distributions in two populations are likely to be different and (b) that the incidence of many diseases (such as cancer) varies by age

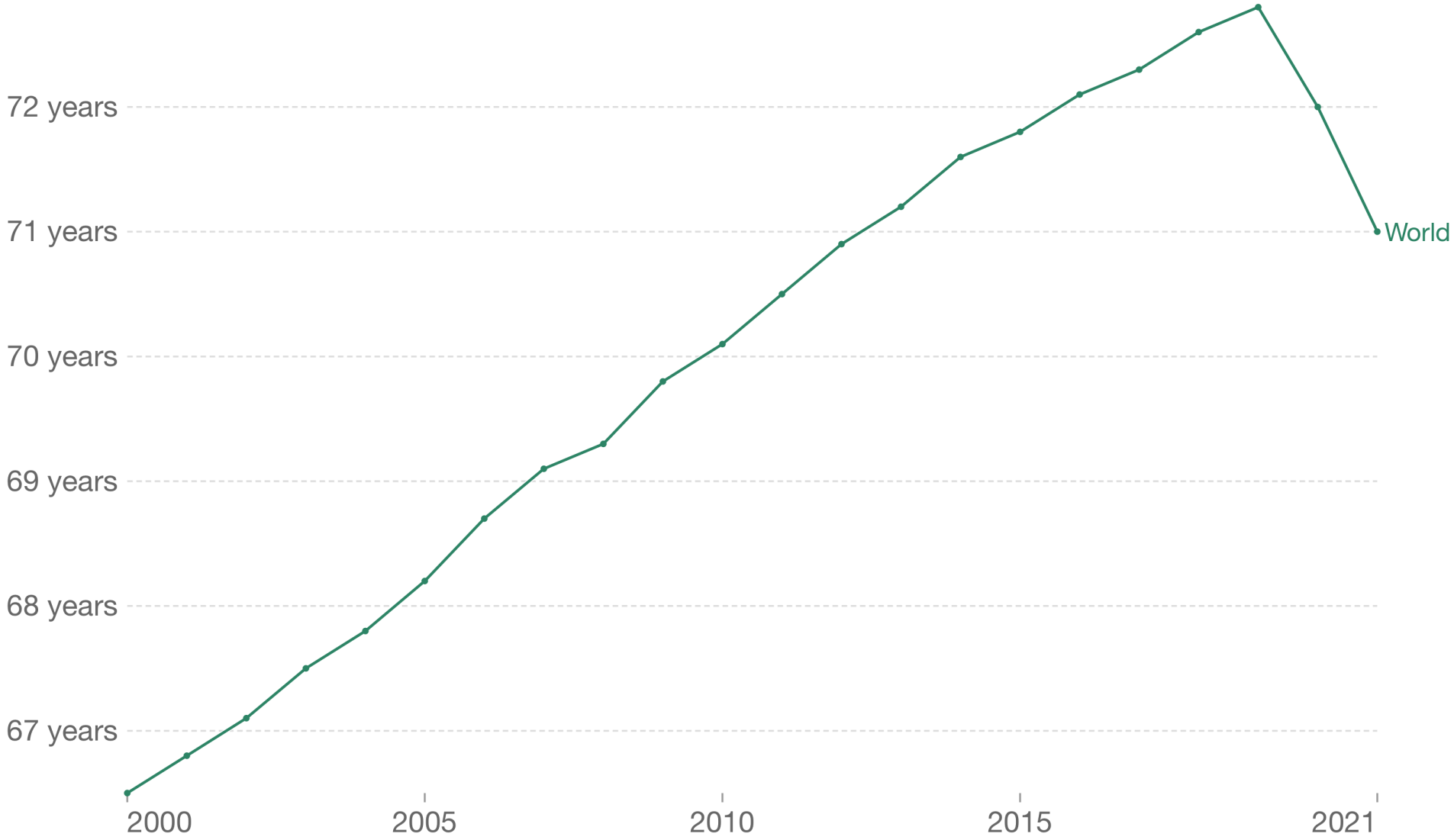
Source: James C. Riley, "Estimates of Regional and Global Life Expectancy, 1800-2001 (2005)

FIGURE 1 World life expectancy estimates compared, 1800–2001



NOTE: HDR = UNDP, *Human Development Report*, various years; WDI = World Bank, *World Development Indicators 2004*.
SOURCES: World Bank 2004; United Nations Development Programme (various years); United Nations 1995, 1998; Siampos 1989, who on p. 424 reproduces without attribution what may be a League of Nations or UN estimate for 1930; United Nations 1975a: 1; 1975b, I: 175; and 1988: 117.

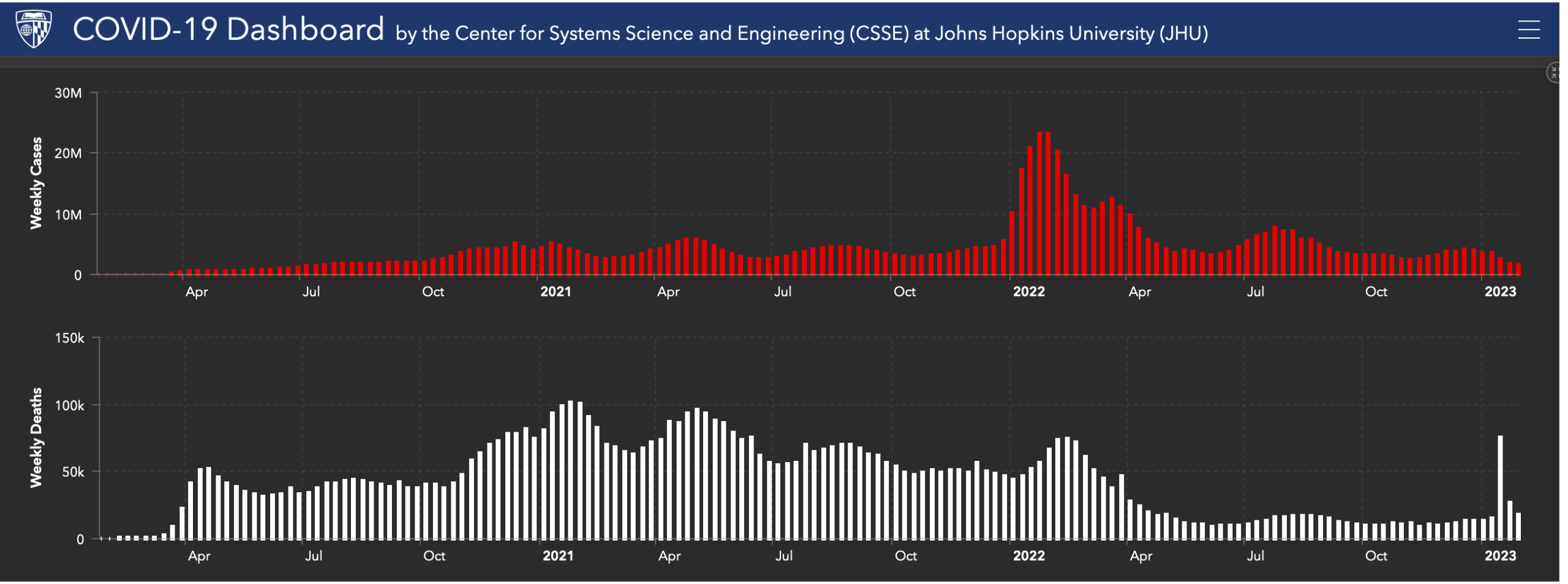
Life expectancy, 2000 to 2021



Source: UN WPP (2022); Zijdeman et al. (2015); Riley (2005)

OurWorldInData.org/life-expectancy • CC BY

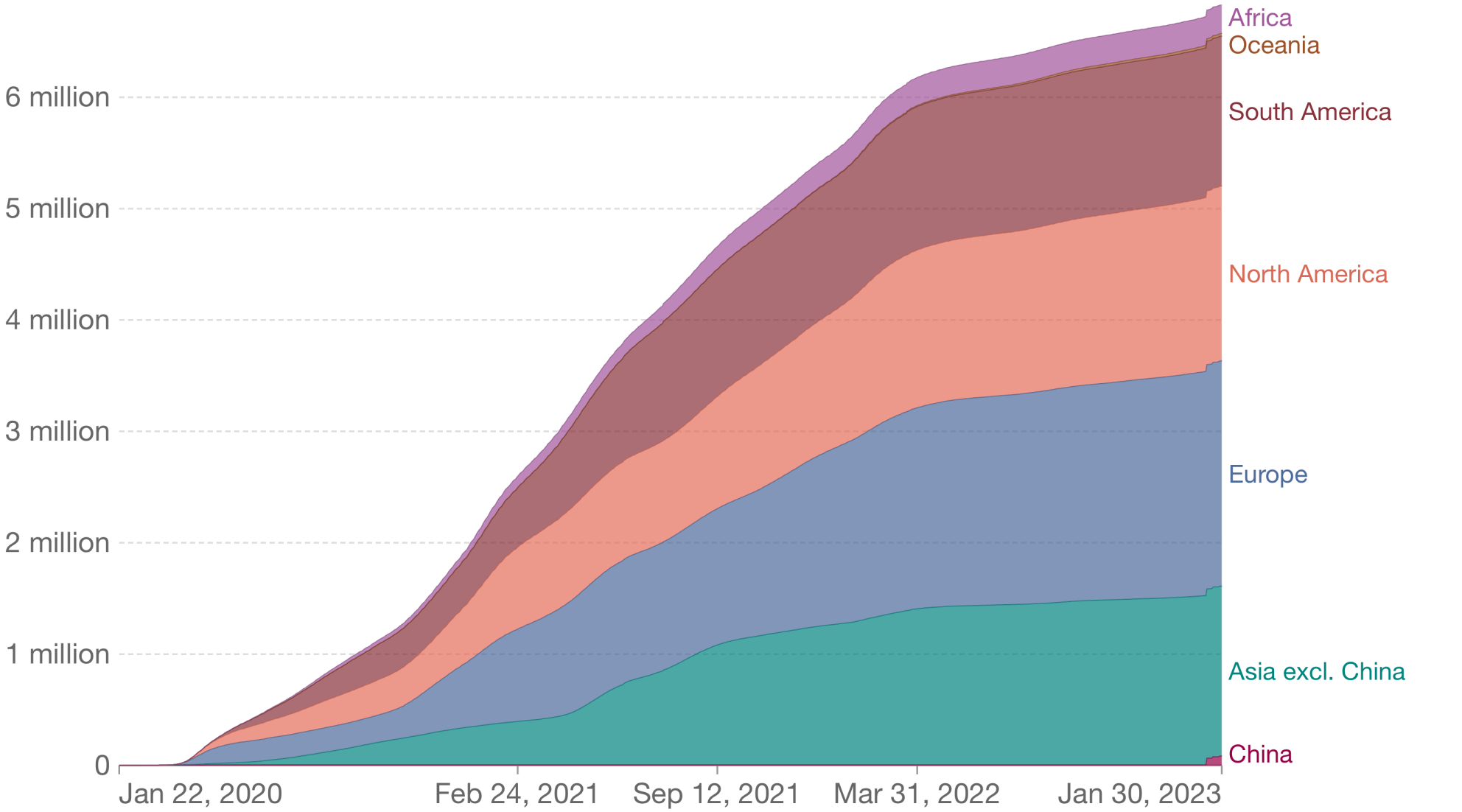
Note: Shown is the 'period life expectancy'. This is the average number of years a newborn would live if age-specific mortality rates in the currer year were to stay the same throughout its life.


COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)
Weekly Cases
30M
20M
10M
0
Apr
Jul
Oct
2021
Apr
Jul
Oct
2022
Apr
Jul
Oct
2023
Weekly Deaths
150k
100k
50k
0
Apr
Jul
Oct
2021
Apr
Jul
Oct
2022
Apr
Jul
Oct
2023

Cumulative confirmed COVID-19 deaths by world region

Due to varying protocols and challenges in the attribution of the cause of death, the number of confirmed deaths may not accurately represent the true number of deaths caused by COVID-19.

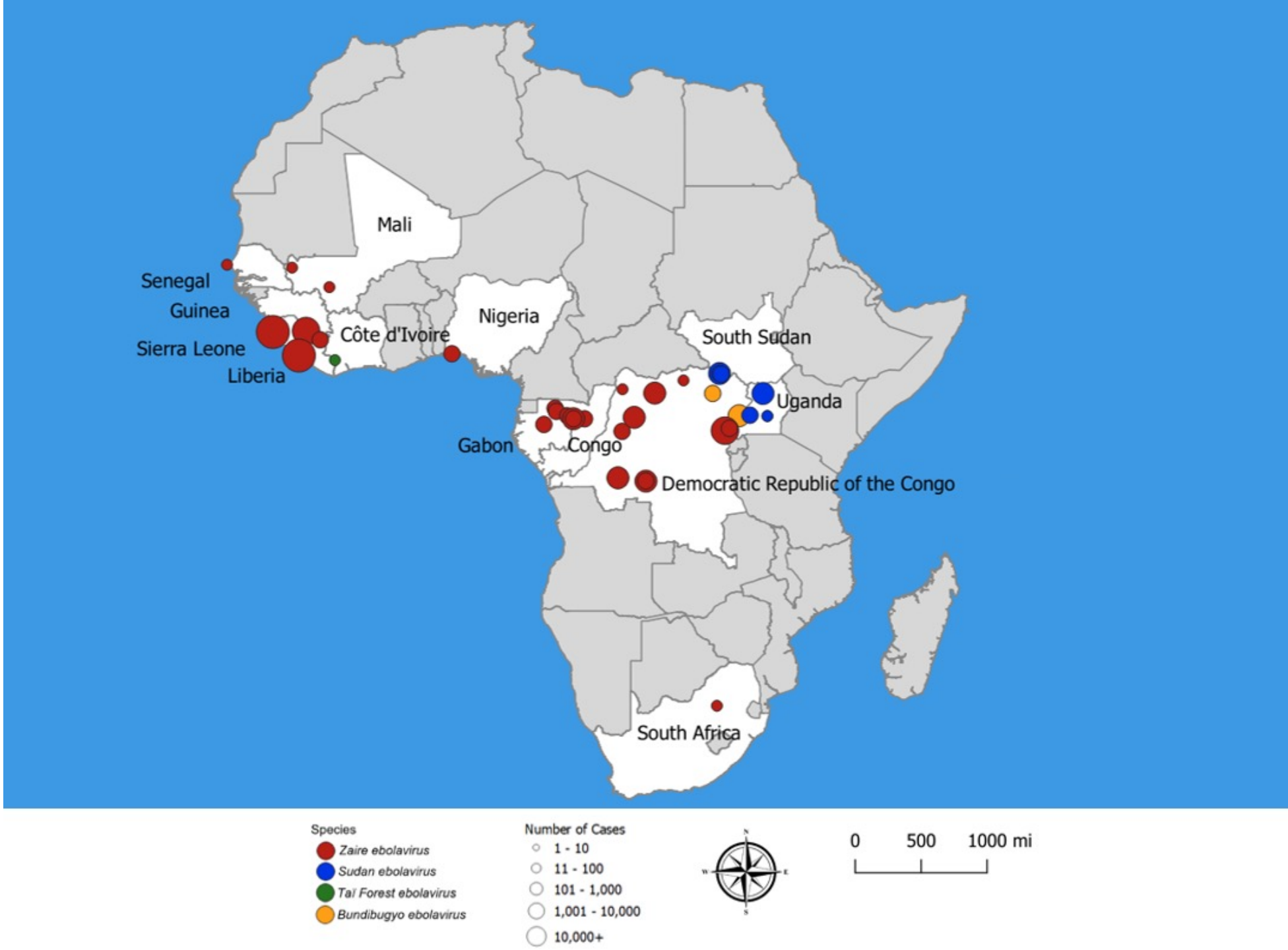
Our World in Data



Source: Johns Hopkins University CSSE COVID-19 Data

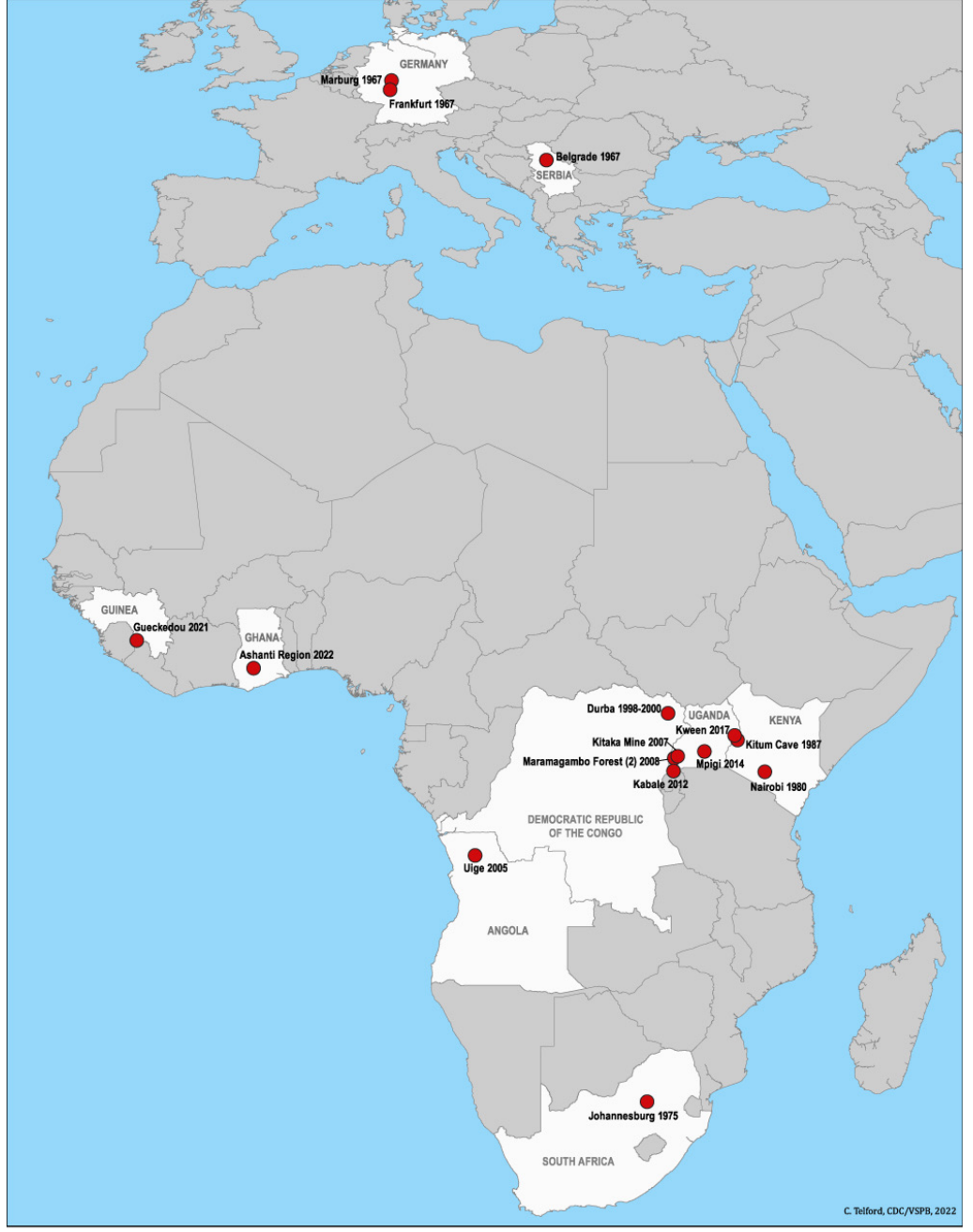
Ebola Outbreaks since 1976

Source: CDC



Marburg Outbreaks

Source: CDC



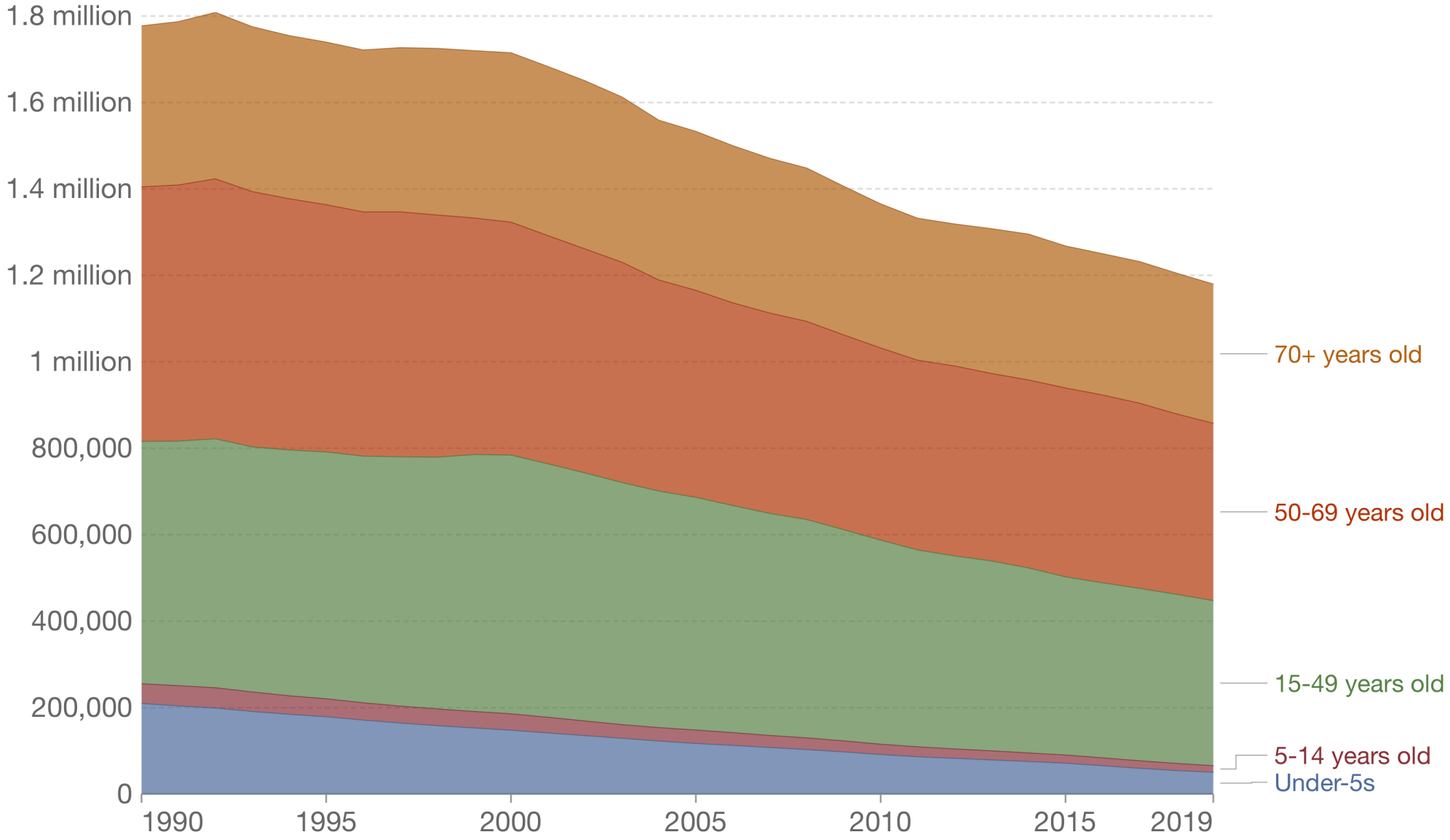
OUTBREAKS OF MARBURG VIRUS DISEASE

● **Outbreak Location and Year**

0 250 500 750 mi

Deaths from tuberculosis, by age, World, 1990 to 2019

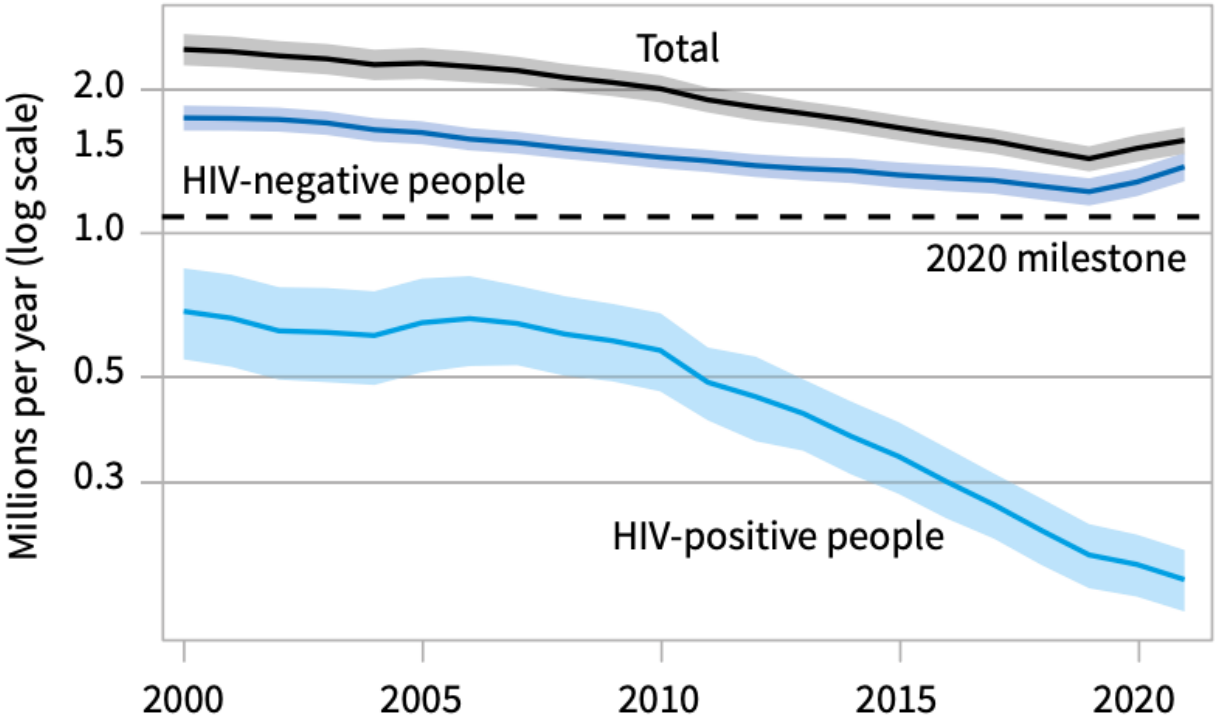
Annual number of deaths from tuberculosis, differentiated by age category.

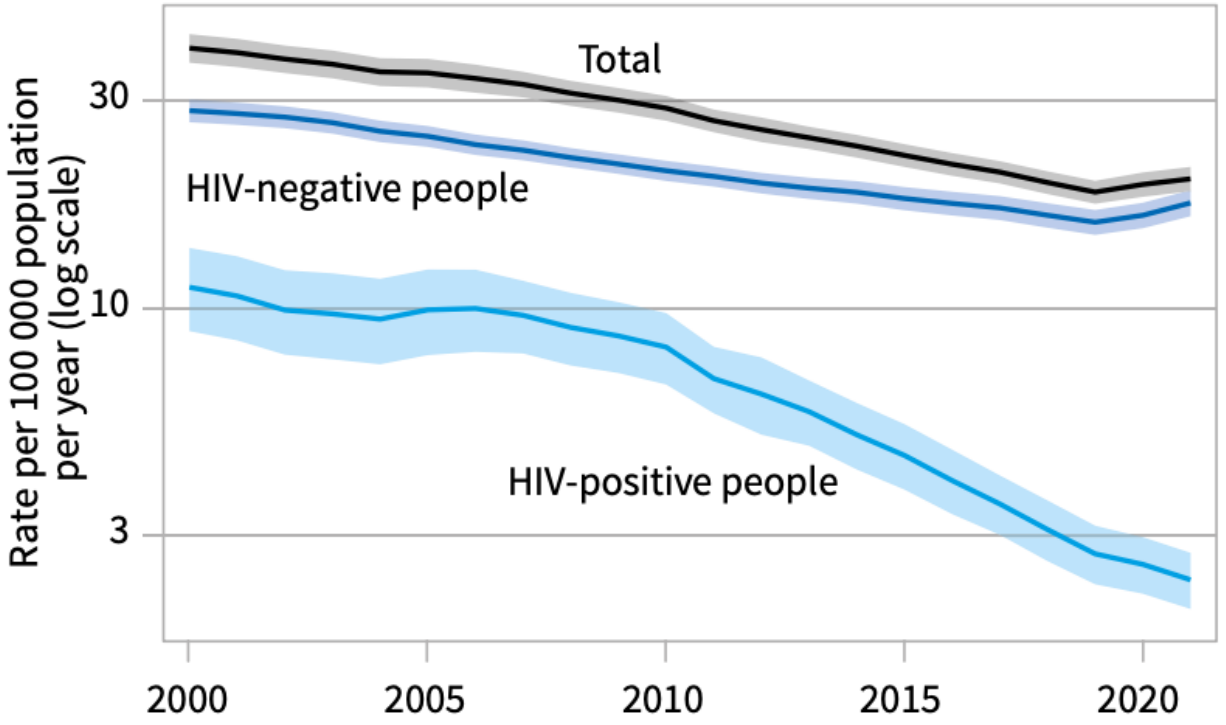


Source: IHME, Global Burden of Disease (2019)

Global trends in the estimated number of TB deaths (left) and the mortality rate (right), 2000–2021

The horizontal dashed line shows the 2020 milestone of the End TB Strategy, which was a 35% reduction in the total number of TB deaths between 2015 and 2020. Shaded areas represent 95% uncertainty intervals.





Source: World Health Organization, Global Tuberculosis Report (2022), p. 11

TABLE 3.1.

Global estimated malaria cases and deaths, 2000–2021 Estimated cases and deaths are shown with 95% upper and lower confidence intervals. *Source: WHO estimates.*

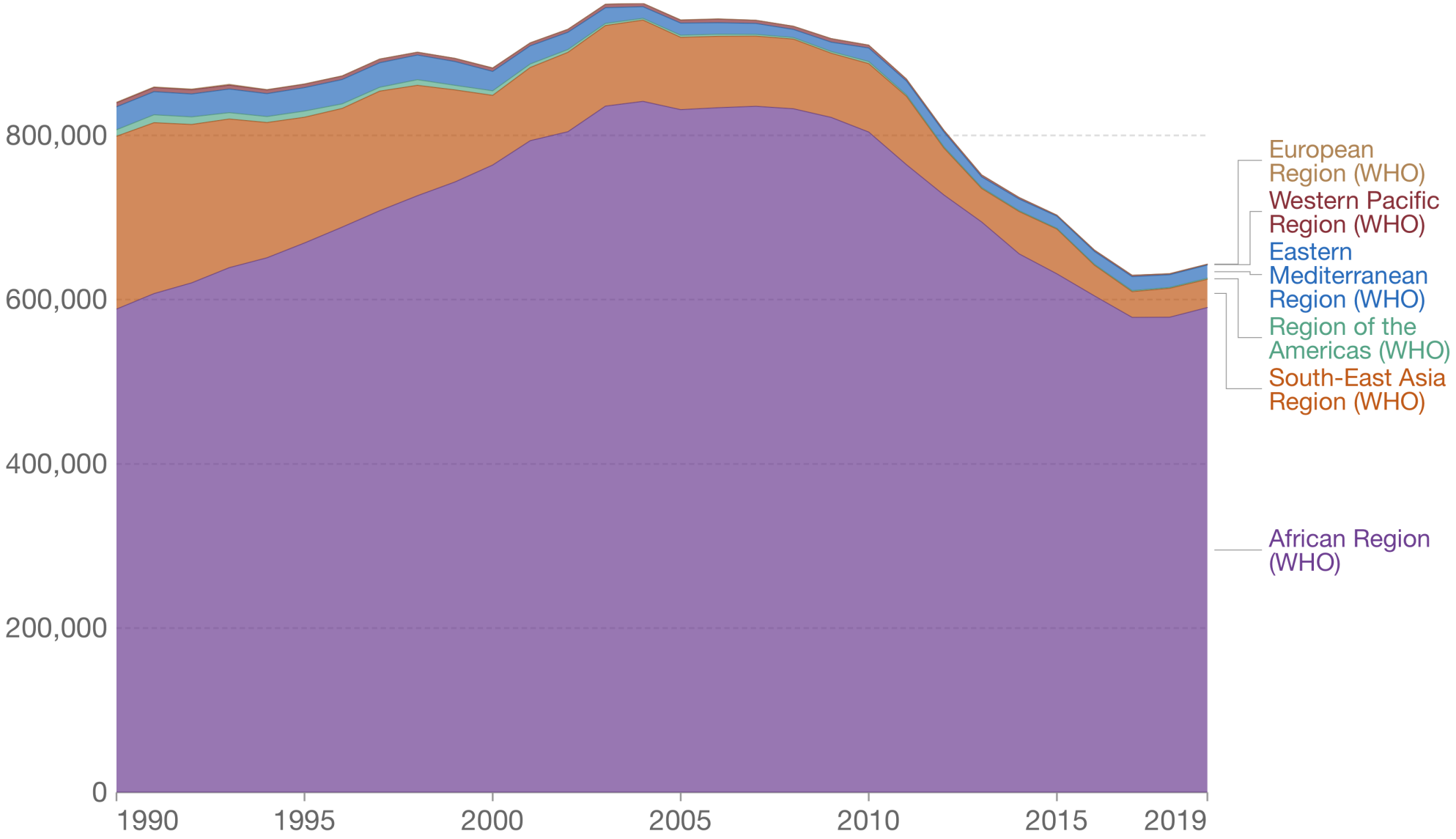
Year	Number of cases (000)				Number of deaths		
	Point	Lower bound	Upper bound	% *P. vivax*	Point	Lower bound	Upper bound
2000	**245 000**	229 000	266 000	8.4%	**897 000**	866 000	938 000
2001	**250 000**	231 000	273 000	8.3%	**888 000**	855 000	933 000
2002	**246 000**	228 000	268 000	7.7%	**847 000**	816 000	890 000
2003	**249 000**	232 000	272 000	8.1%	**825 000**	794 000	870 000
2004	**251 000**	232 000	278 000	7.9%	**807 000**	773 000	866 000
2005	**249 000**	231 000	272 000	8.0%	**783 000**	751 000	832 000
2006	**244 000**	226 000	268 000	7.0%	**771 000**	739 000	820 000
2007	**241 000**	224 000	263 000	6.6%	**751 000**	721 000	794 000
2008	**241 000**	224 000	262 000	6.4%	**731 000**	700 000	773 000
2009	**246 000**	228 000	269 000	6.3%	**721 000**	685 000	771 000
2010	**248 000**	229 000	272 000	6.6%	**704 000**	667 000	757 000
2011	**242 000**	225 000	262 000	7.0%	**660 000**	629 000	704 000
2012	**238 000**	222 000	258 000	6.9%	**622 000**	593 000	664 000
2013	**233 000**	217 000	253 000	5.9%	**603 000**	572 000	648 000
2014	**231 000**	211 000	253 000	5.5%	**584 000**	549 000	639 000
2015	**230 000**	211 000	253 000	4.9%	**577 000**	540 000	635 000
2016	**232 000**	214 000	253 000	4.6%	**580 000**	545 000	642 000
2017	**237 000**	219 000	257 000	3.7%	**587 000**	553 000	654 000
2018	**231 000**	214 000	252 000	3.0%	**567 000**	532 000	642 000
2019	**232 000**	213 000	255 000	2.7%	**568 000**	532 000	654 000
2020	**245 000**	222 000	273 000	1.8%	**625 000**	583 000	747 000
2021	**247 000**	224 000	276 000	2.0%	**619 000**	577 000	754 000

Total malaria cases (in thousands)

Total malaria deaths

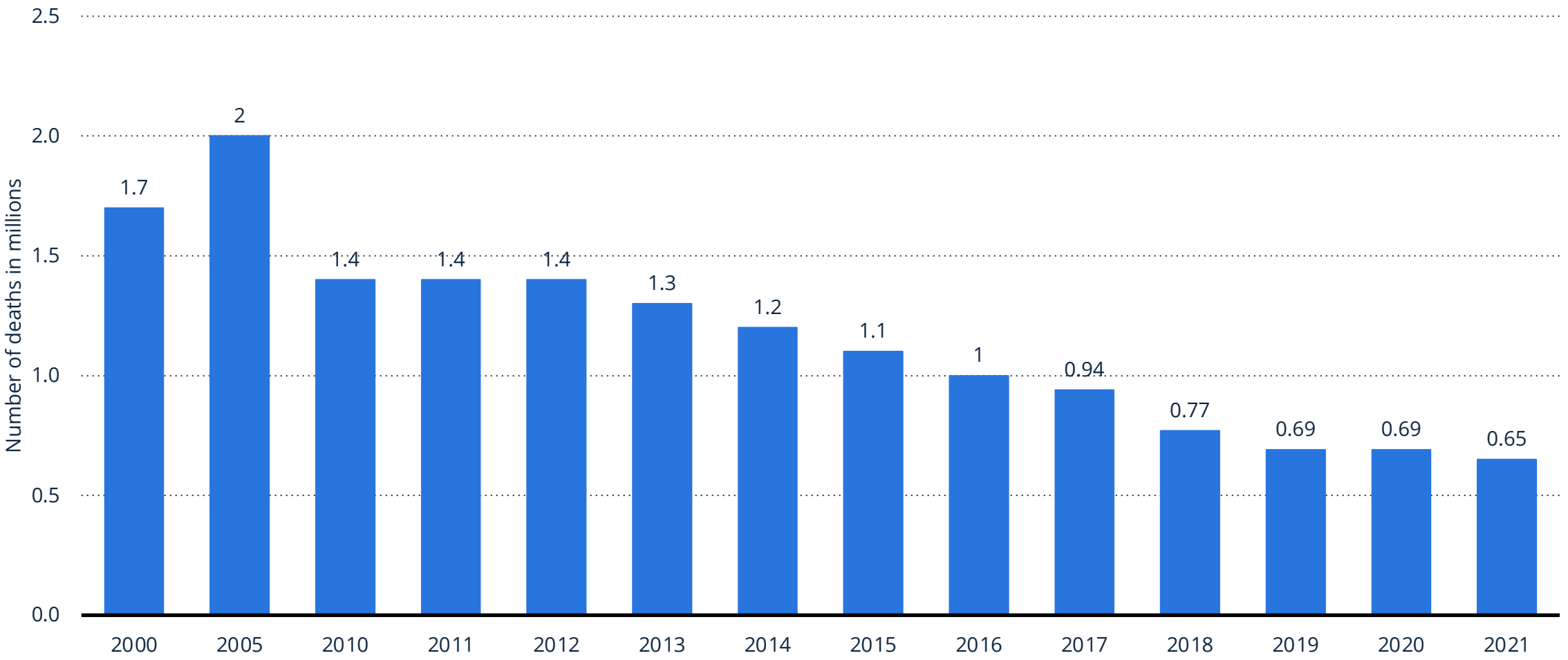
Malaria deaths by world region, 1990 to 2019

Annual number of deaths from malaria across all ages and both sexes.



Source: IHME, Global Burden of Disease (2019)

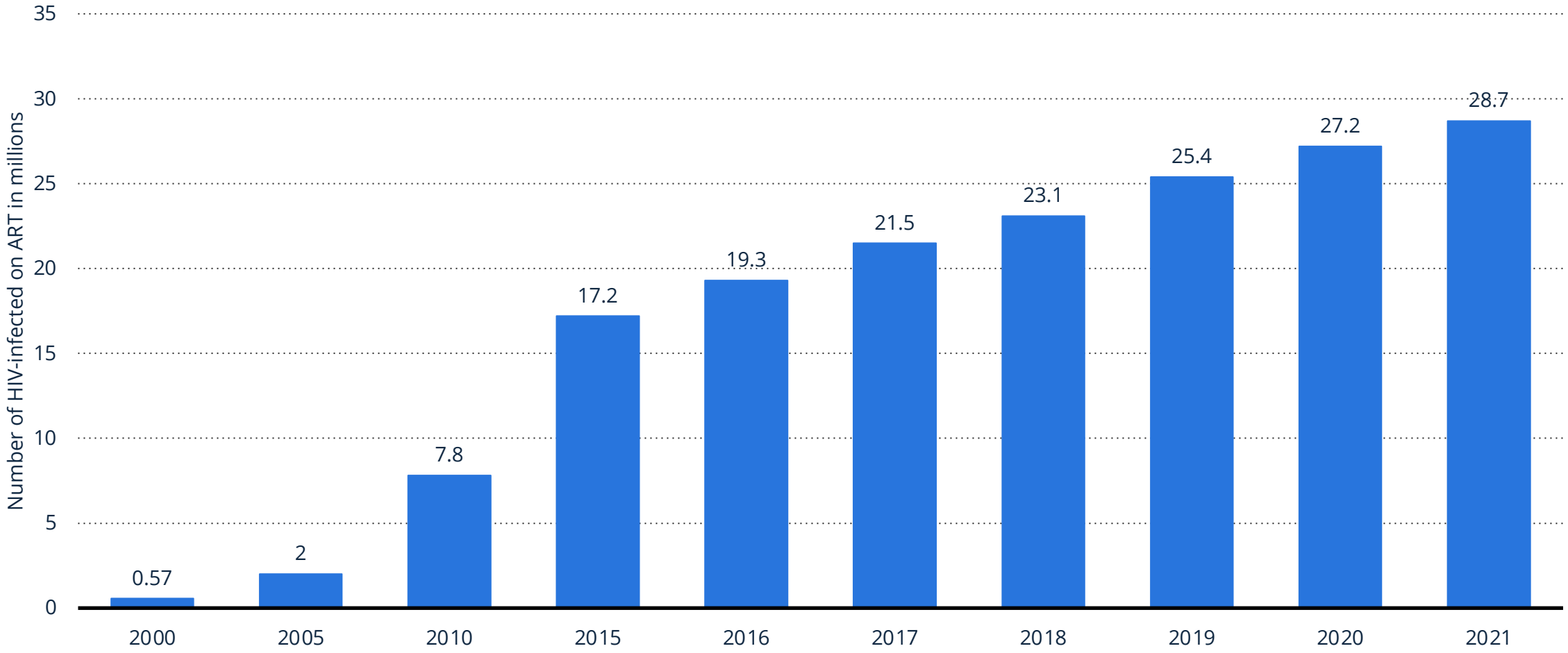
Total number of AIDS-related deaths worldwide from 2000 to 2021 (in millions)



Description: UNAIDS estimated that there were some 650,000 people worldwide that died from acquired immune deficiency syndrome (AIDS) in 2021. This statistic depicts the total number of annual AIDS-related deaths worldwide from 2000 to 2021. Read more
Note(s): Worldwide
Source(s): UNAIDS

statista

Access to antiretroviral therapy (ART) among HIV-infected people worldwide from 2000 to 2021 (in millions)

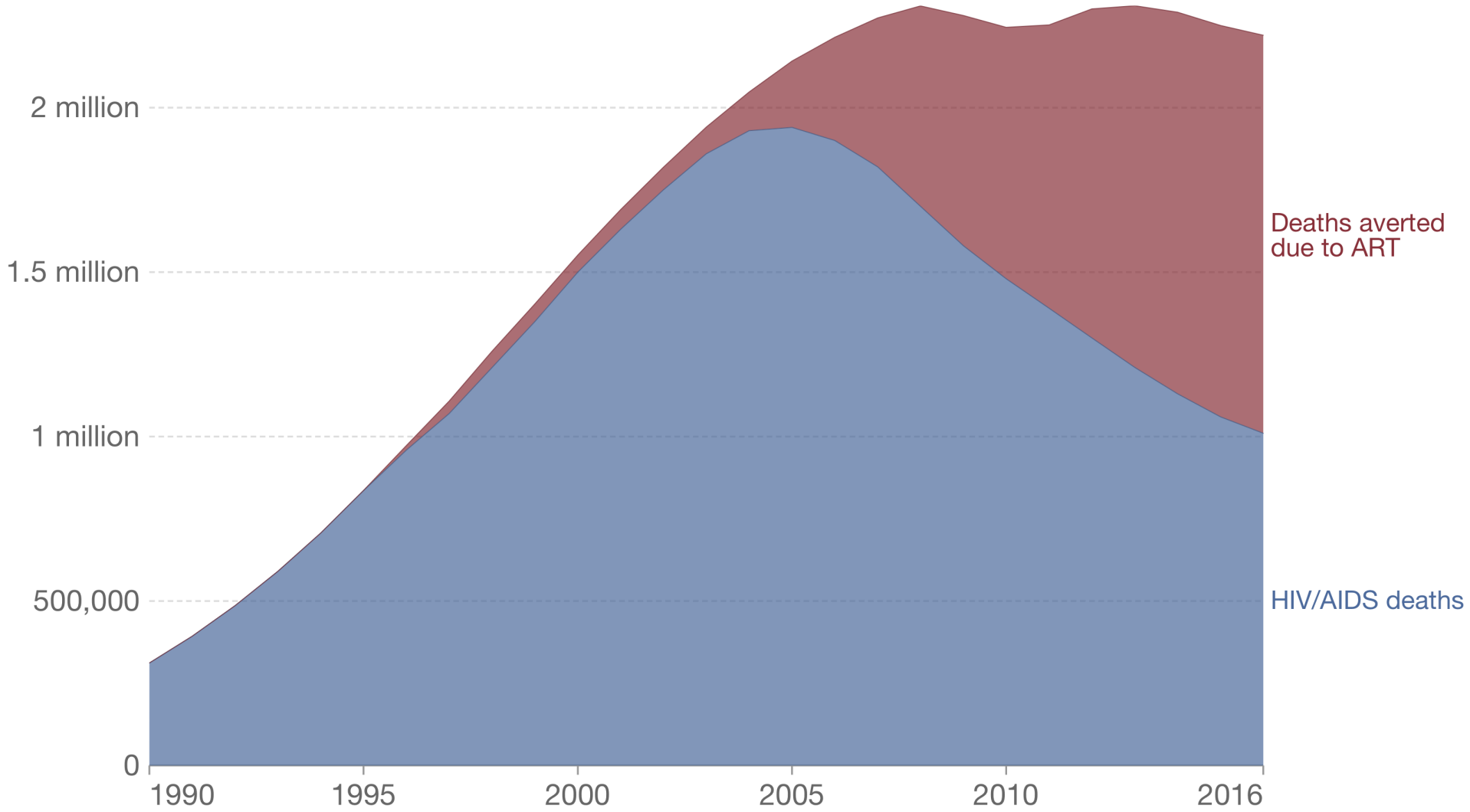


Description: This statistic depicts the access to antiretroviral therapy (ART) among HIV-infected people worldwide from 2000 to 2021, based on the number of recipients in millions. In 2021, there were around 28.7 million people living with HIV who at the same time were on antiretroviral therapy. Read more
Note(s): Worldwide; 2000 to 2021
Source(s): UNAIDS

statista

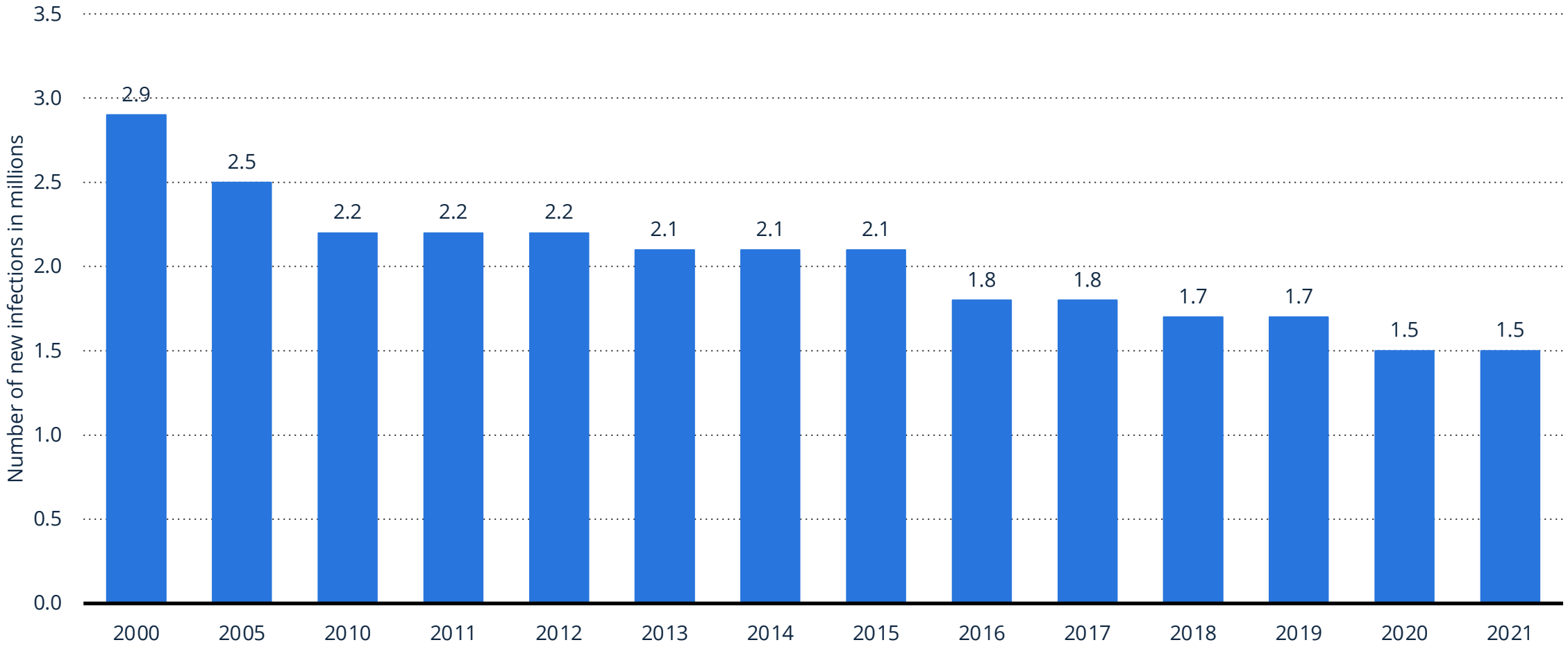
HIV/AIDS deaths and deaths averted due to antiretroviral therapy (ART), World, 1990 to 2016

Annual number of deaths from HIV/AIDS and the estimated number which have been averted as a result of antiretroviral therapy (ART).



Source: UNAIDS

Total number of new HIV infections worldwide from 2000 to 2021 (in millions)

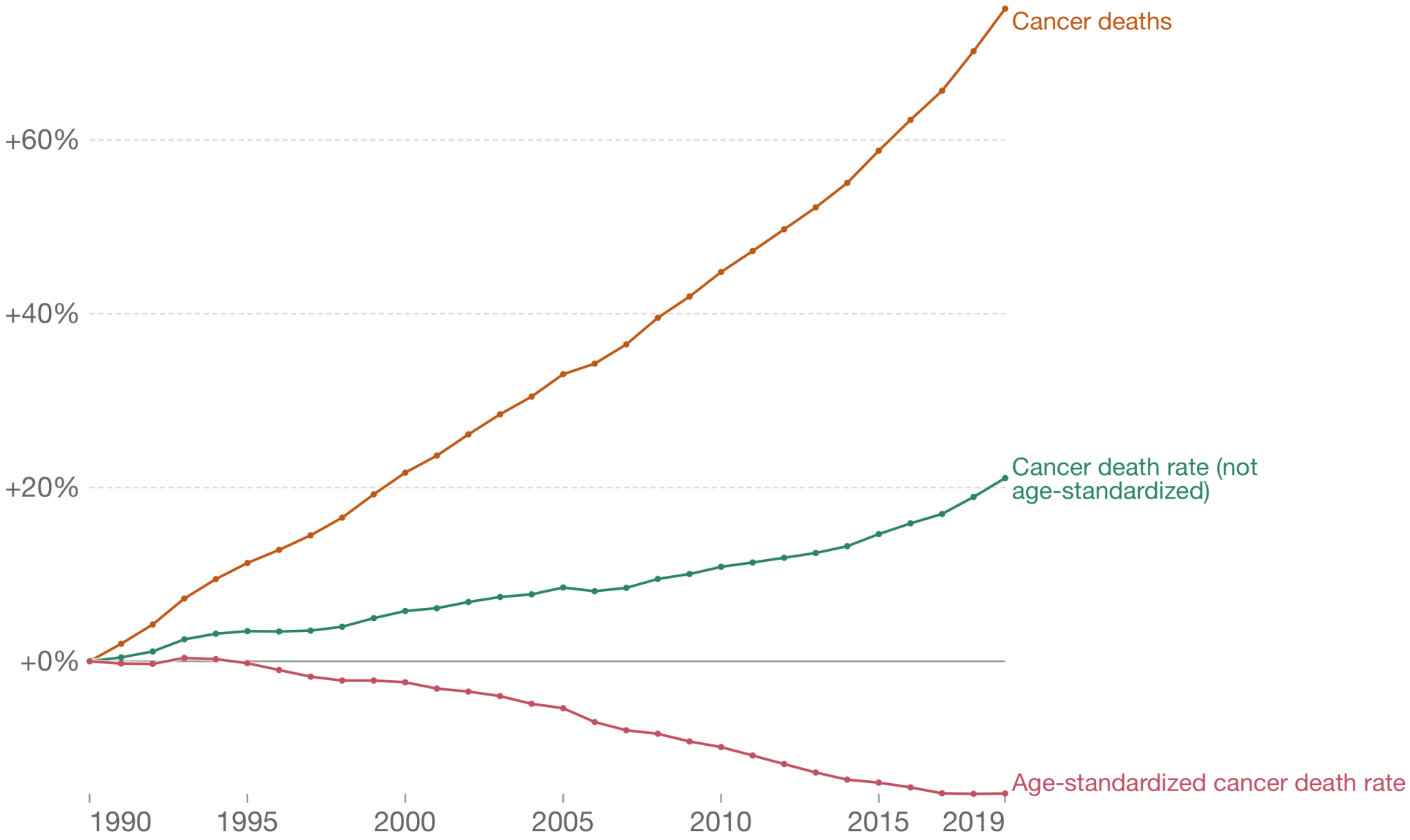


Description: This statistic depicts the total number of annual new HIV infections worldwide from 2000 to 2021. UNAIDS estimated that there were some 1.5 million people worldwide that were newly infected with HIV in 2021. Read more
Note(s): Worldwide
Source(s): UNAIDS

statista

Change in three measures of cancer mortality, World, 1990 to 2019

This chart compares cancer deaths, the cancer death rate, and the age-standardized death rate.



Source: IHME, Global Burden of Disease (2019)

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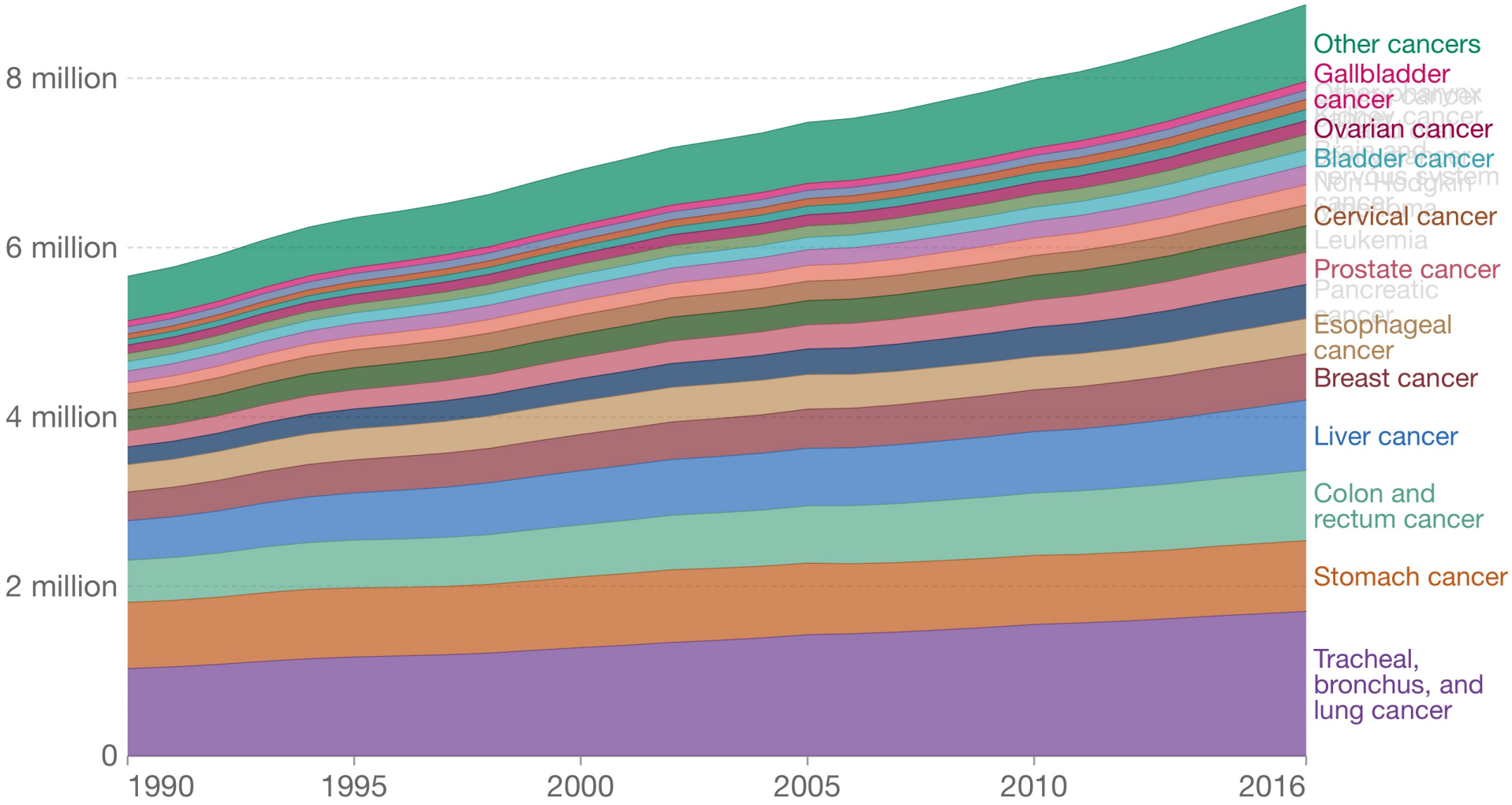
Cancer deaths by type, World, 1990 to 2016

Annual cancer deaths by cancer type, measured as the total number of deaths across all age categories and both sexes. Smaller categories of cancer types with global deaths <100,000 in 2016 have been grouped into a collective category 'Other cancers'. See sources for list of grouped cancers.



Source: IHME, Global Burden of Disease (GBD)

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Note: All cancer types with less than 100,000 global deaths in 2016 into a collective category 'Other cancers'.

Parkinson's Disease, 1990-2016

Prevalence	
2016 counts	Percentage change in age-standardised rates, 1990–2016
6 062 893 (4 971 461 to 7 324 997)	21·7% (18·1 to 25·3)

Deaths	
2016 counts	Percentage change in age-standardised rates, 1990–2016
211 296 (167 771 to 265 160)	19·5% (15·6 to 23·3)

DALYs	
2016 counts	Percentage change in age-standardised rates, 1990–2016
3 234 514 (2 563 609 to 4 012 766)	22·1% (18·2 to 25·8)

Source: "Global, regional, and national burden of Parkinson's disease, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016," The Lancet Neurology (2018)

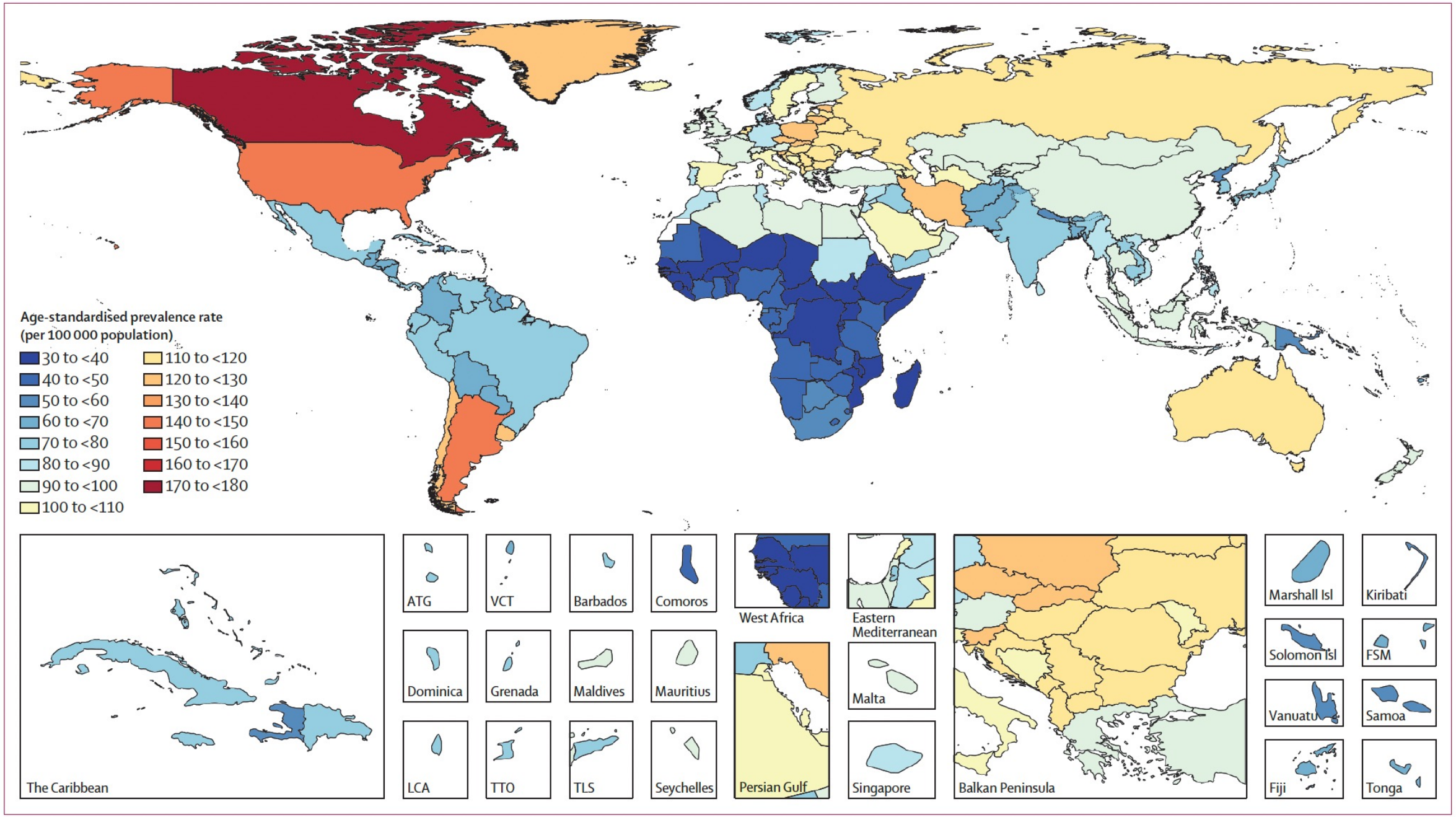


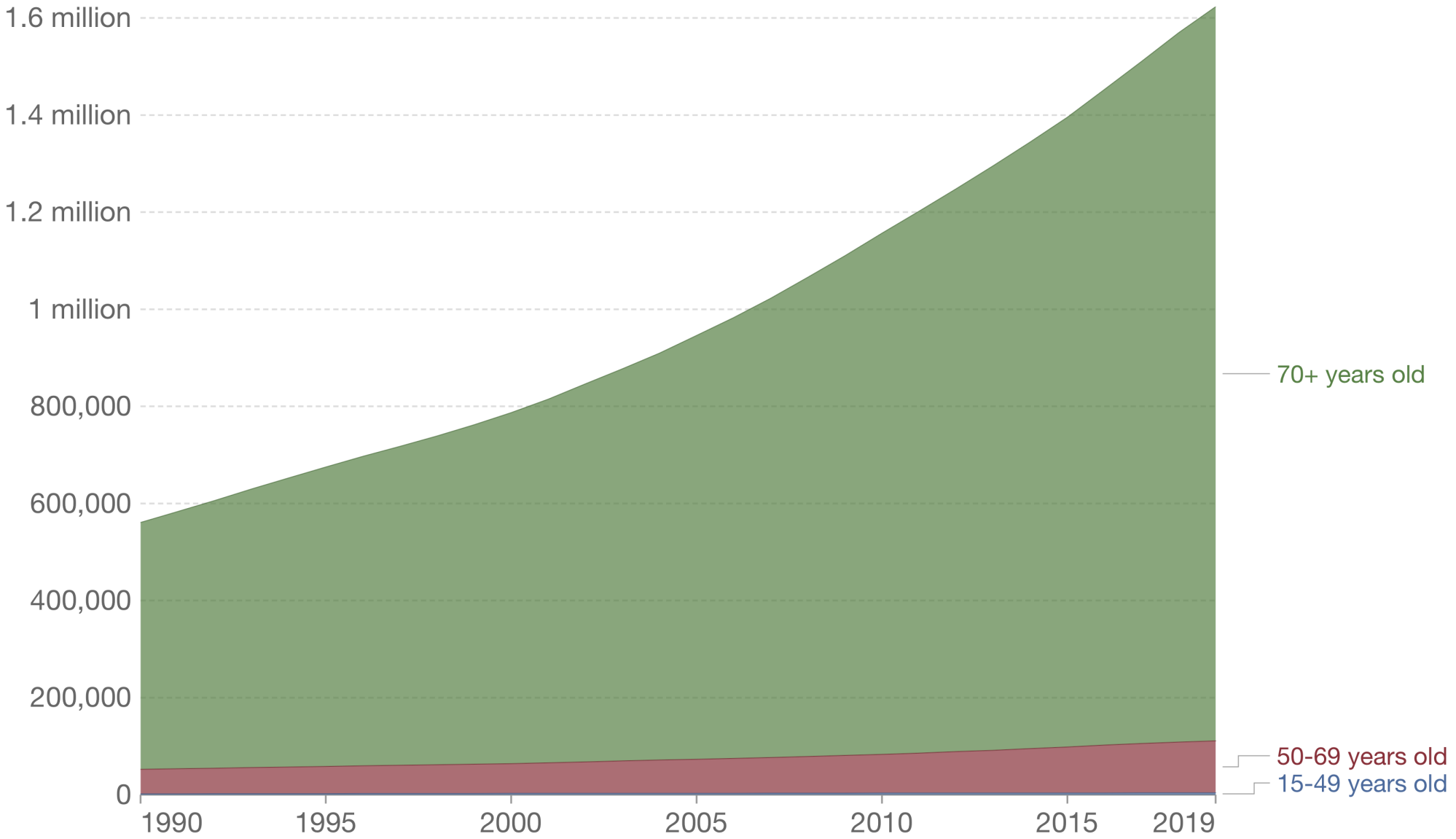
Figure 1: **Age-standardised prevalence of Parkinson's disease per 100 000 population by location for both sexes, 2016**

ATG=Antigua and Barbuda. FSM=Federated States of Micronesia. Isl=Islands. LCA=Saint Lucia. TLS=Timor-Leste. TTO=Trinidad and Tobago. VCT=Saint Vincent and the Grenadines.

Source: "Global, regional, and national burden of Parkinson's disease, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016," The Lancet Neurology (2018)

Deaths from dementia-related diseases, by age, World, 1990 to 2019

Annual number of deaths from Alzheimer's and other dementia diseases



Source: IHME, Global Burden of Disease (2019)

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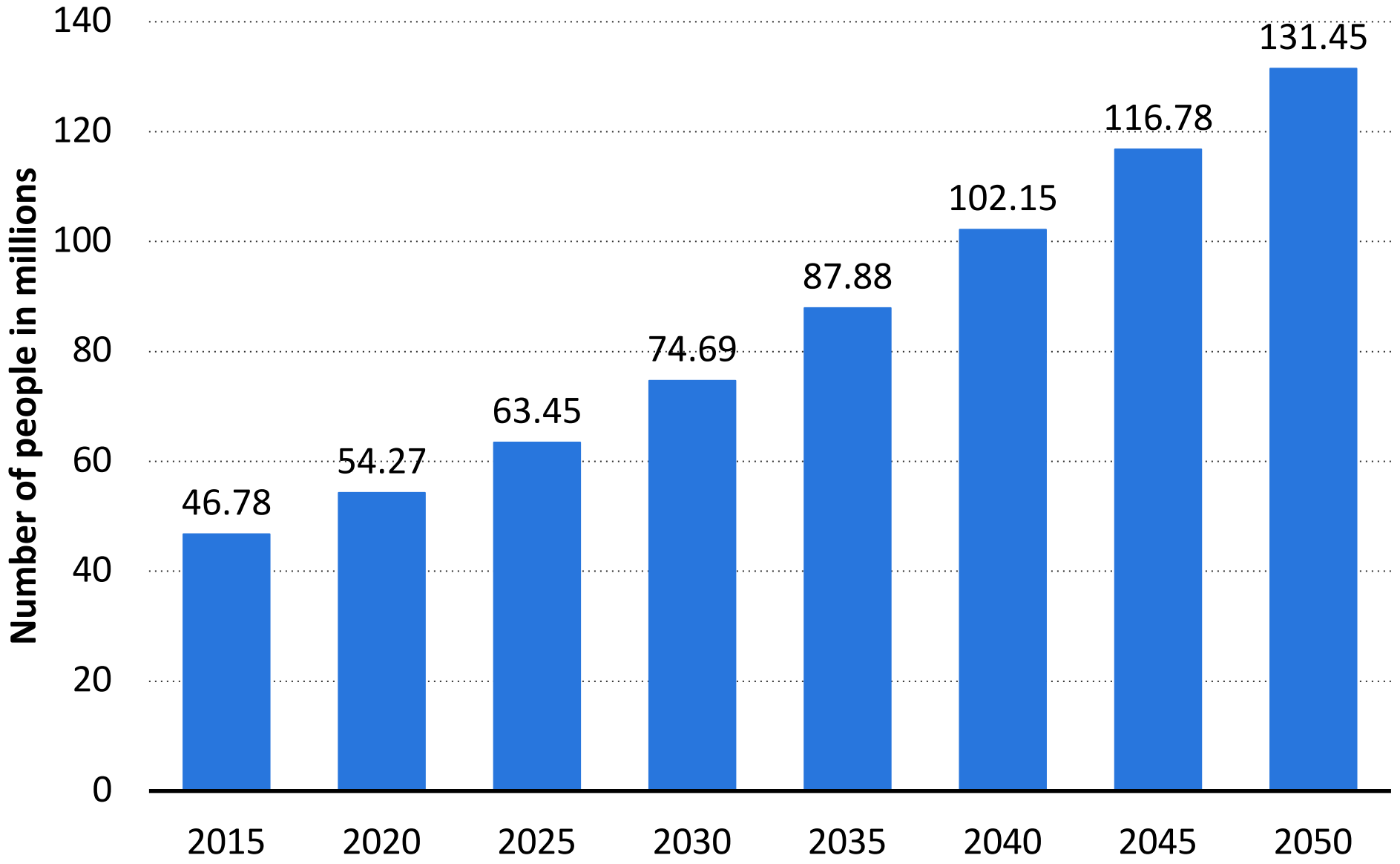
Global forecast of the total number of people with dementia worldwide from 2015 to 2050 (in millions)



Diabetes: Global estimates of the number of adults (20-79) with the disease

World Bank income classification	2021		
	Number of people with diabetes (millions)	Diabetes prevalence[i] (%)	Comparative diabetes prevalence[ii] (%)
World	536.6 (424.2–612.3)	10.5 (8.3–12.0)	9.8 (7.7–11.2)
High-income countries	103.9 (87.6–116.9)	11.1 (9.3–12.5)	8.4 (7.1–9.6)
Middle-income countries	414.0 (321.6–470.8)	10.8 (8.4–12.3)	10.5 (8.0–11.9)
Low-income countries	18.7 (15.0–24.6)	5.5 (4.4–7.2)	6.7 (5.5–9.0)

[Prevalence standardized to the national population (20-79)]

[Prevalence standardized to the global population (20-79)]

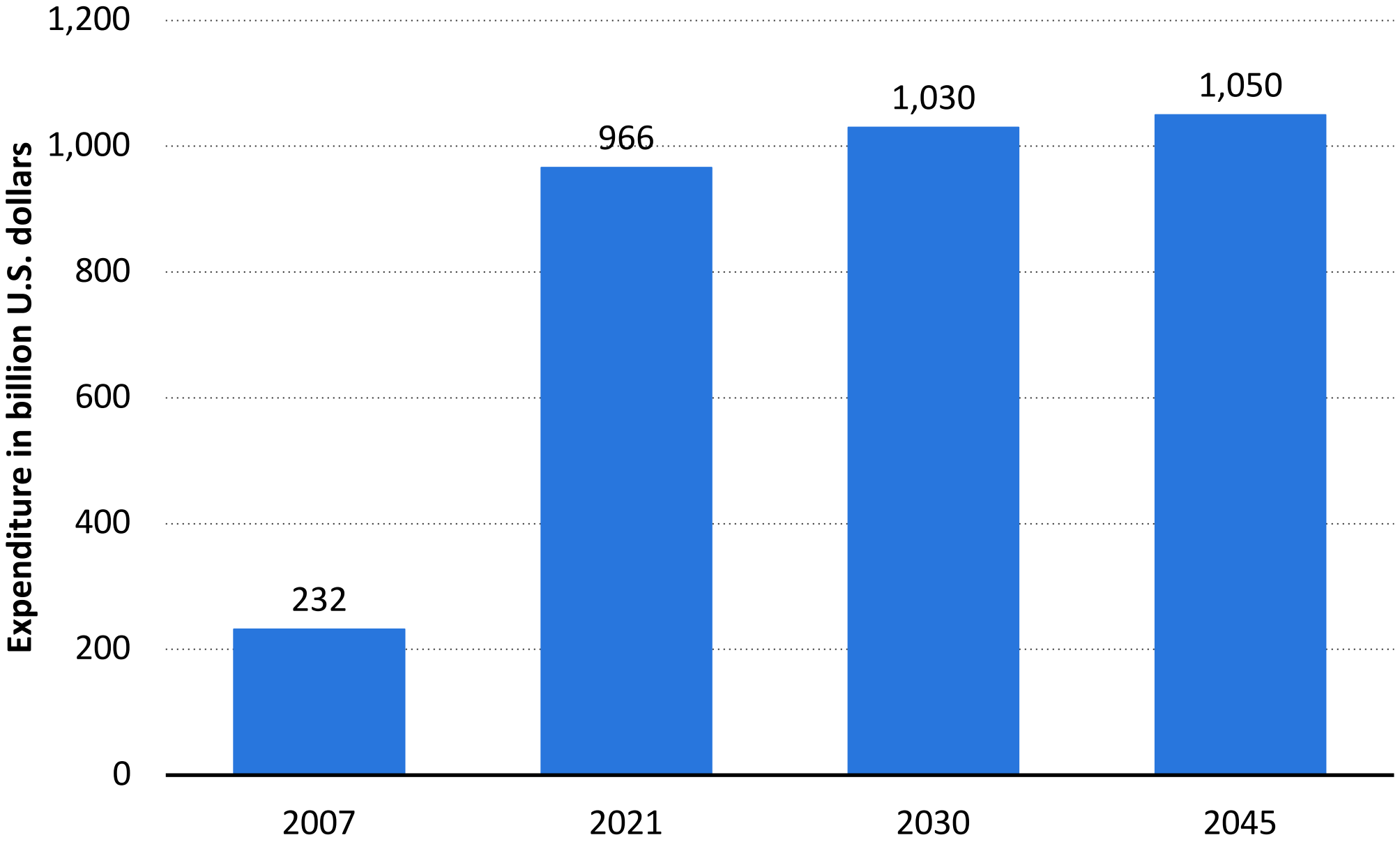
Diabetes: Global estimates of the number of adults (20-79) with the disease

World Bank income classification	2045 Number of people with diabetes (millions)	Diabetes prevalence[i] (%)	Comparative diabetes prevalence[ii] (%)
World	783.2 (605.2–898.6)	12.2 (9.5–14.0)	11.2 (8.6–12.9)
High-income countries	117.7 (98.4–132.4)	12.4 (10.4–14.0)	10.3 (8.8–11.7)
Middle-income countries	623.3 (473.0–709.3)	13.1 (9.9–14.9)	12.0 (9.0–13.6)
Low-income countries	42.2 (33.8–56.9)	6.1 (4.9–8.3)	7.0 (5.8–9.7)

[Prevalence standardized to the national population (20-79)]

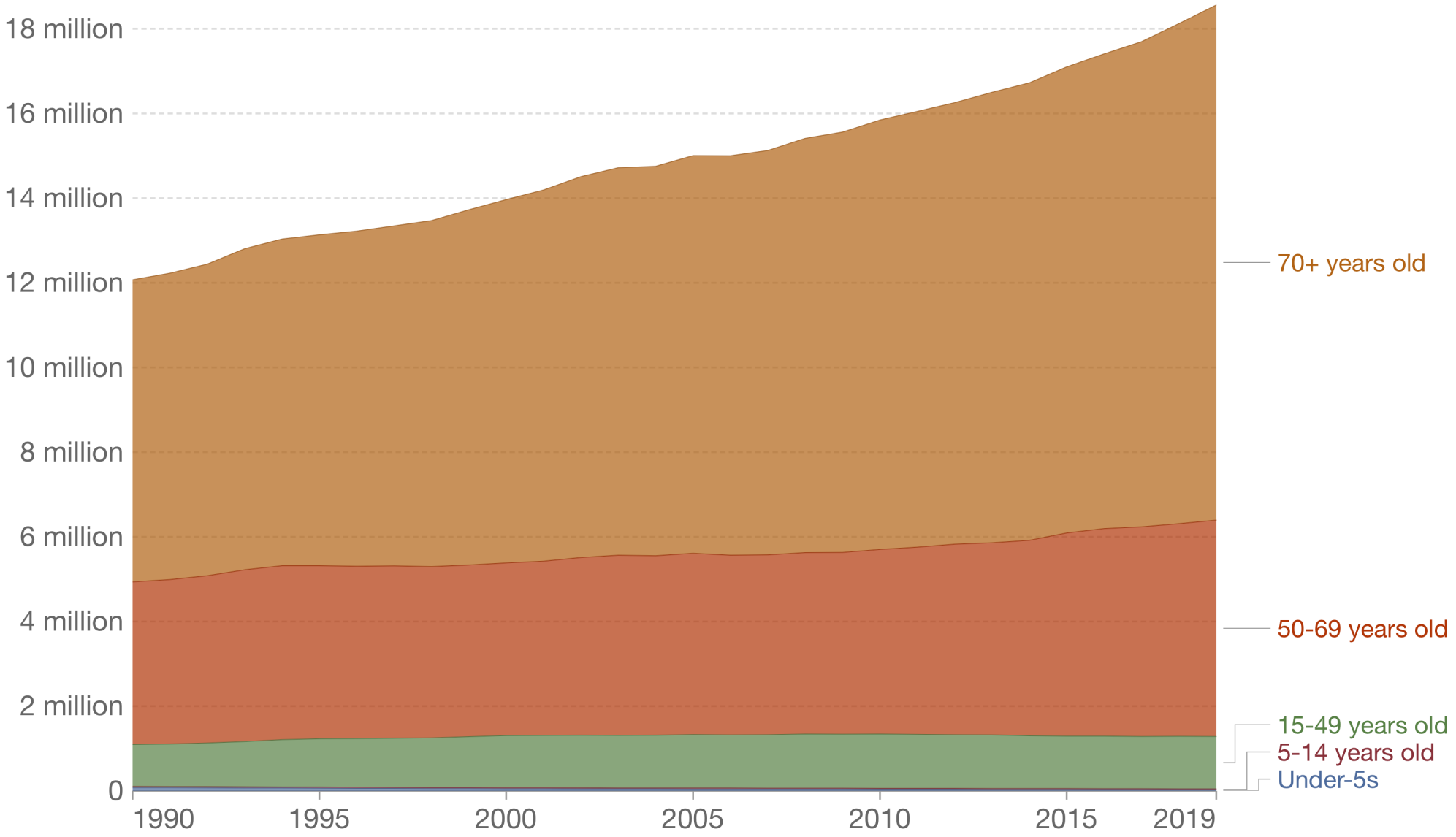
[Prevalence standardized to the global population (20-79)]

Estimated global healthcare expenditure to treat diabetes in 2007, 2021, 2030, and 2045 (in billion U.S. dollars)



Deaths from cardiovascular diseases, by age, World, 1990 to 2019

Annual number of deaths from cardiovascular diseases



Source: IHME, Global Burden of Disease (2019)

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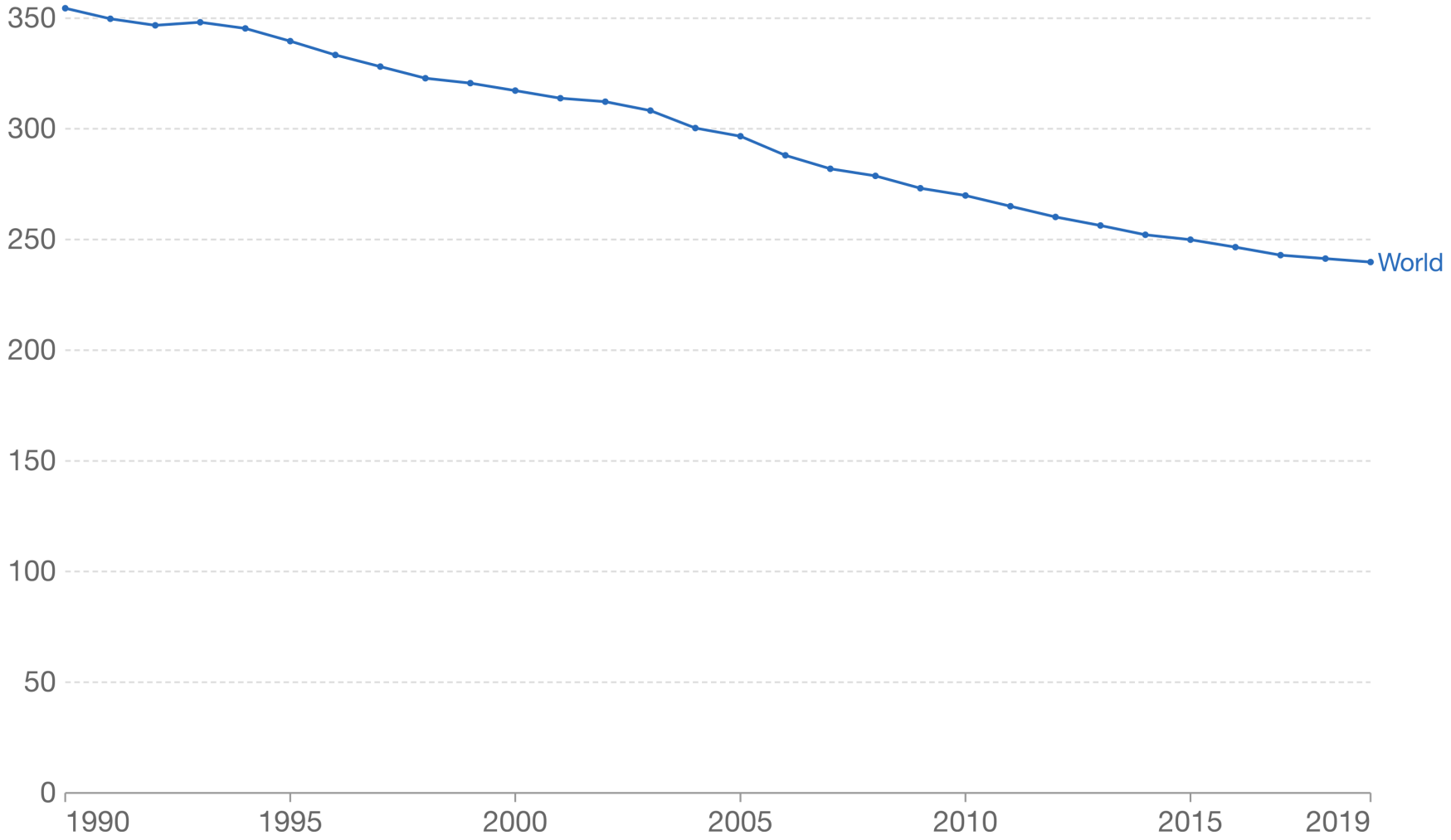
Death rate from cardiovascular disease, 1990 to 2019

Annual number of deaths from cardiovascular disease[1] per 100,000 people.



Source: IHME, Global Burden of Disease (2019)
Note: To allow comparisons between countries and over time this metric is age-standardized.

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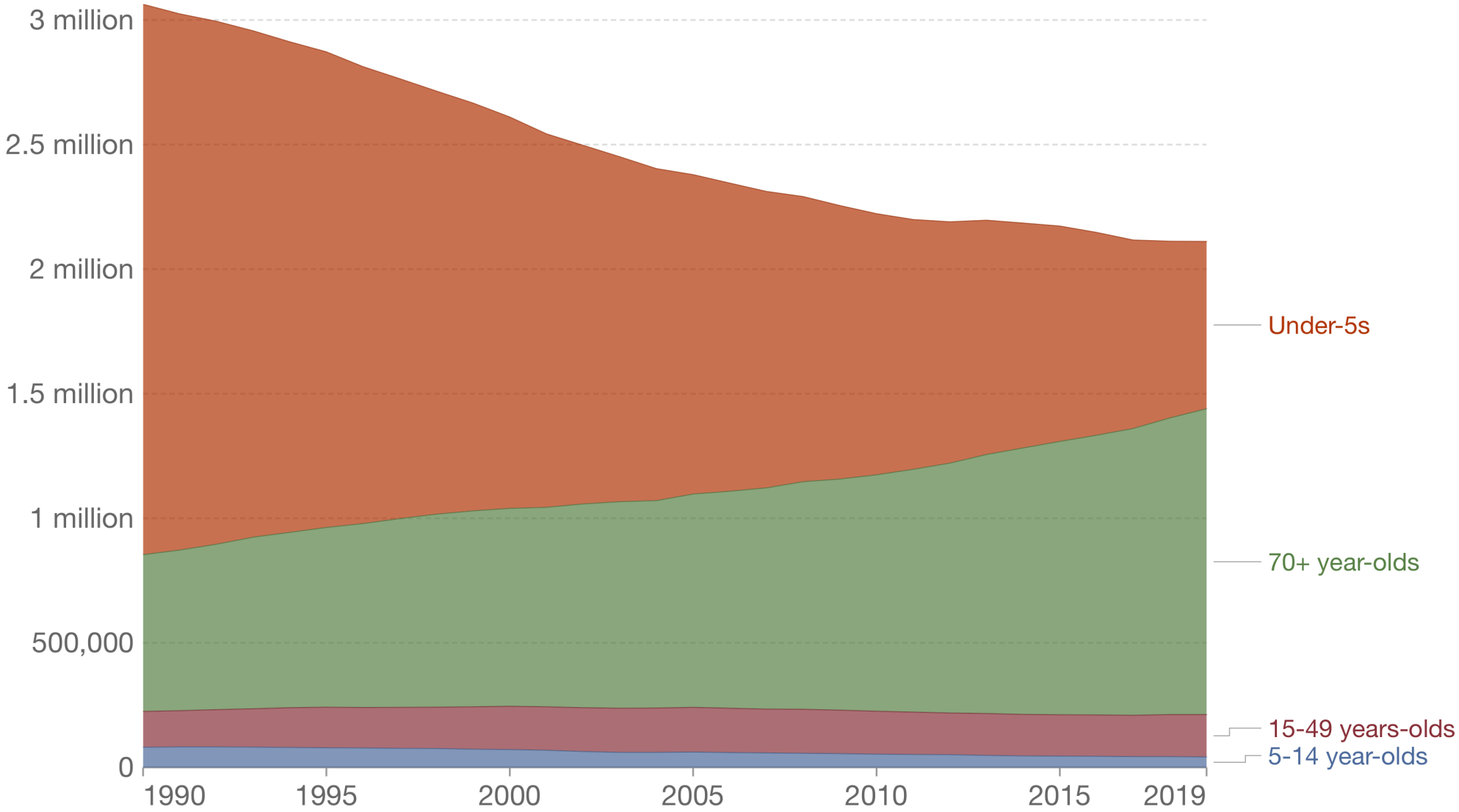
1. Cardiovascular disease: Cardiovascular disease (CVD) is a general term that describes a disease of the heart or blood vessels. It can impact the supply of blood to the heart muscle, the brain, or other parts of the body. Cardiovascular diseases are the leading cause of death globally.

Deaths from lower respiratory infections, by age, World, 1990 to 2019

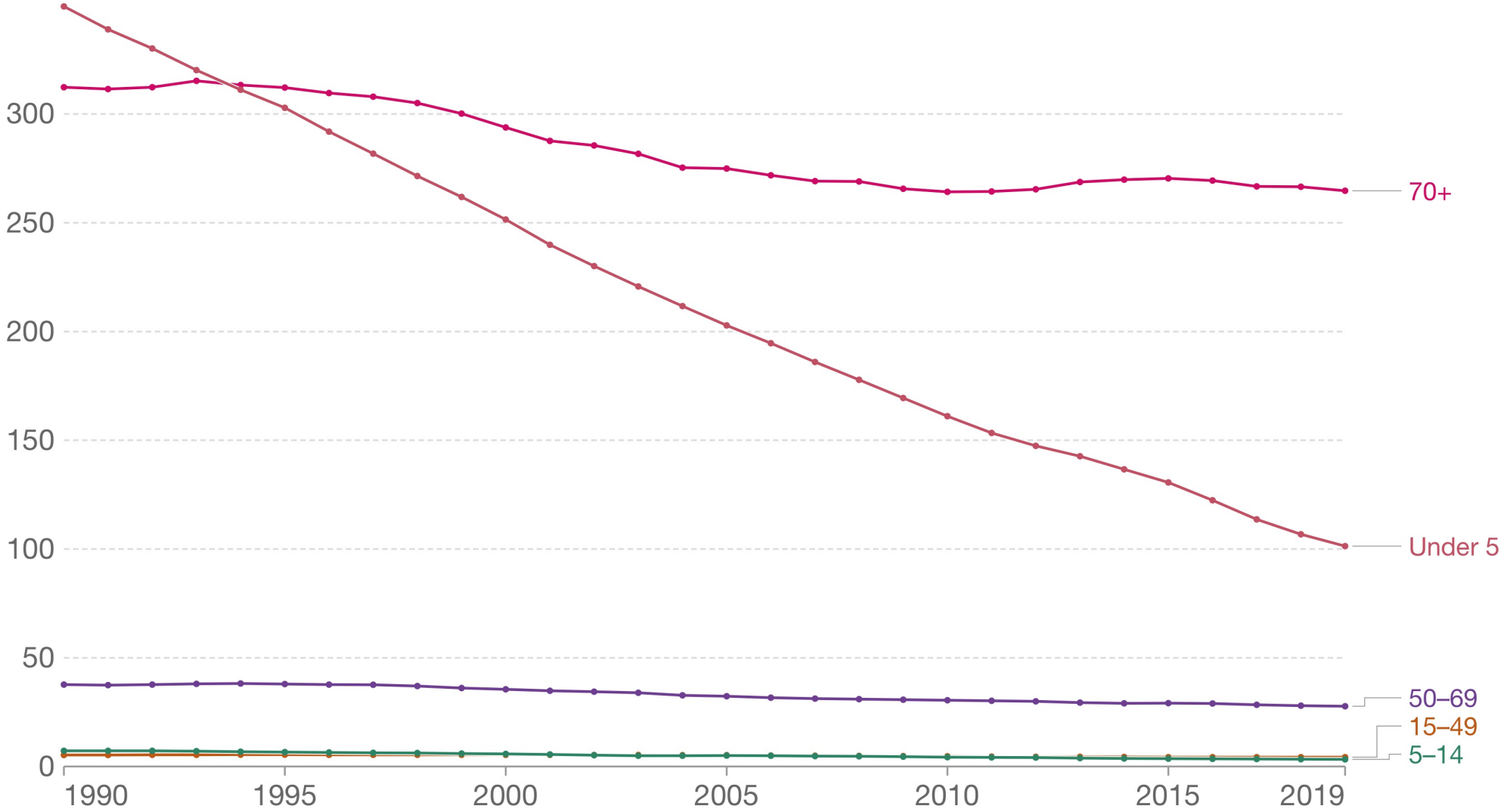
Annual deaths from lower respiratory infections, differentiated by age categories. Pneumonia accounts for the majority of lower respiratory infections.



Source: IHME, Global Burden of Disease (2019)

Death rate from pneumonia, by age, World

The annual number of deaths from pneumonia per 100,000 people in each age group.



Source: IHME, Global Burden of Disease (2019)

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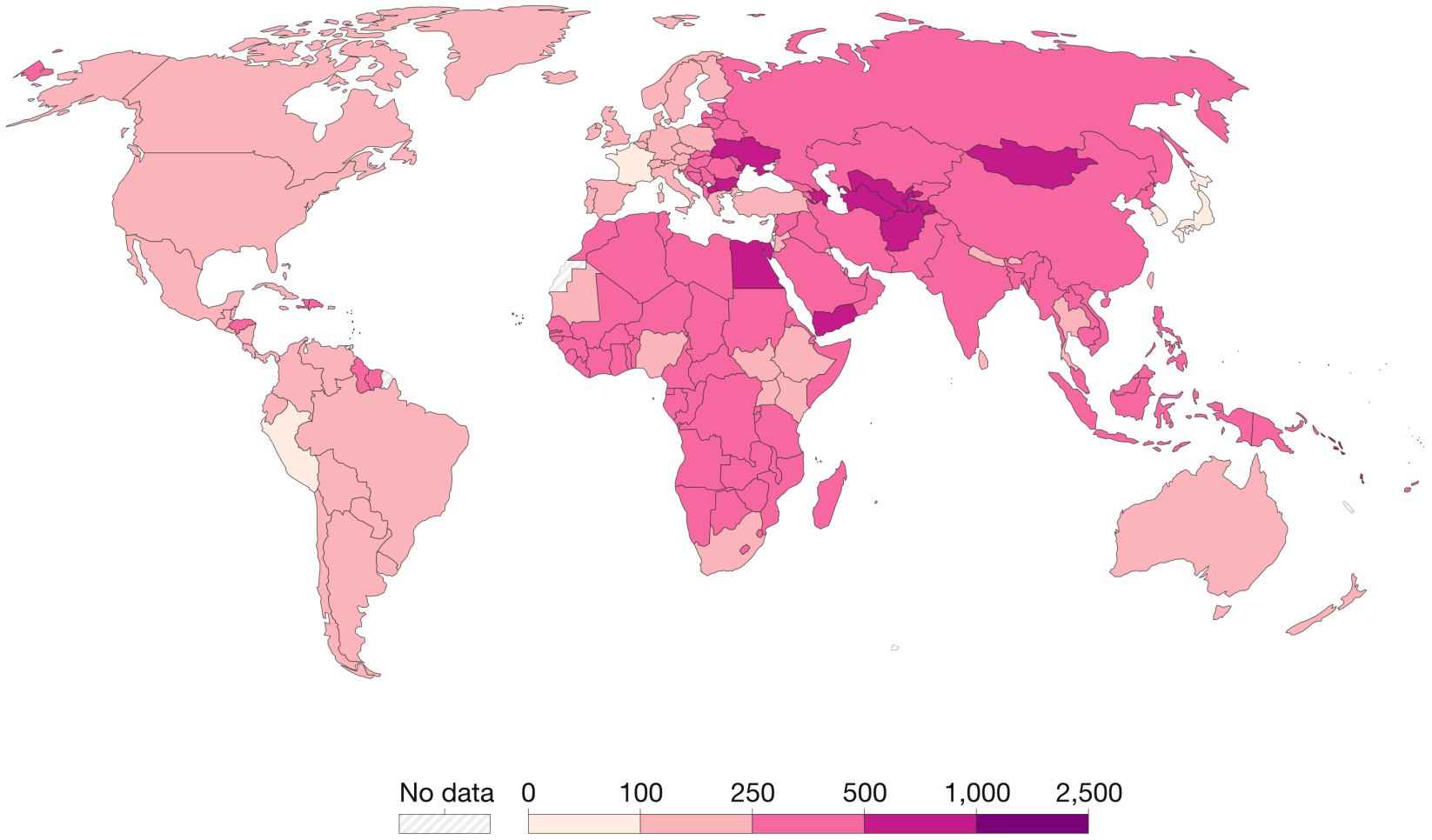
Note: Deaths from 'clinical pneumonia', which refers to a diagnosis based on disease symptoms such as coughing and difficulty breathing and n
include other lower respiratory diseases.

Death rate from cardiovascular disease, 2019

Annual number of deaths from cardiovascular disease[1] per 100,000 people.

Our World in Data



Source: IHME, Global Burden of Disease (2019)

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Note: To allow comparisons between countries and over time this metric is age-standardized.

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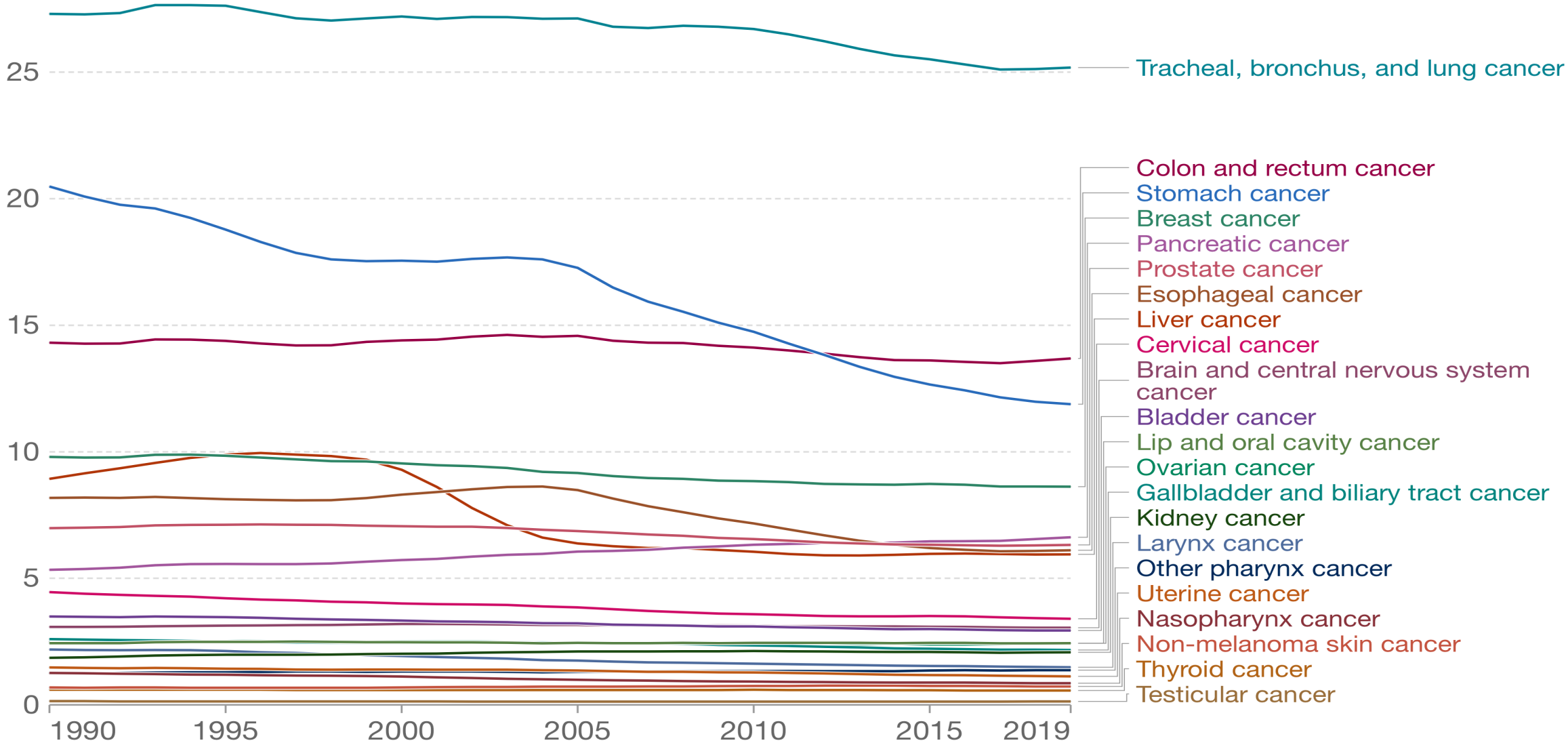
1. Cardiovascular disease: Cardiovascular disease (CVD) is a general term that describes a disease of the heart or blood vessels. It can impact the supply of blood to the heart muscle, the brain, or other parts of the body. Cardiovascular diseases are the leading cause of death globally.

Cancer death rate by type, World, 1990 to 2019

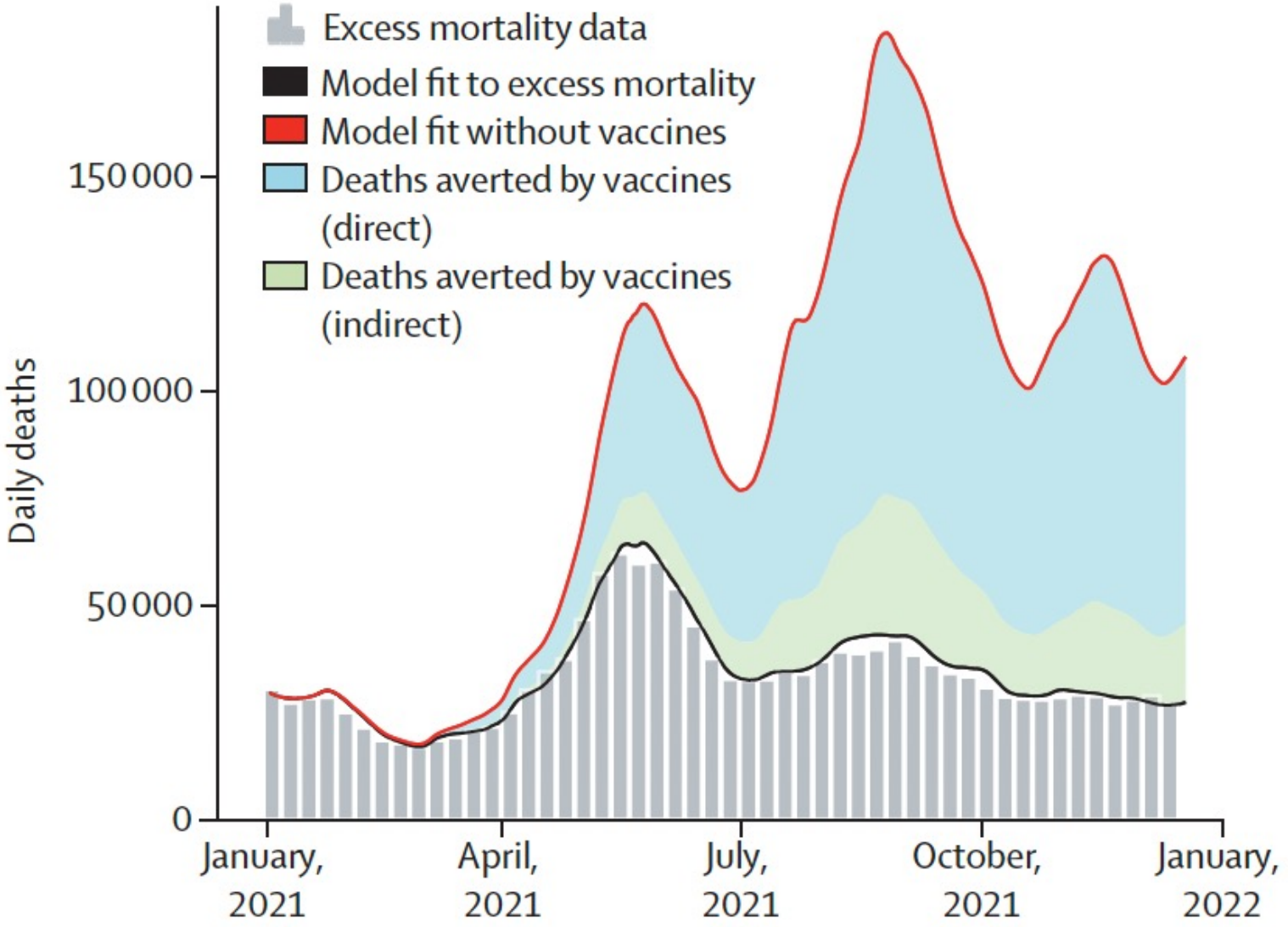
The number of deaths from different types of cancer per 100,000 individuals.
To allow comparisons between countries and over time this metric is age-standardized.

Our World in Data



Source: IHME, Global Burden of Disease (2019)

Global COVID-19 deaths averted due to vaccination based on excess mortality



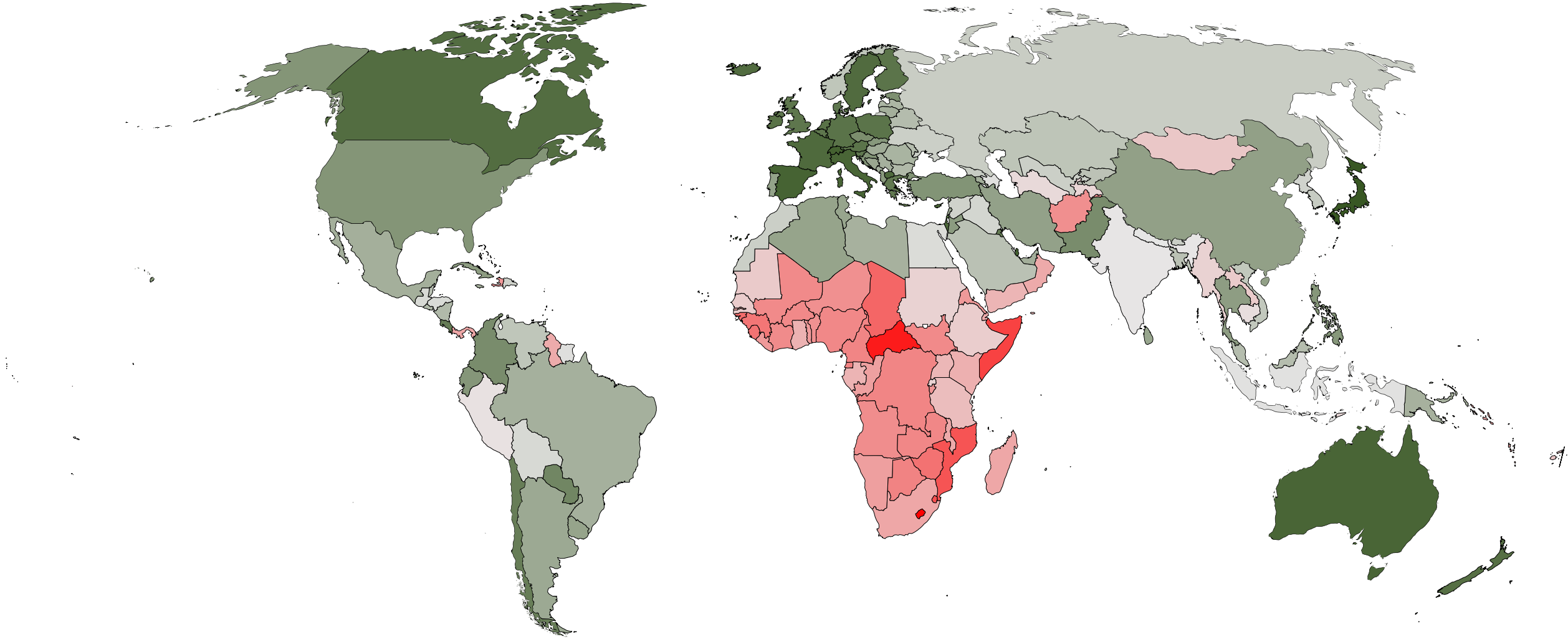
Median number of daily COVID-19 deaths based on excess mortality estimates (grey vertical bars) in the first year of vaccination. The baseline estimate of daily COVID-19 deaths from the model fit to excess mortality is plotted with the solid black line and the counterfactual scenario without vaccines is plotted with a red line. The gap between the red and black line indicates the deaths averted due to vaccination, with the proportion of total deaths averted by direct protection conferred by vaccination shown in blue and indirect protection shown in green.

Source: Oliver J Watson*, Gregory Barnsley*, Jaspreet Toor, Alexandra B Hogan, Peter Winskill, Azra C Ghani, "Global impact of the first year of COVID-19 vaccination: a mathematical modelling study," The Lancet Infectious Diseases 22 (2022):1293-302

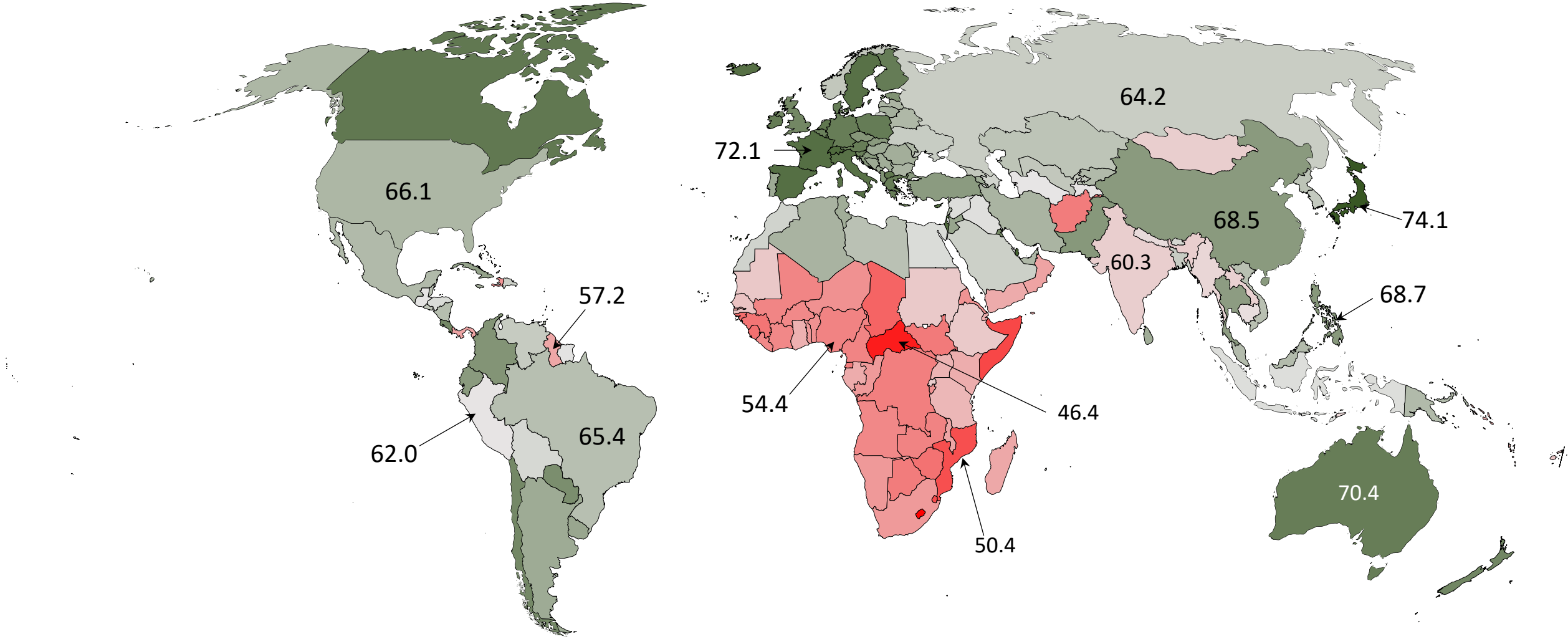
The Major Threats

- COVID-19
- Other filoviruses
- Tuberculosis
- Malaria
- HIV/AIDS
- Some cancers
- Parkinson’s disease
- Alzheimer’s disease and other forms of dementia
- Depression
- Diabetes

Life Expectancy at Birth (2019)

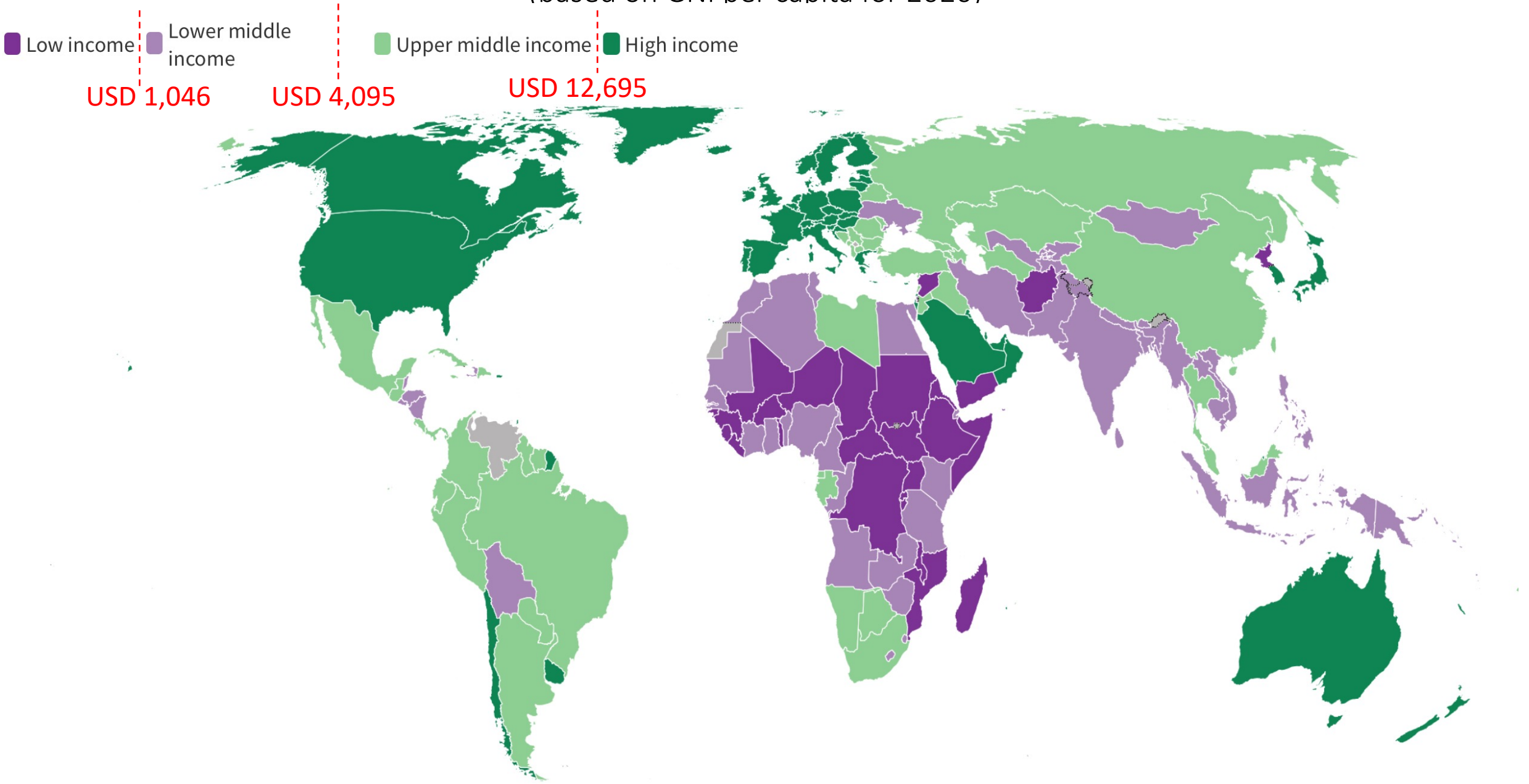


Healthy Life Expectancy (HALE) at Birth (2019)



World Bank country classifications by income level: 2021-2022

(based on GNI per capita for 2020)



Mortality and Morbidity by Region and Cause (2019)

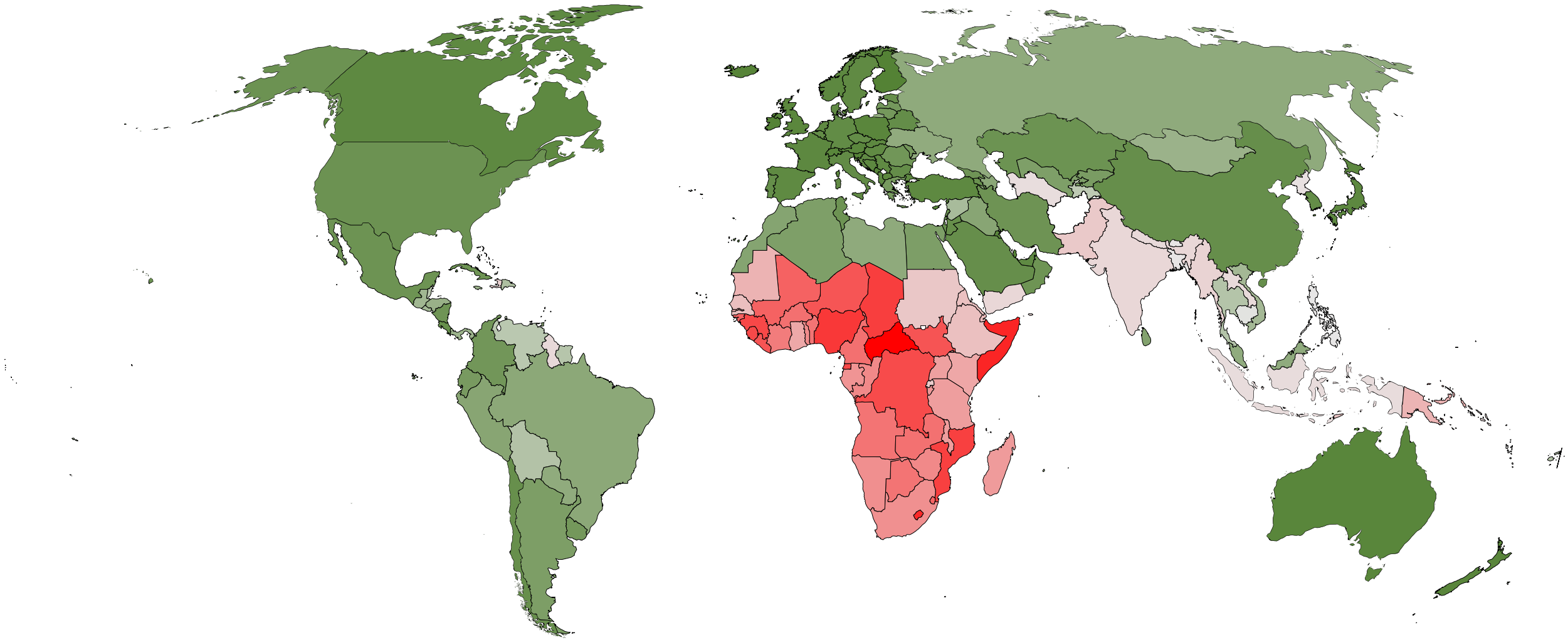
In each cell,
the first number represents the loss per year (in thousands of DALYs) attributable to the cause;

the second number is the proportion of the global burden associated with the cause borne by the region;

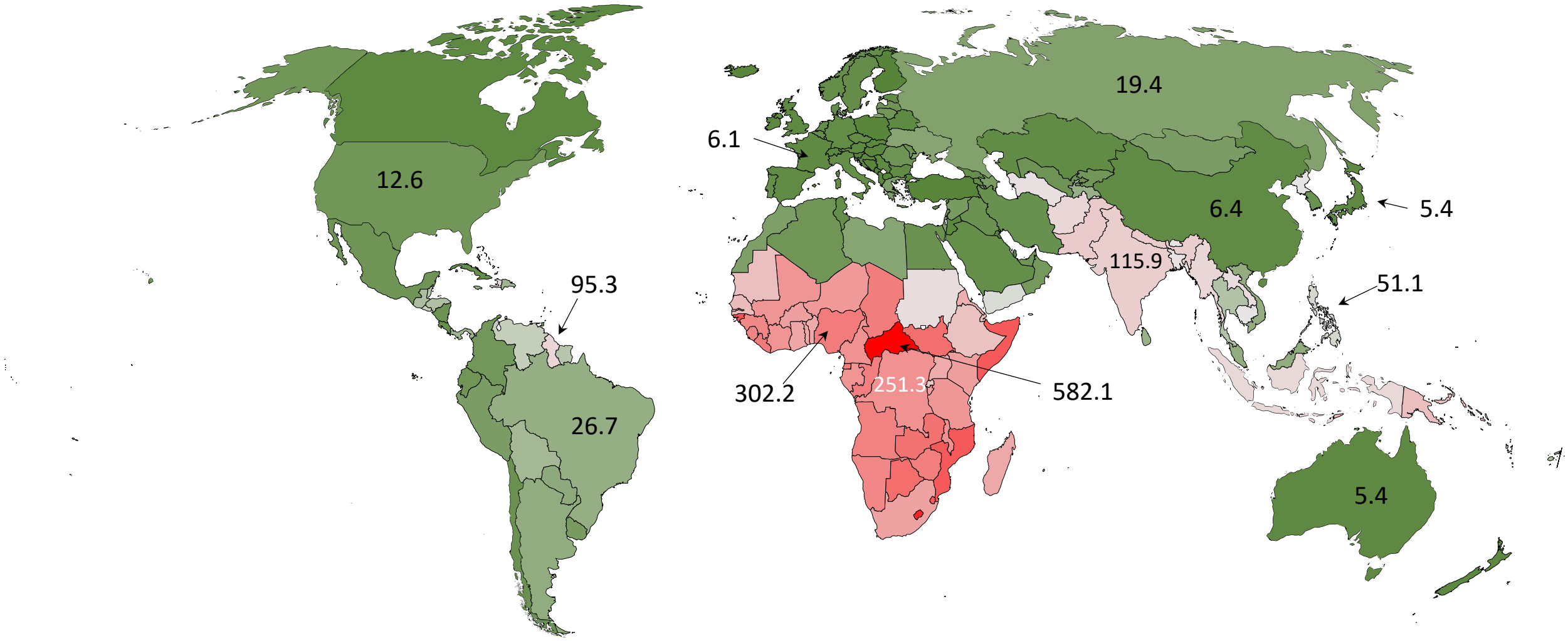
the third number is the number of DALYs lost per 100,000 people in the region

	A	B	C	D	E	F
1		**Low Income Countries**	**Lower Middle Income Countries**	**Upper Middle Income Countries**	**High Income Countries**	**All countries**
2	Population	668455 (8.7%)	2913534 (37.8%)	2902542 (37.7%)	1223729 (15.9%)	7708261
3	Infectious and Parasitic Diseases	82989 (26.7%) 12415	182400 (58.6%) 6260	40117 (12.9%) 1382	5812 (1.9%) 475	311318 4039
4	Respiratory Infections	27212 (23.8%) 4071	60336 (52.7%) 2071	20058 (17.5%) 691	6825 (6.0%) 558	114431 2200
5	Maternal Conditions	4333 (34.3%) 648	6903 (54.6%) 237	1276 (10.1%) 44	137 (0.1%) 11	12649 164
6	Neonatal Conditions	48277 (23.9%) 7222	123036 (60.1%) 4223	26134 (12.9%) 900	4374 (2.2%) 357	201821 2618
7	Nutritional Deficiencies	9351 (19.4%) 1399	28883 (60.0%) 991	7979 (16.6%) 275	1912 (4.0%) 156	48125 624
8	Noncommunicable Conditions	105219 (6.6%) 15741	559850 (35.4%) 19215	622356 (39.3%) 21442	295231 (18.7%) 24126	1582657 20532
9	Injuries	34034 (13.1%) 5091	105188 (40.3%) 3610	88065 (33.8%) 3034	33423 (12.8%) 2731	260710 3382
10	**All Causes**	**311416 (12.3%) 46587**	**1066596 (42.1%) 36608**	**805985 (31.8%) 27768**	**347714 (13.7%) 28414**	**2531710 32844**

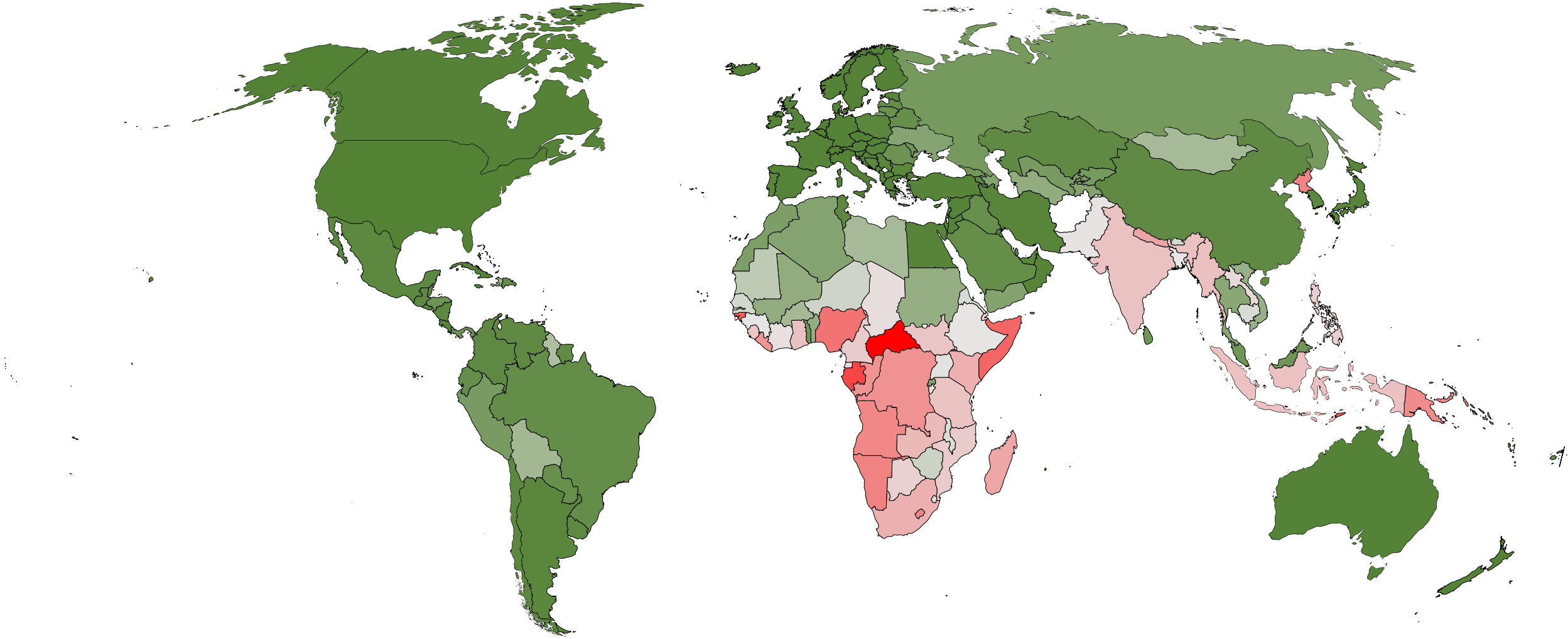
DALYs per capita from Infectious Diseases (2019)



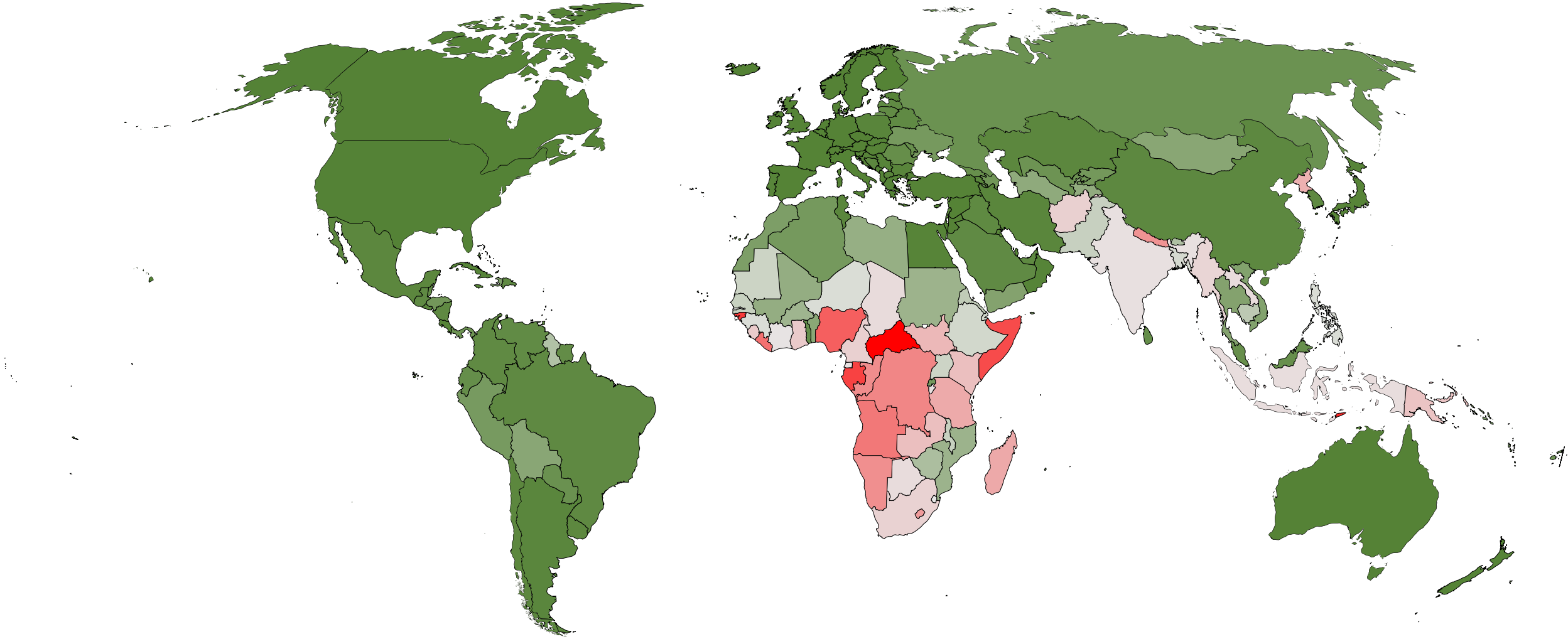
Age-Standardized Mortality from Infectious Diseases (2019)



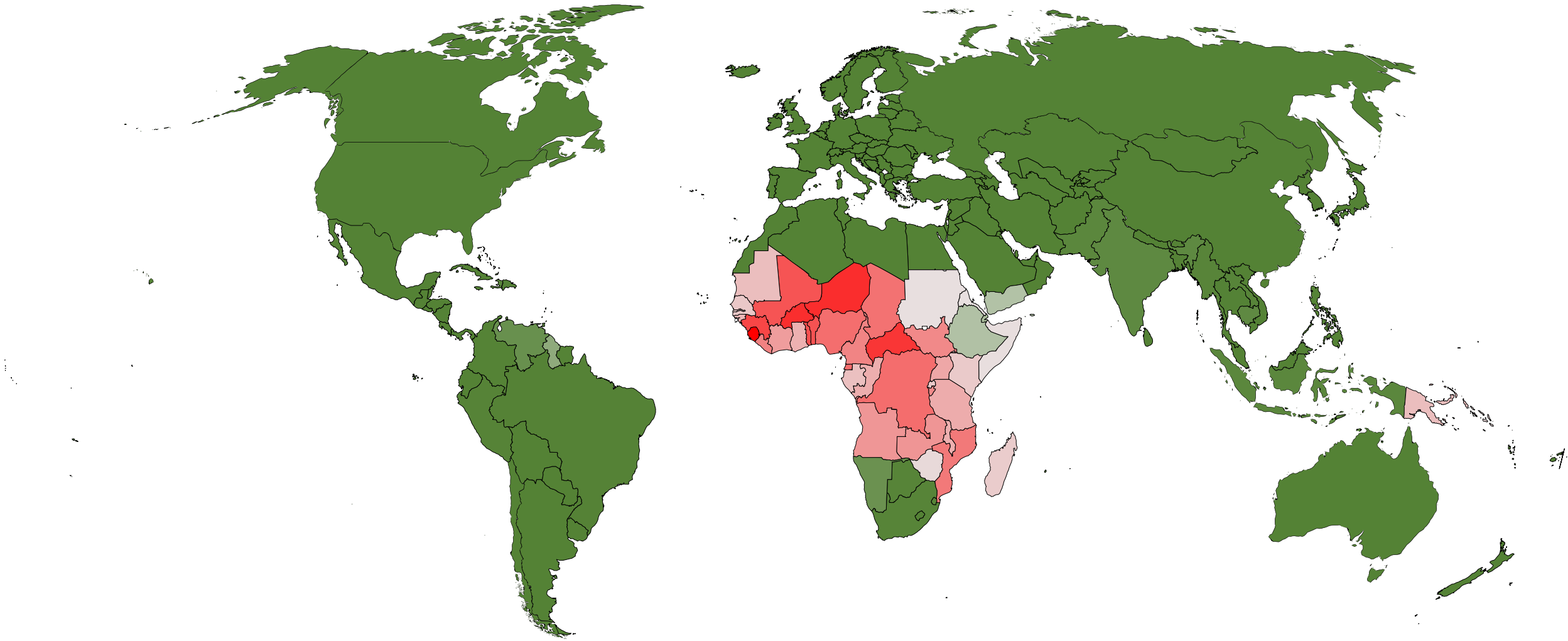
DALYs per capita from Tuberculosis (2019)



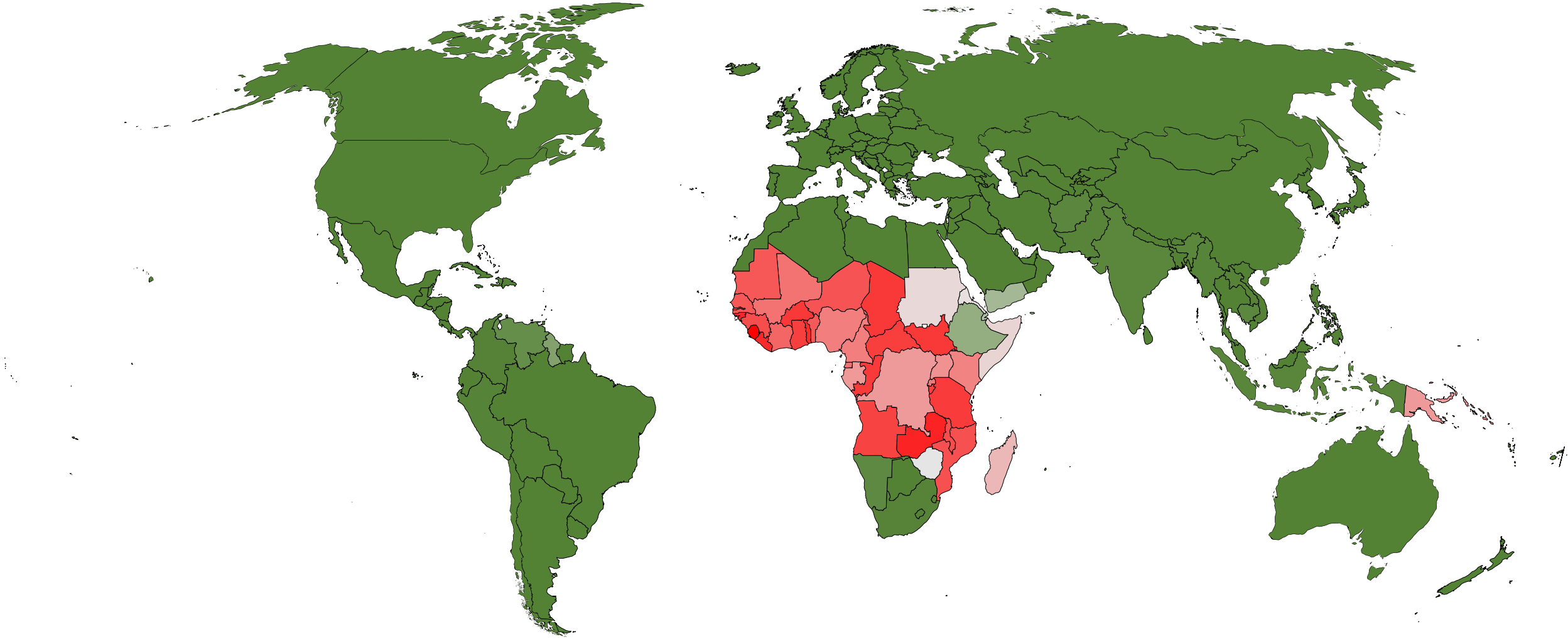
Age-Standardized Mortality from Tuberculosis (2019)



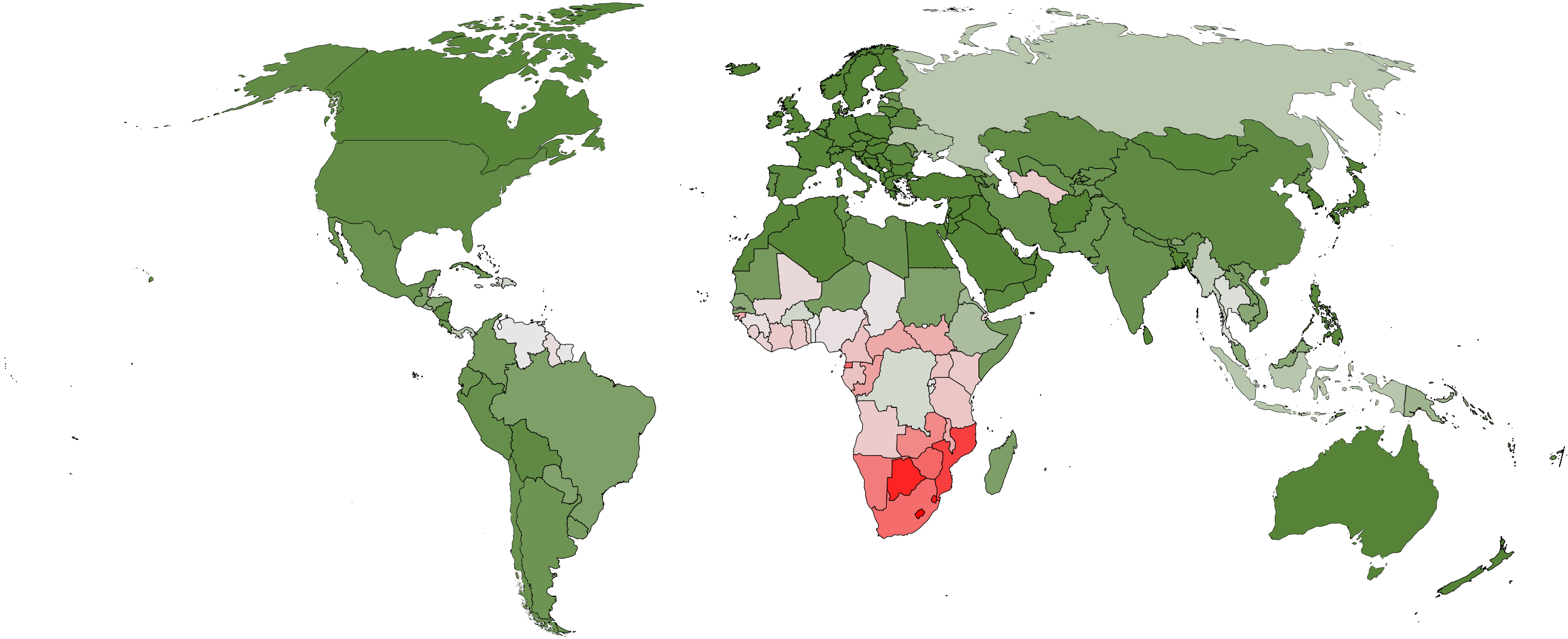
DALYs per capita from Malaria (2019)



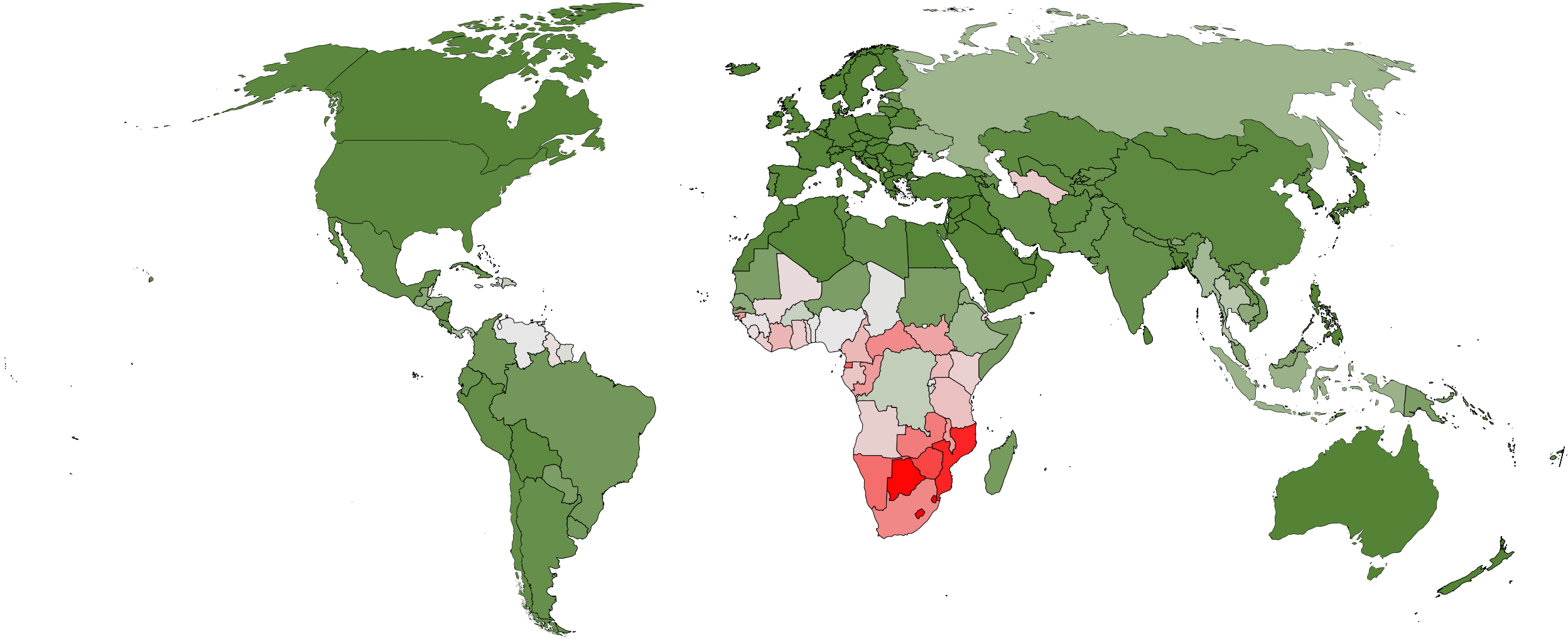
Age-Standardized Mortality from Malaria (2019)



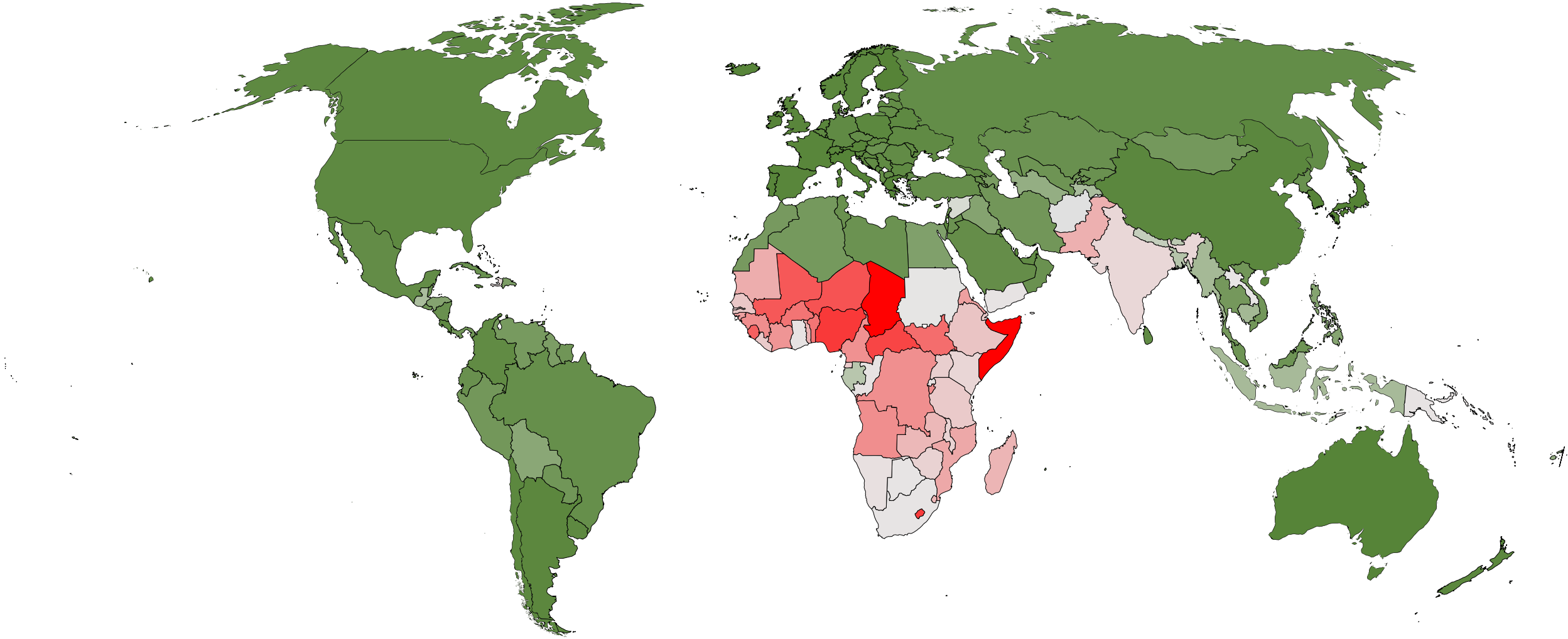
DALYs per capita from HIV/AIDS (2019)



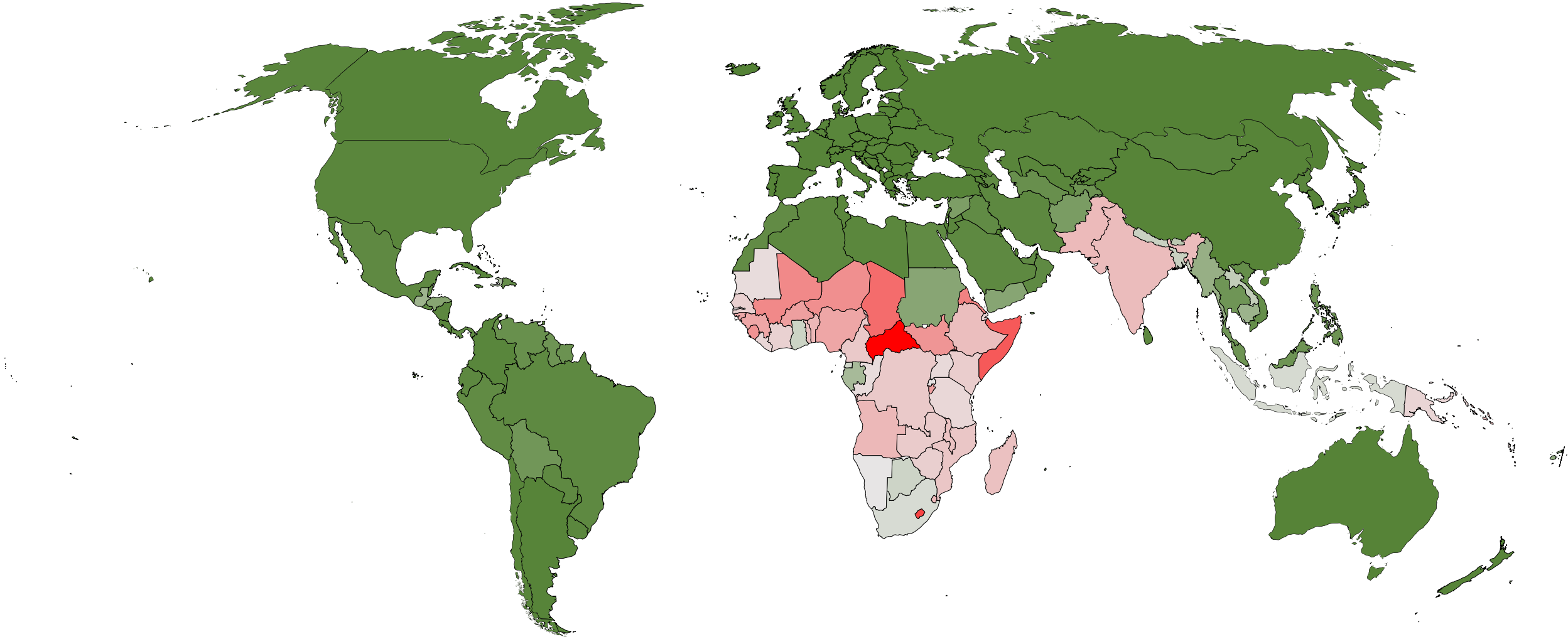
Age-Standardized Mortality from HIV/AIDS (2019)



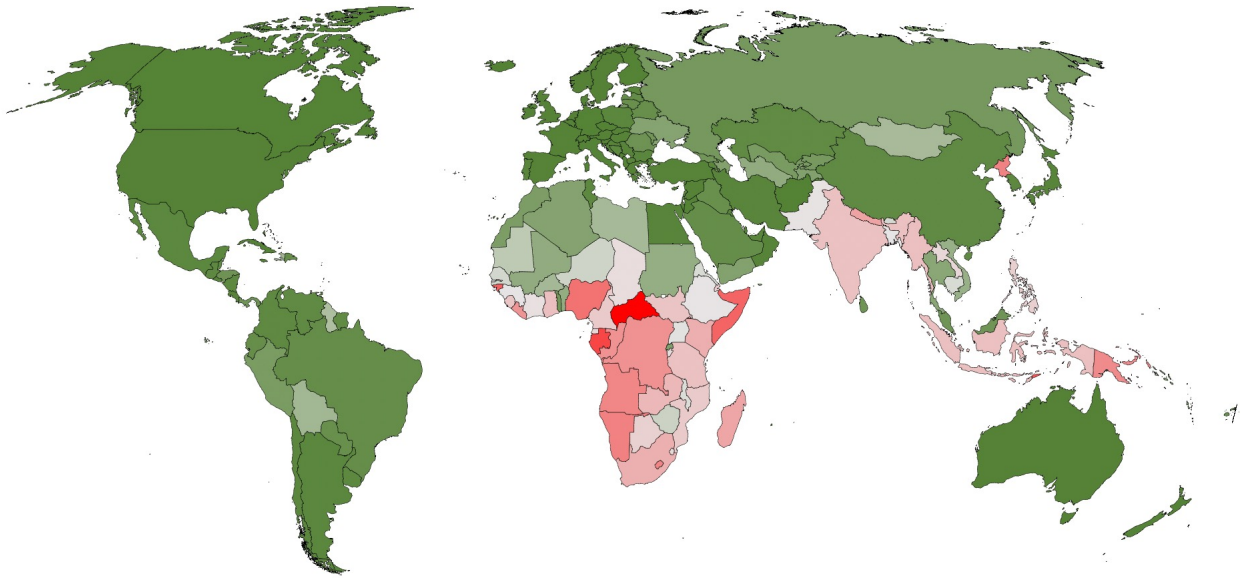
DALYs per capita from Diarrhoeal Diseases (2019)



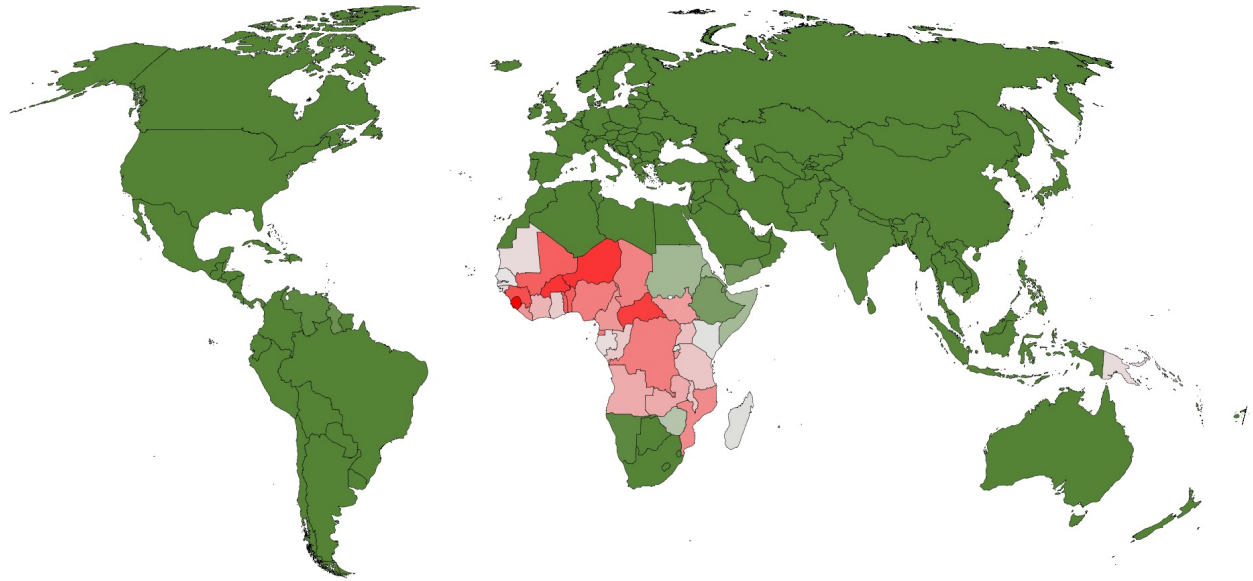
Age-Standardized Mortality from Diarrhoeal Diseases (2019)



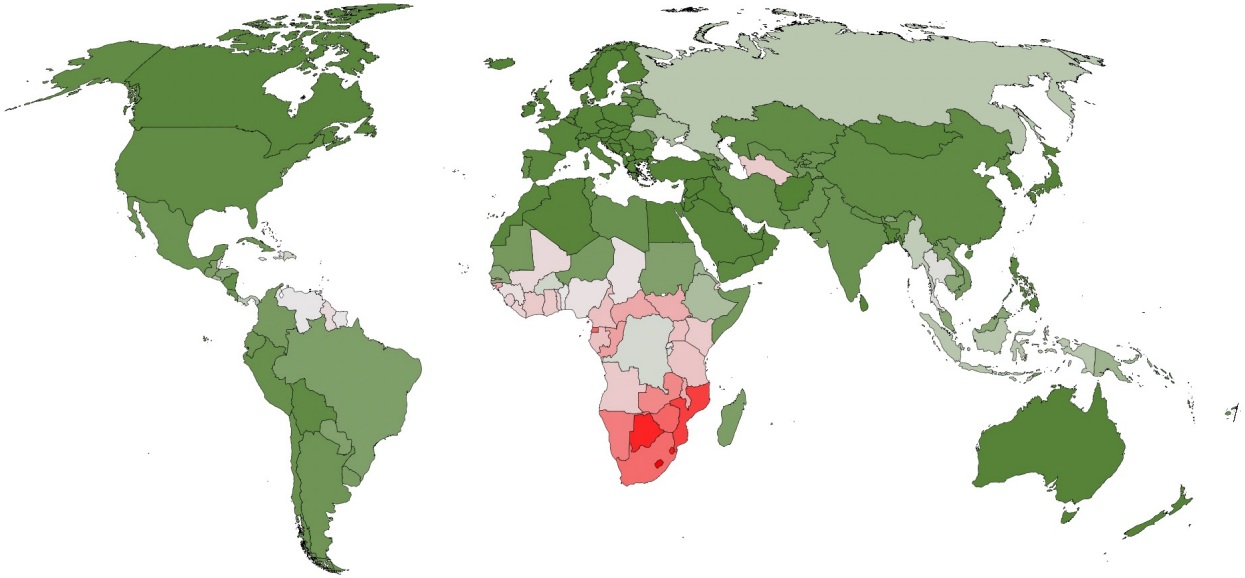
DALYs per capita from Tuberculosis (2019)



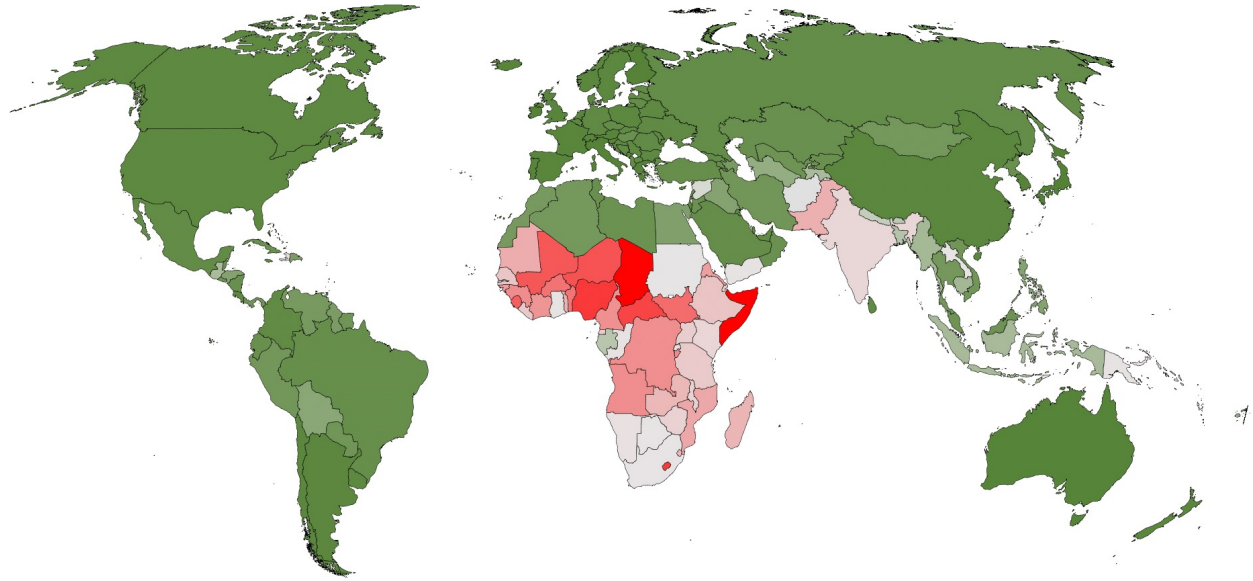
DALYs per capita from Malaria (2019)



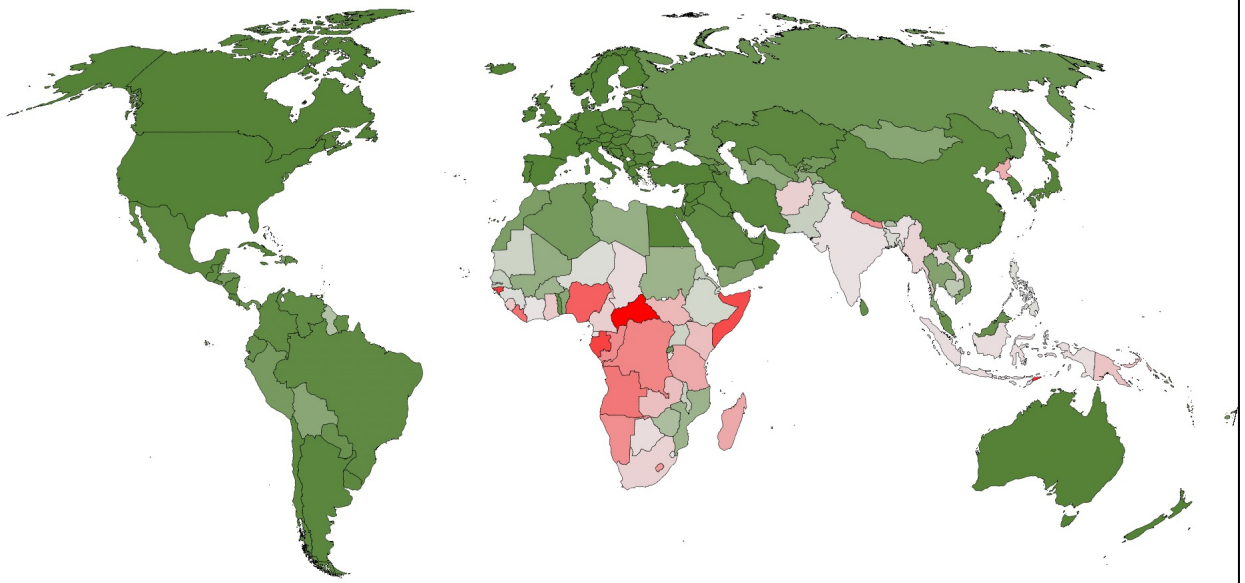
DALYs per capita from HIV/AIDS (2019)



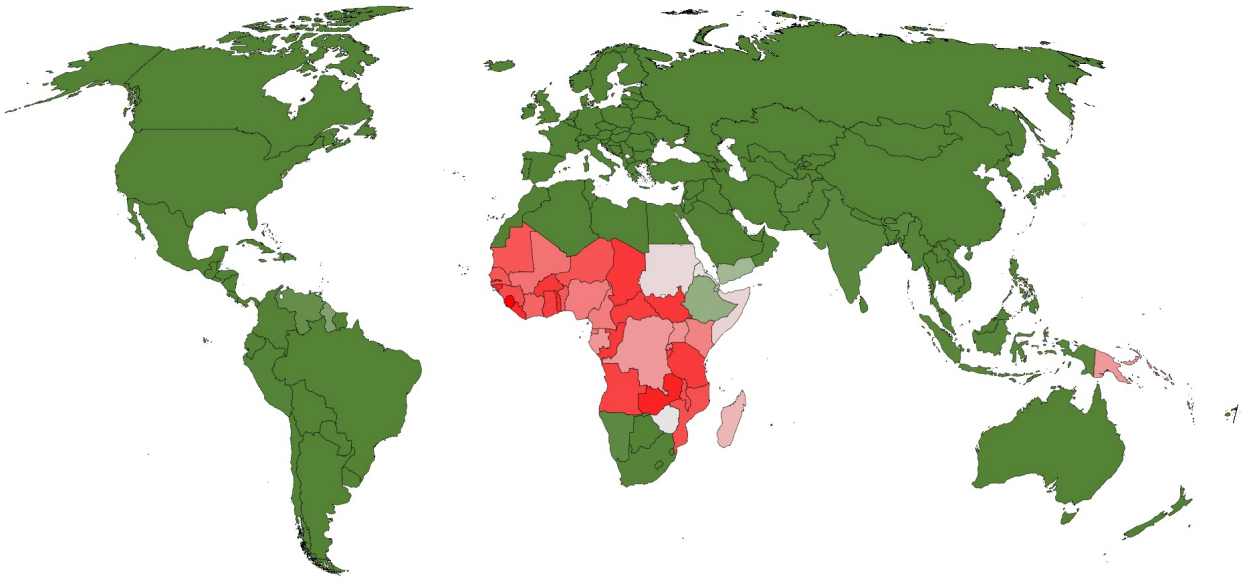
DALYs per capita from Diarrhoeal Diseases (2019)



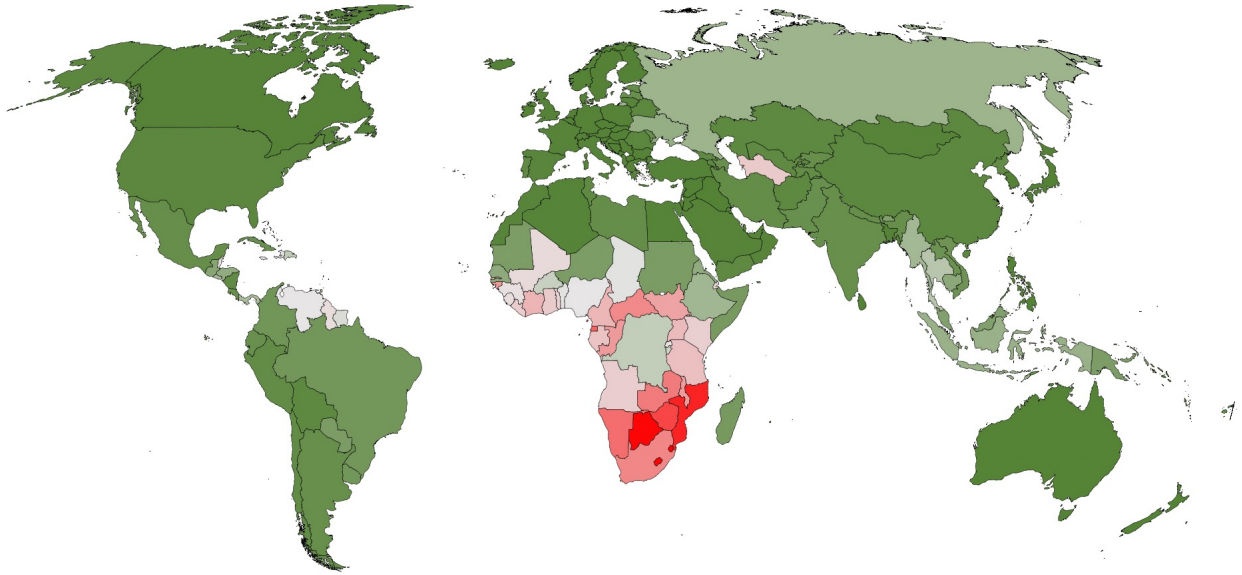
Age-Standardized Mortality from Tuberculosis (2019)



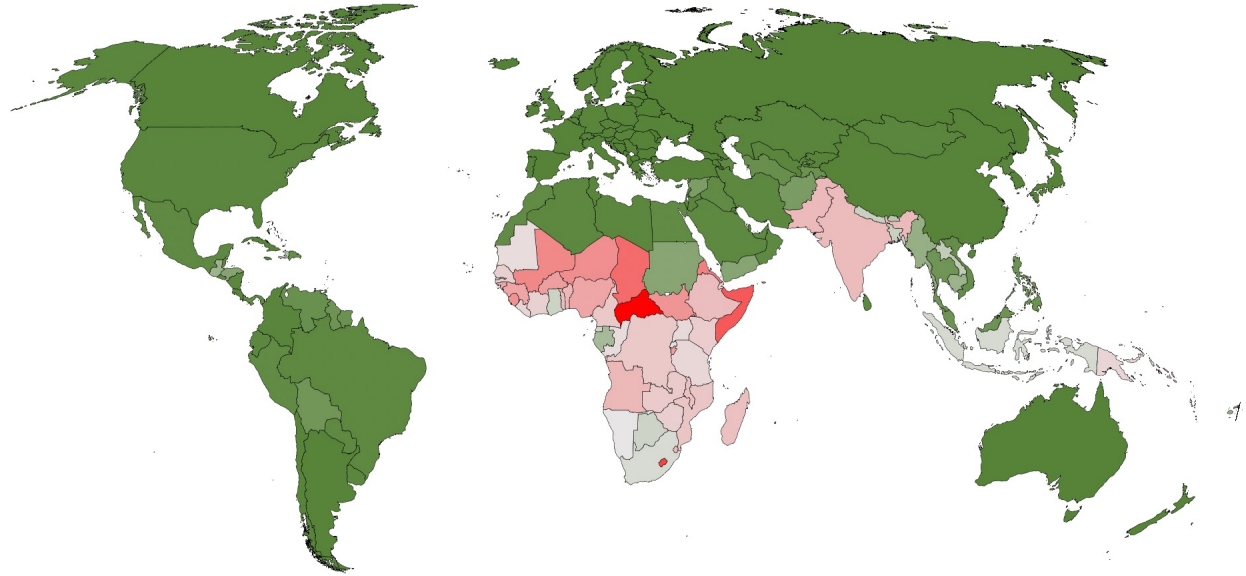
Age-Standardized Mortality from Malaria (2019)



Age-Standardized Mortality from HIV/AIDS (2019)



Age-Standardized Mortality from Diarrhoeal Diseases (2019)

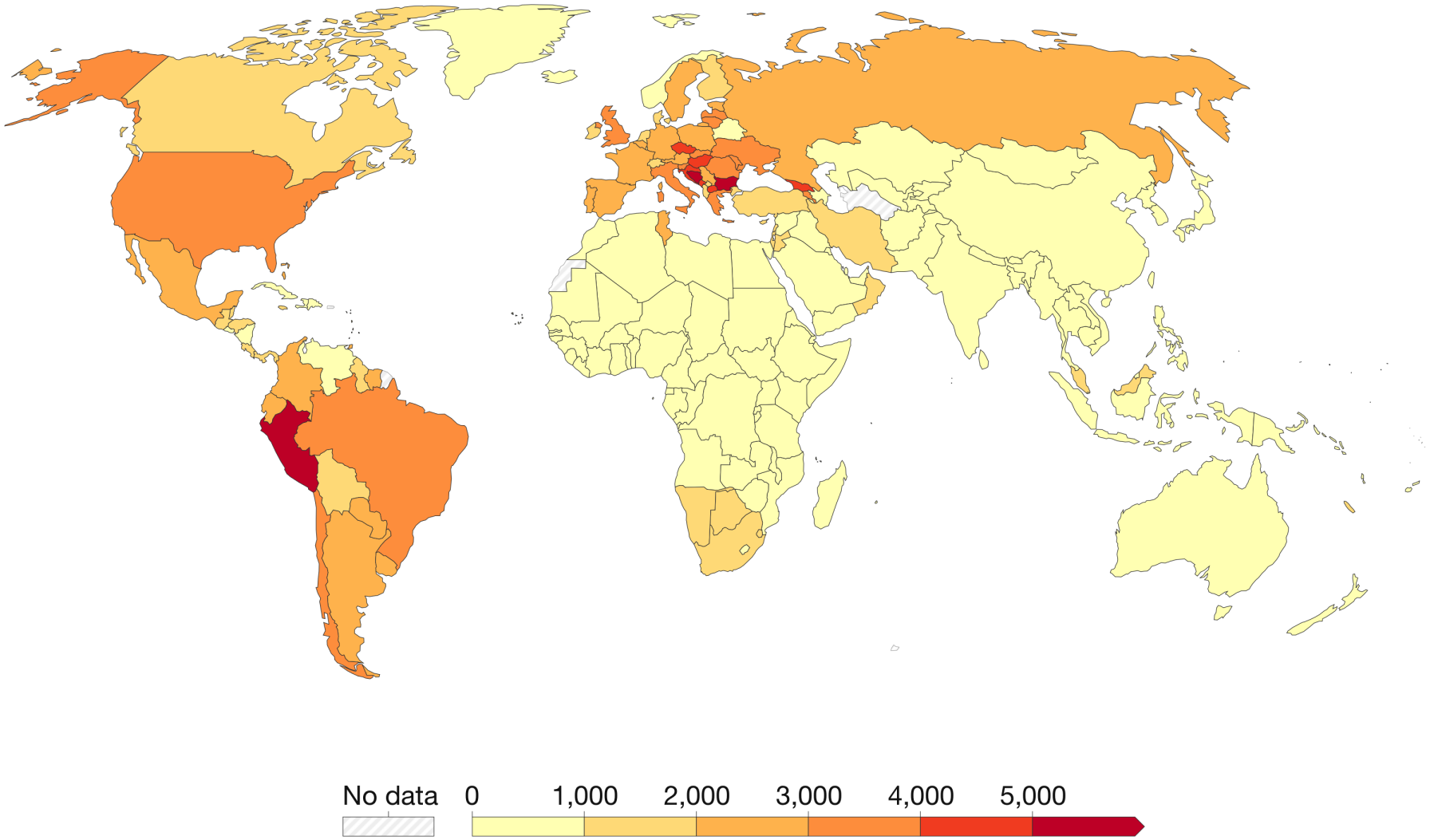


(thousands)	Global Deaths	Global DALYs
HIV/AIDS	675	40147
Tuberculosis*	1208	66024
Malaria*	411	33398
STDs (excluding HIV/AIDS)		
Syphilis	43	3814
Chlamydia	1	324
Gonorrhoea	2	231
Trichomoniasis	0	282
Genital herpes	0	250
Other STDs	3	352
Diarrhoeal Diseases	1519	79311
Childhood Diseases		
Pertussis (“whooping cough”)	111	9839
Diphtheria	5	420
Measles	165	14528
Tetanus	47	3474
Meningitis	233	16314
Encephalitis	78	4174
Hepatitis		
A	40	2102
B	36	1633
C	22	655
E	2	123

(thousands)	Global Deaths	Global DALYs
Parasitic and vector diseases (excluding Malaria)		
Trypanosomiasis*	2	102
Chagas*	8	217
Schistosomiasis	12	1628
Leishmaniasis*	6	722
Lymphatic filariasis (elephantiasis)	0	1616
Onchocerciasis (river blindness)	0	1210
Cysticercosis	7	988
Echinococcosis	9	461
Dengue	30	1952
Trachoma (infectious blindness)	0	194
Yellow fever	6	413
Rabies	47	2634
Intestinal nematode infections		
Ascariasis	2	749
Trichuriasis	0	232
Hookworm	0	962
Food-bourne trematodes	7	805
Leprosy	13	36
Other infectious diseases	370	19000
Totals	5101	311318

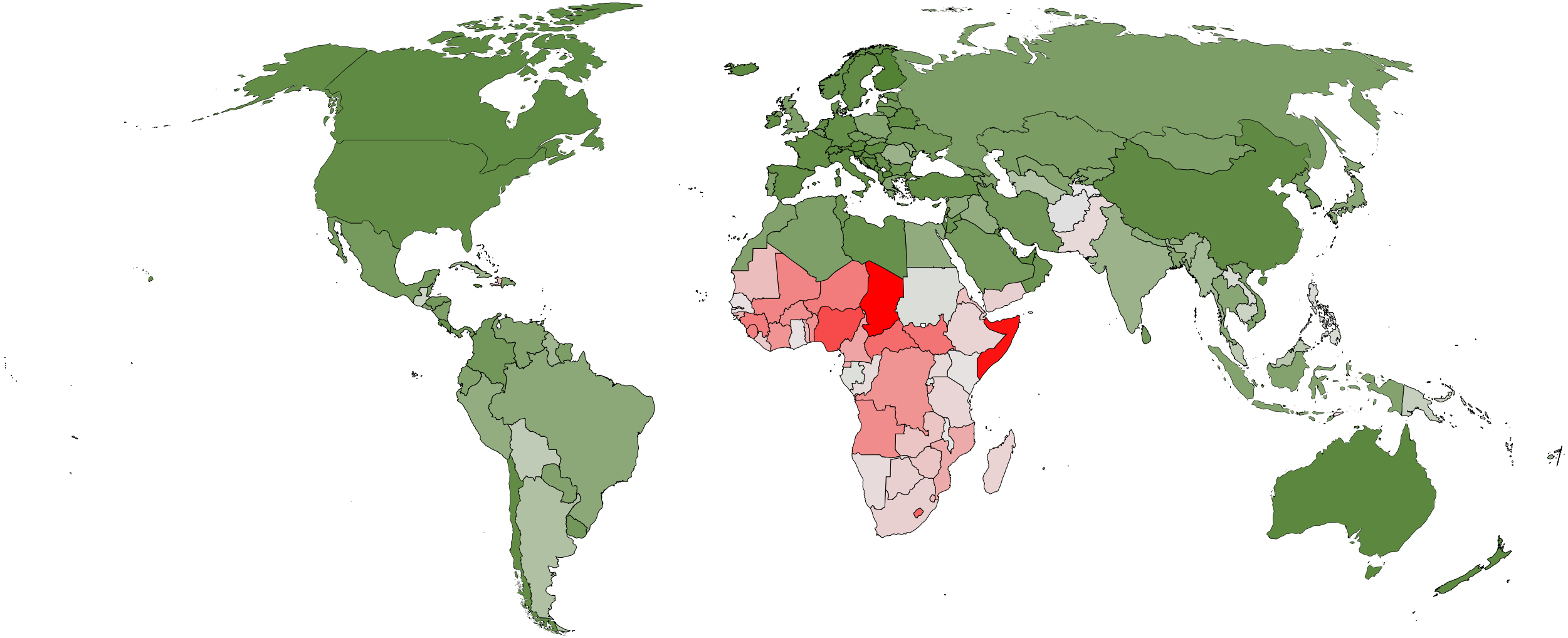
Cumulative confirmed COVID-19 deaths per million people, Feb 28, 2023

Due to varying protocols and challenges in the attribution of the cause of death, the number of confirmed deaths may not accurately represent the true number of deaths caused by COVID-19.

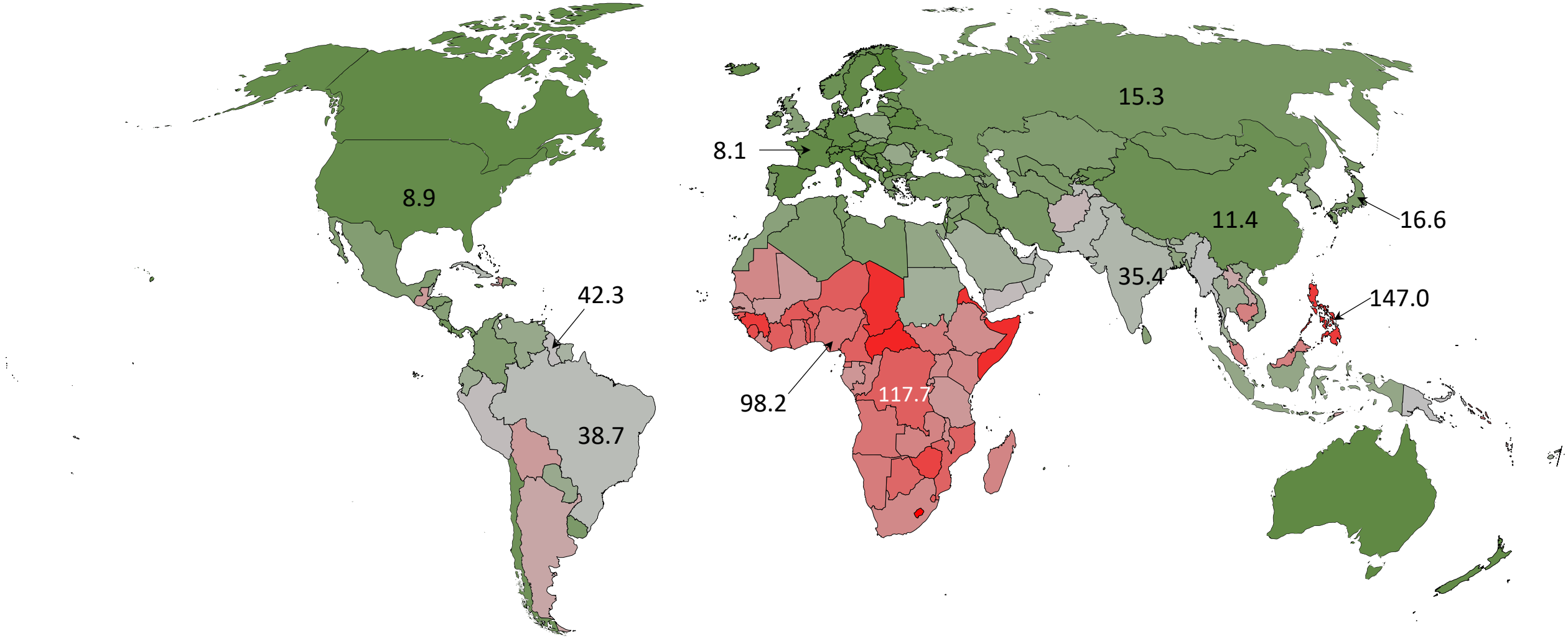


Source: Johns Hopkins University CSSE COVID-19 Data

DALYs per capita from Respiratory Infections (2019)



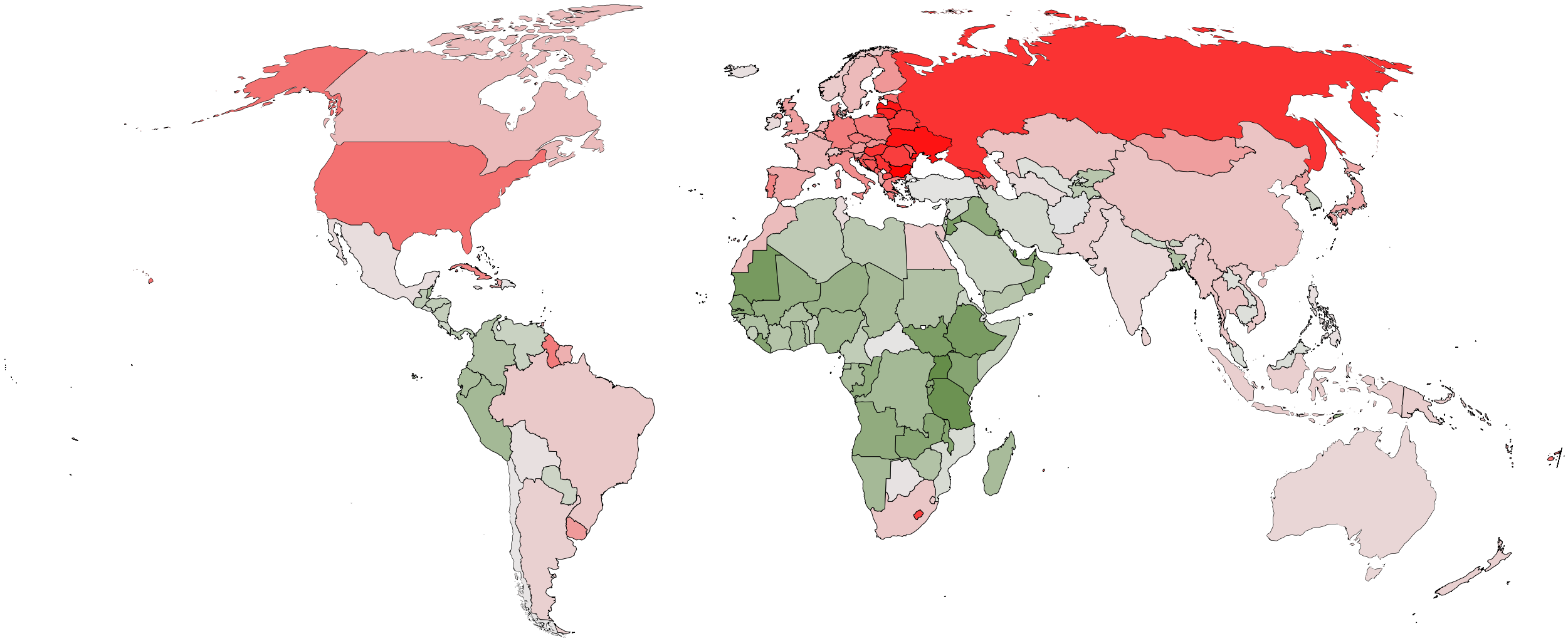
Age-Standardized Mortality from Respiratory Infections (2019)



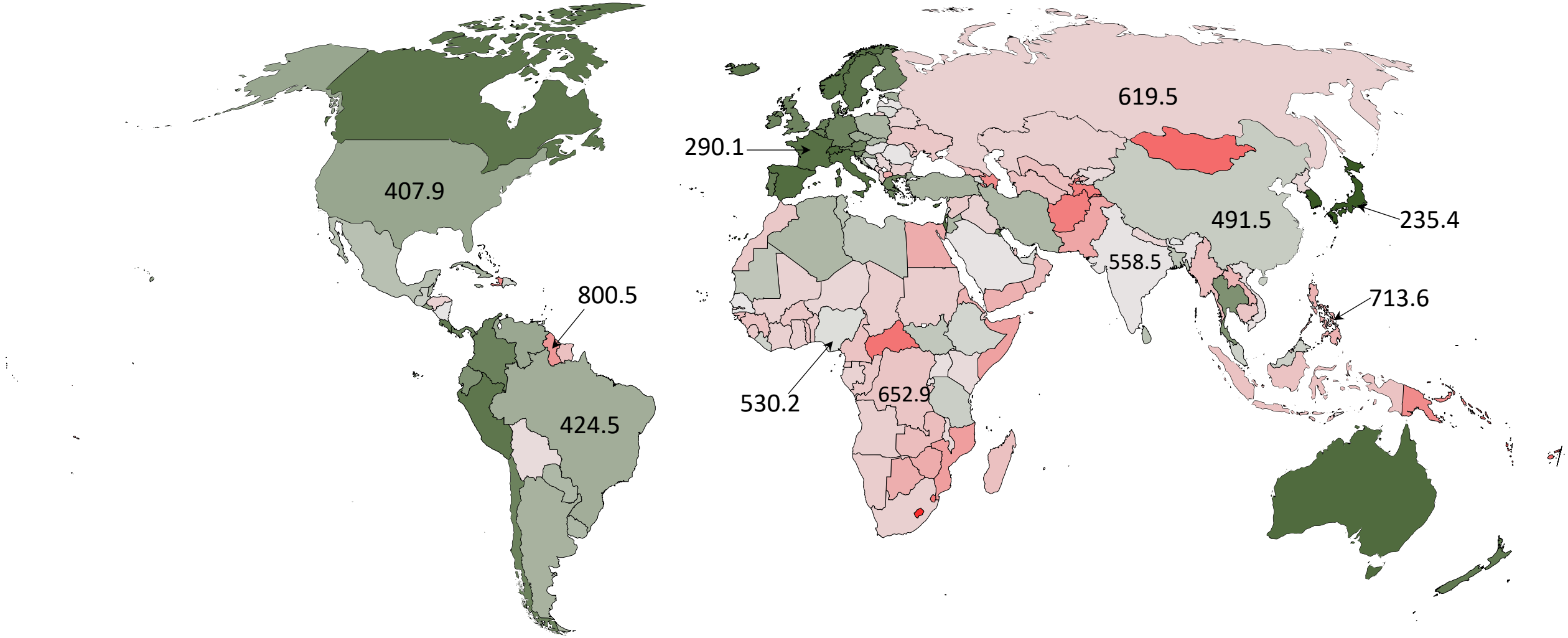
Mortality per 100,000 population

2.8 193.2

DALYs per capita from Noncommunicable Diseases (2019)



Age-Standardized Mortality from Non-communicable Conditions (2019)



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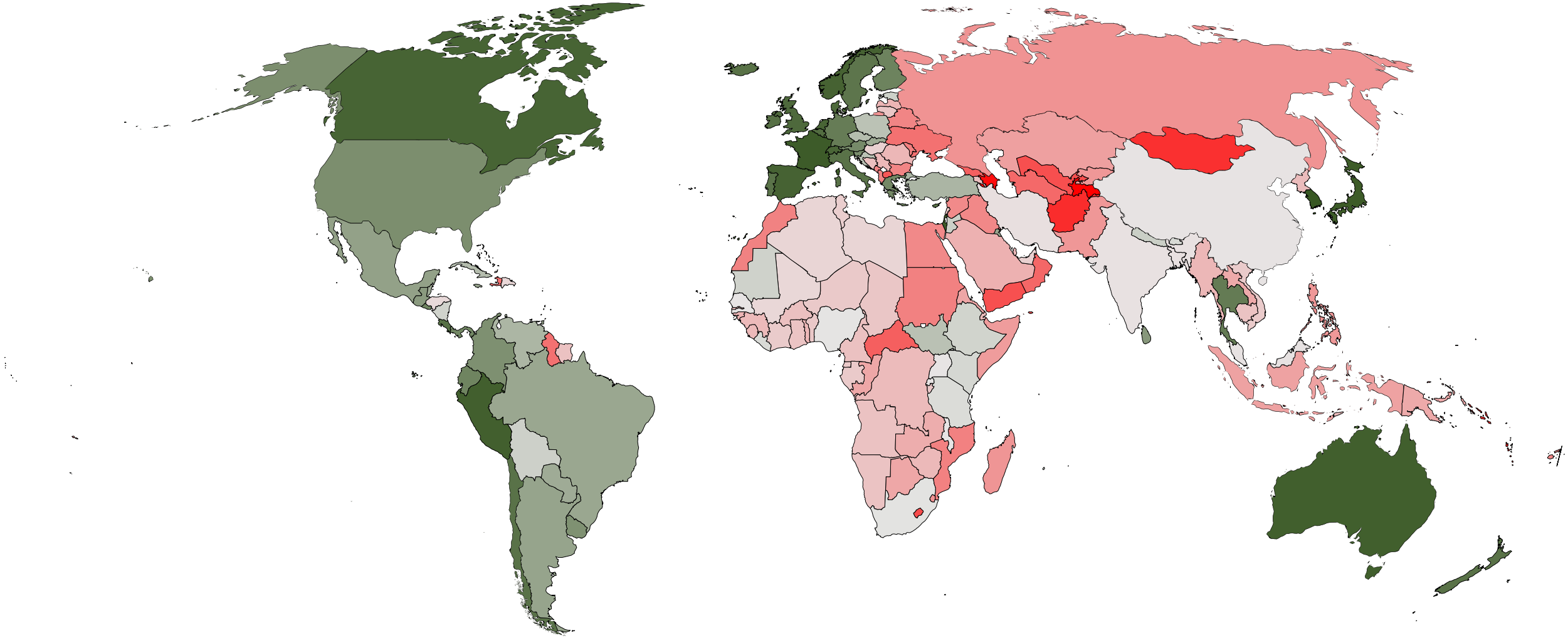
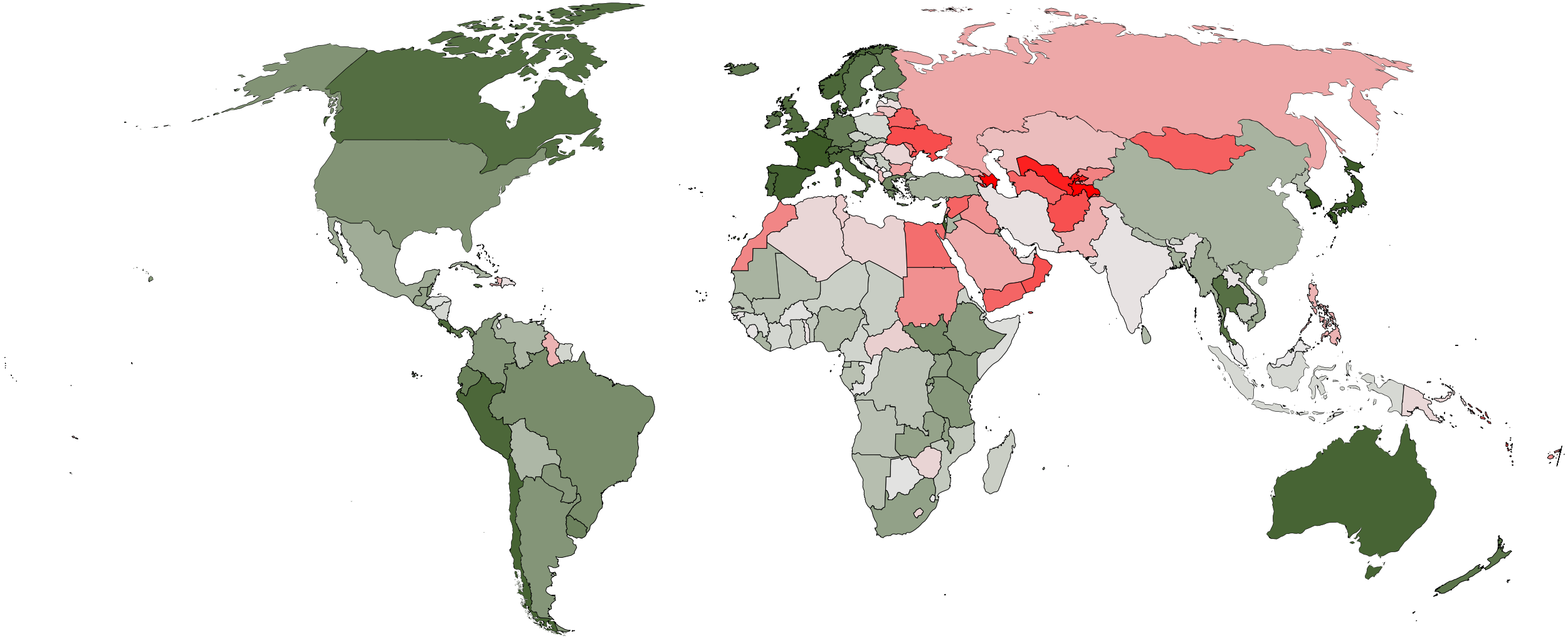
NCD Mortality per 100,000 population

234.8 1281.4

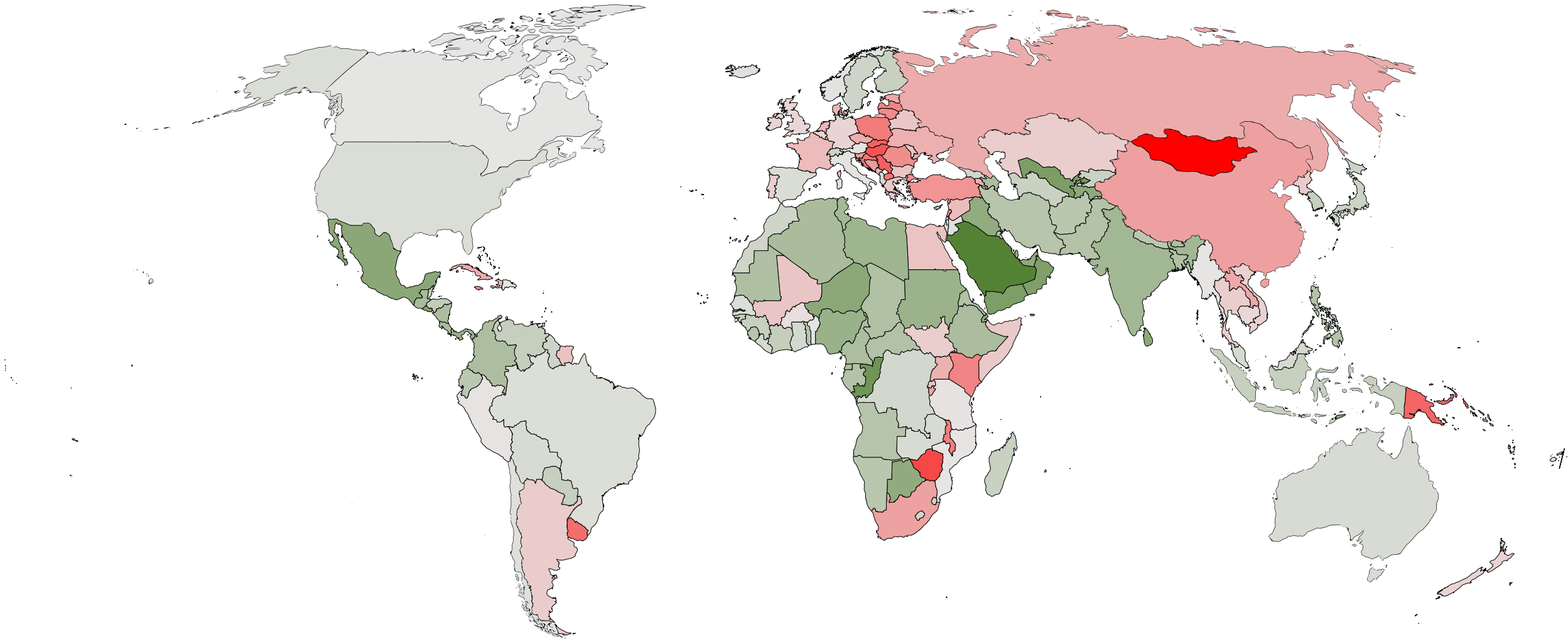
Age-Standardized Mortality from Cardiovascular Diseases (2019)



Age-Standardized Mortality from Ischaemic Heart Disease (2019)



Age-Standardized Mortality from Cancers (2019)



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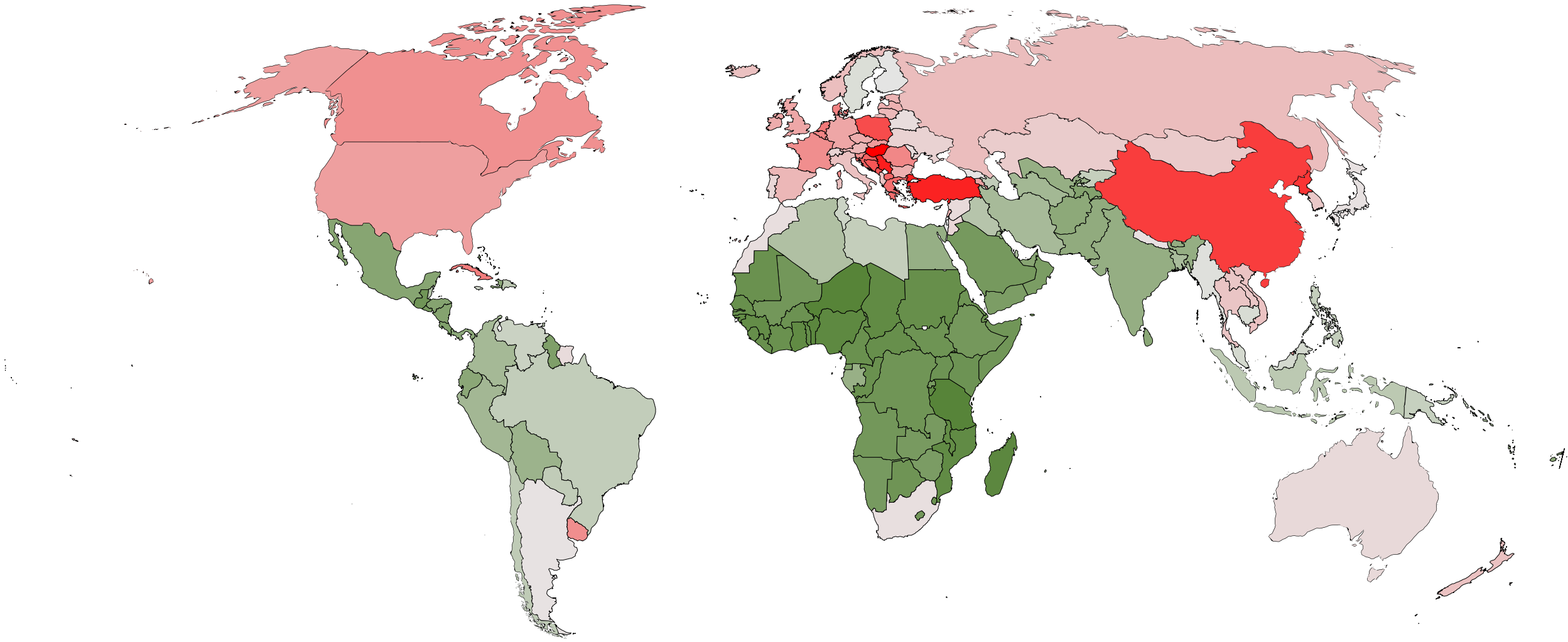
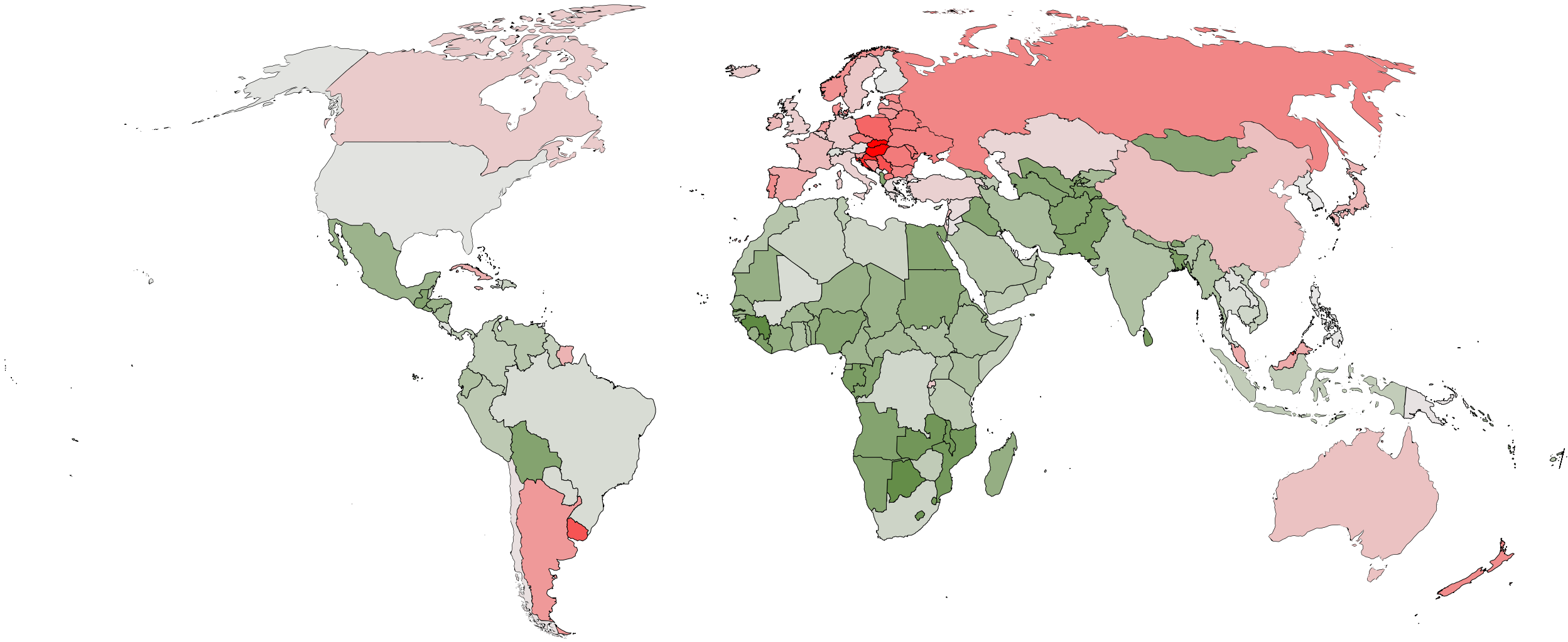
per 100,000 population

49.3 194.4

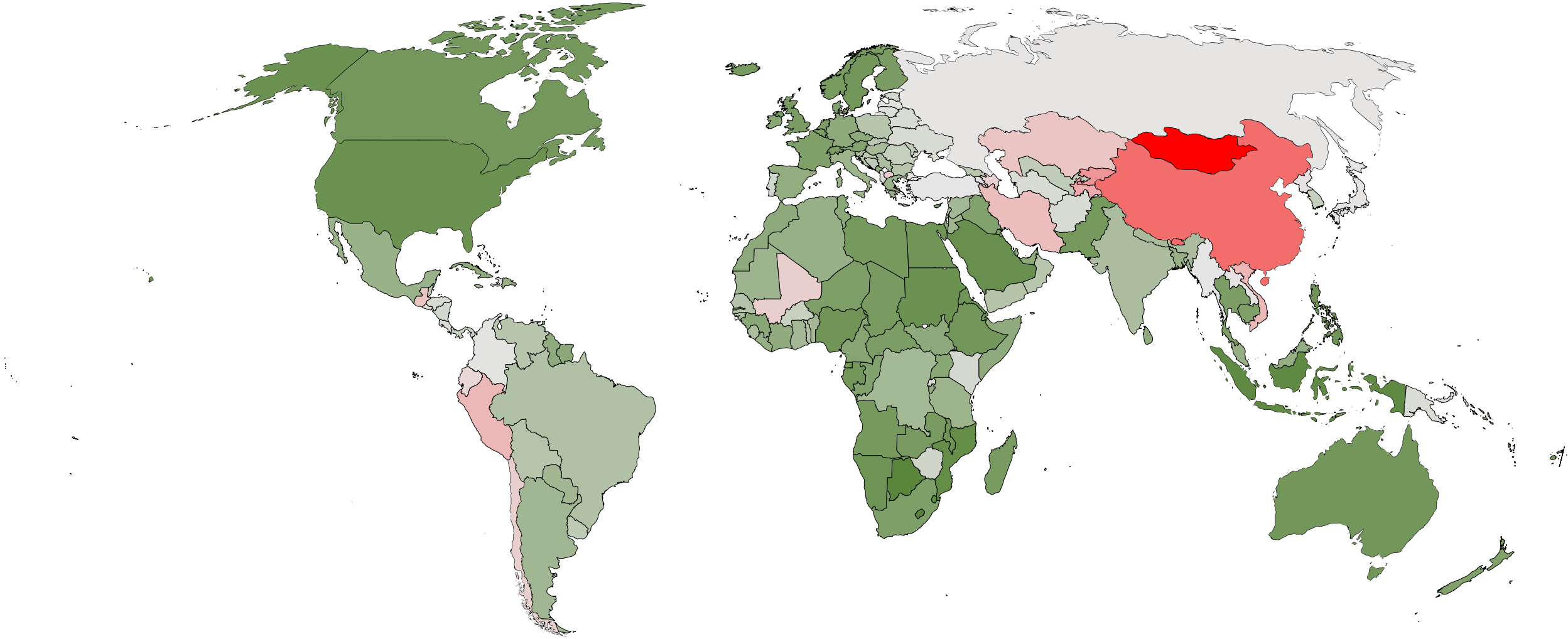
Age-Standardized Mortality from Lung Cancer (2019)



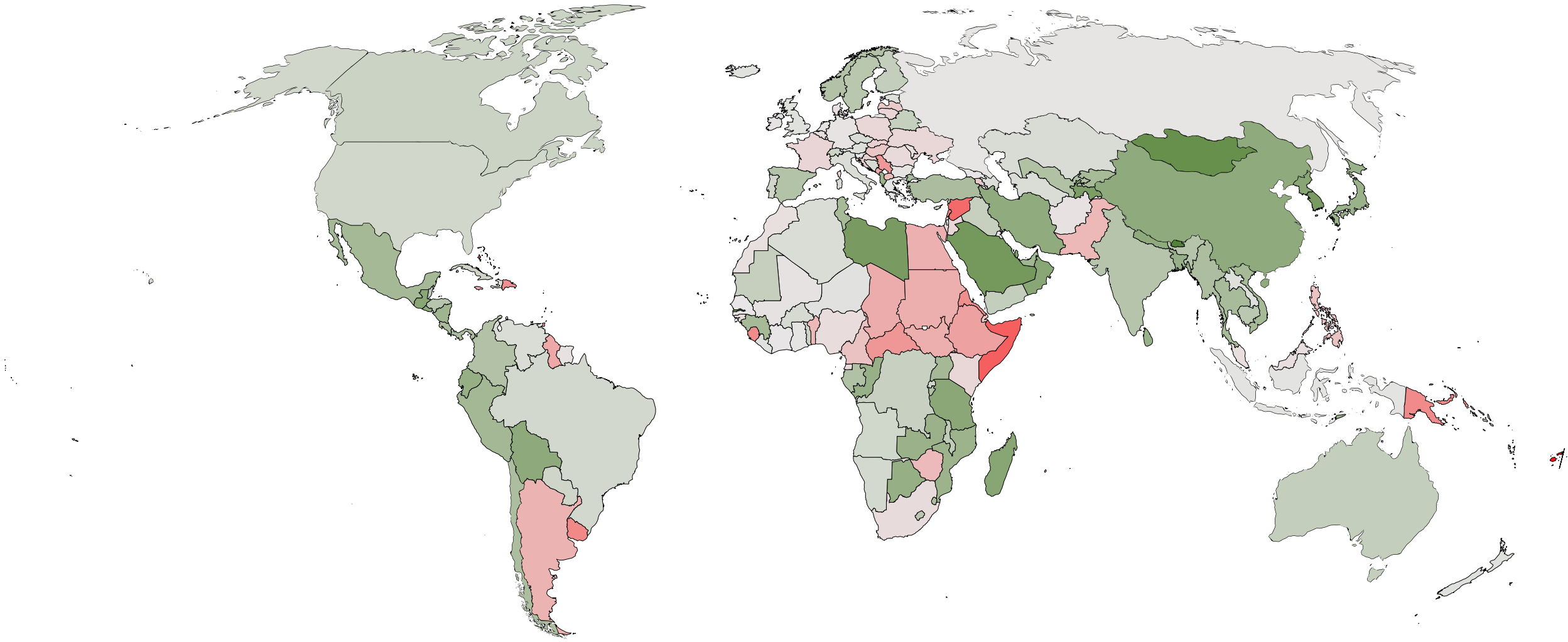
Age-Standardized Mortality from Colon Cancer (2019)



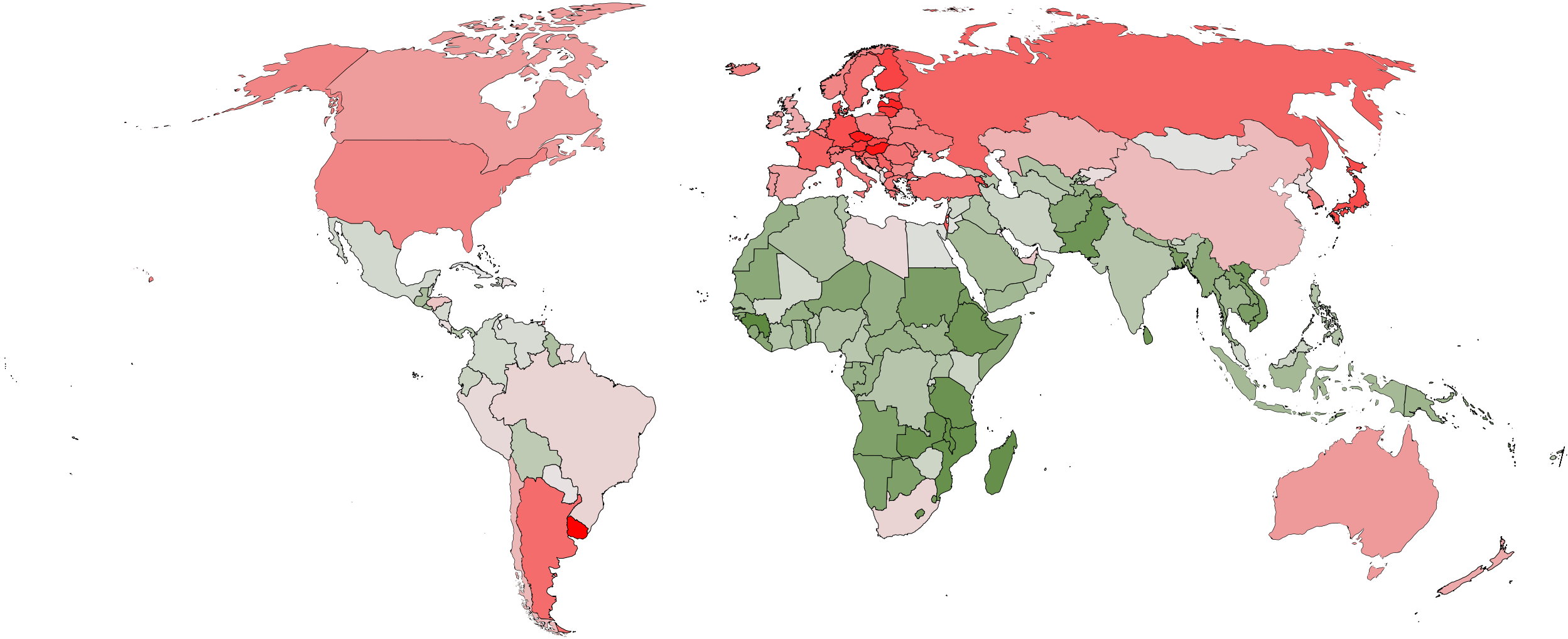
Age-Standardized Mortality from Stomach Cancer (2019)



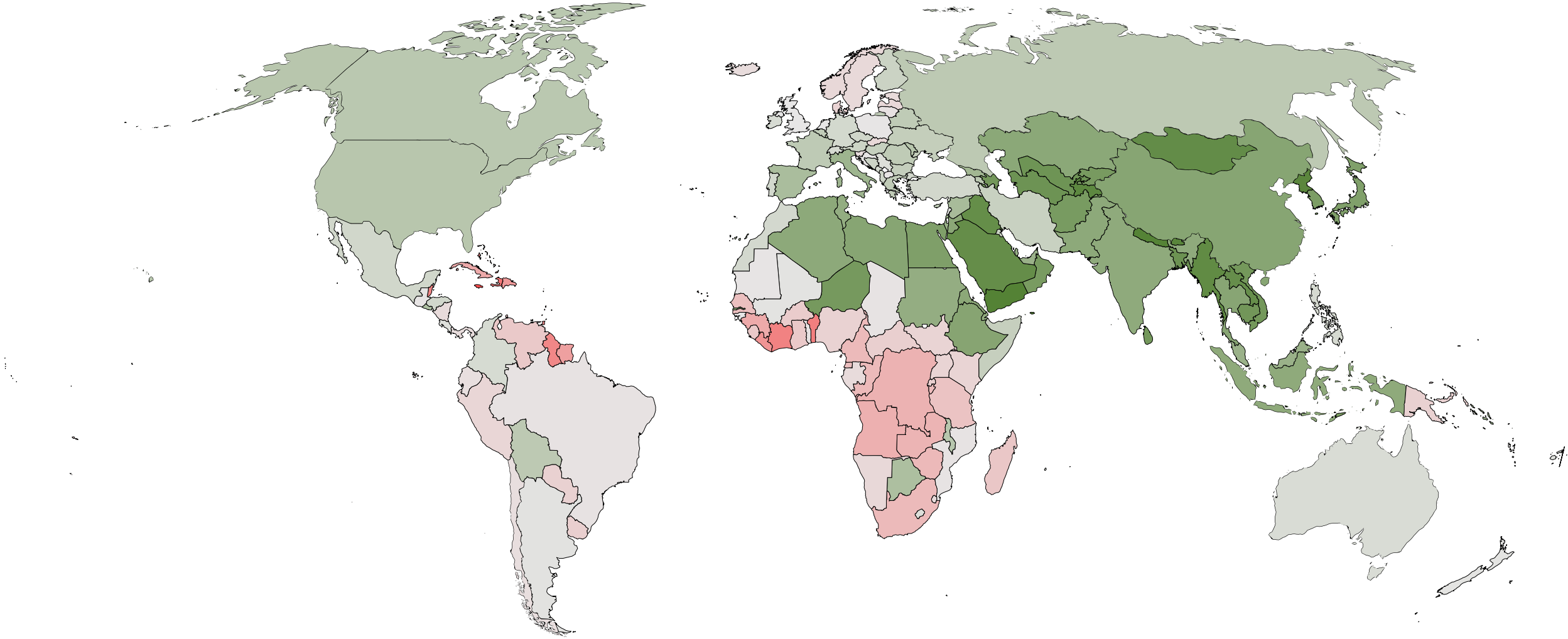
Age-Standardized Mortality from Breast Cancer (2019)



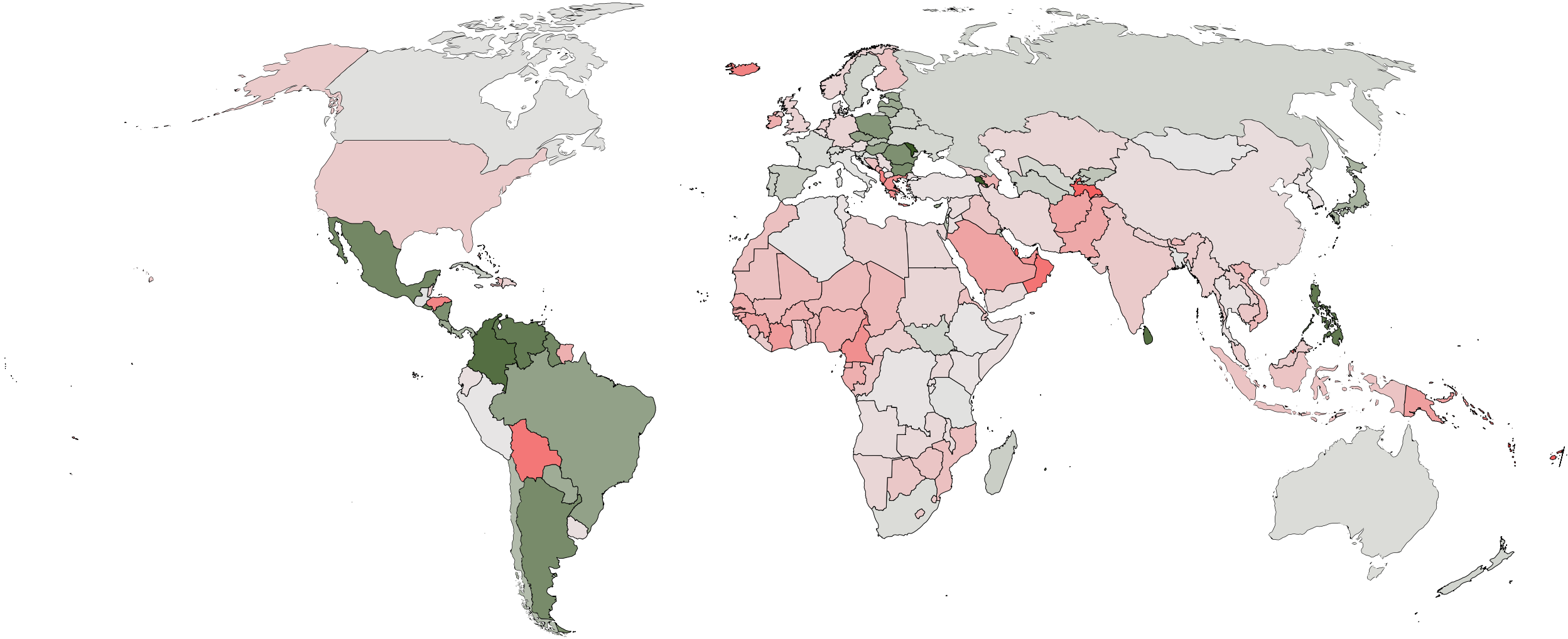
Age-Standardized Mortality from Pancreatic Cancer (2019)



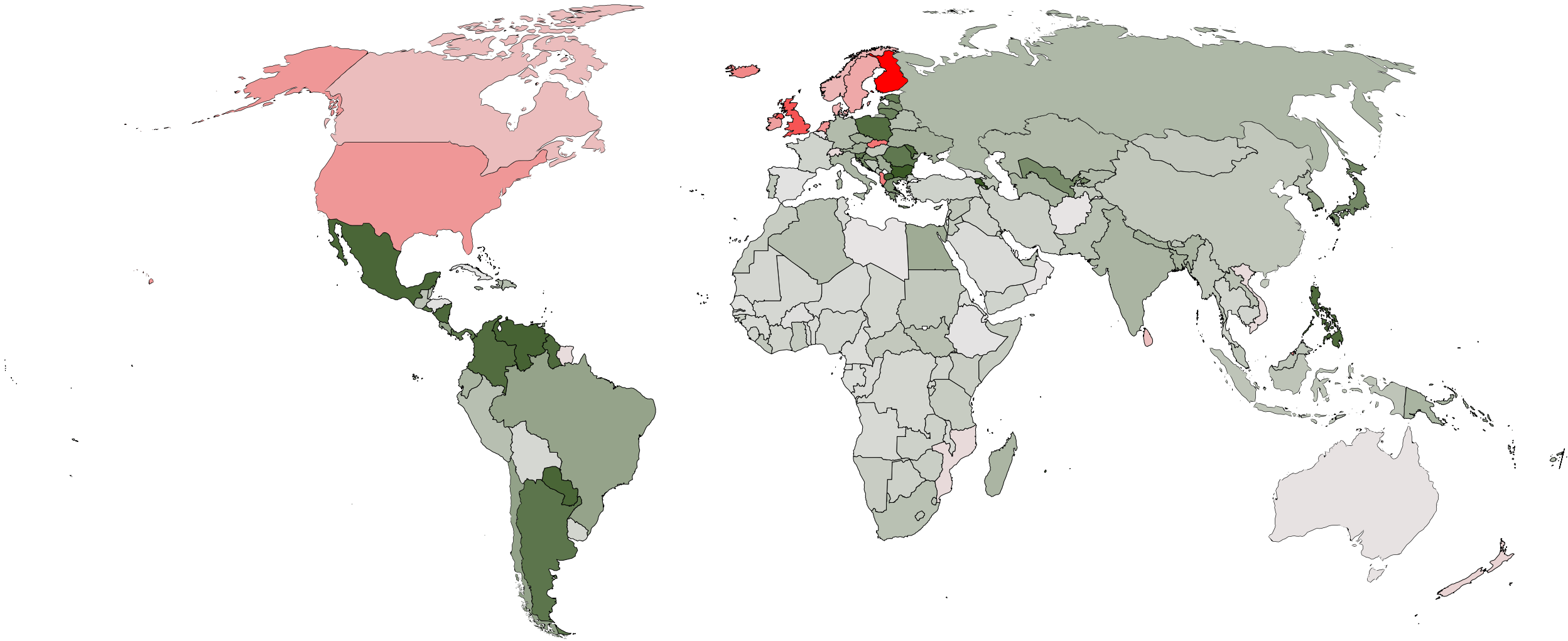
Age-Standardized Mortality from Prostate Cancer (2019)



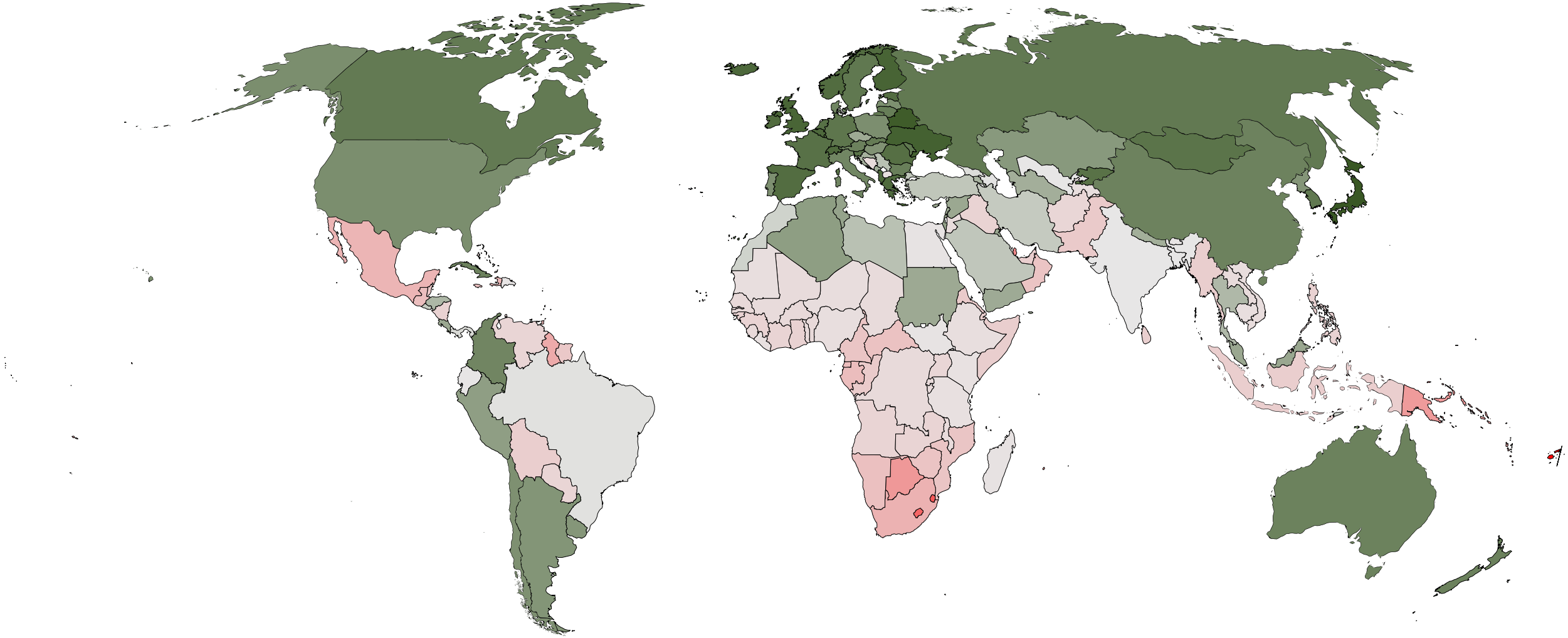
Age-Standardized Mortality from Parkinson's Disease (2019)



Age-Standardized Mortality from Dementia (2019)



Age-Standardized Mortality from Diabetes (2019)



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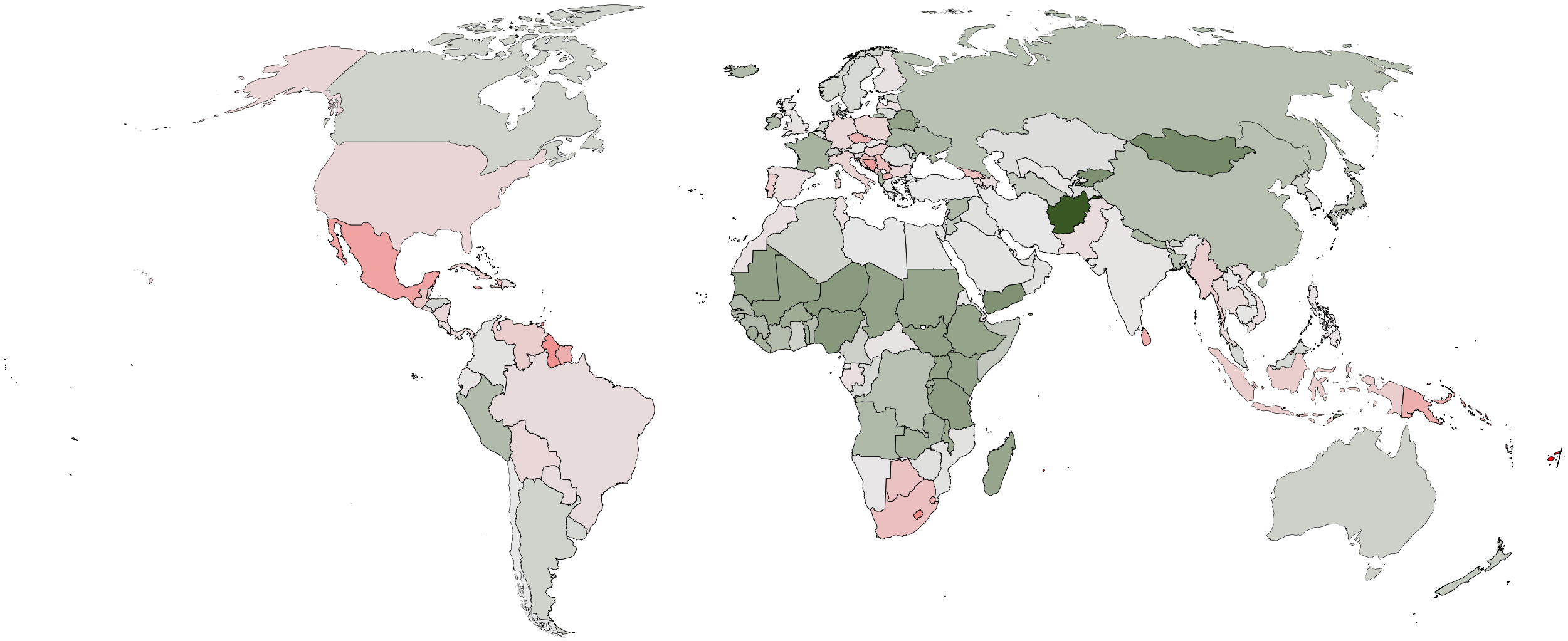
Mortality per 100,000 population

1.3 243.6

DALYs per capita from Diabetes (2019)



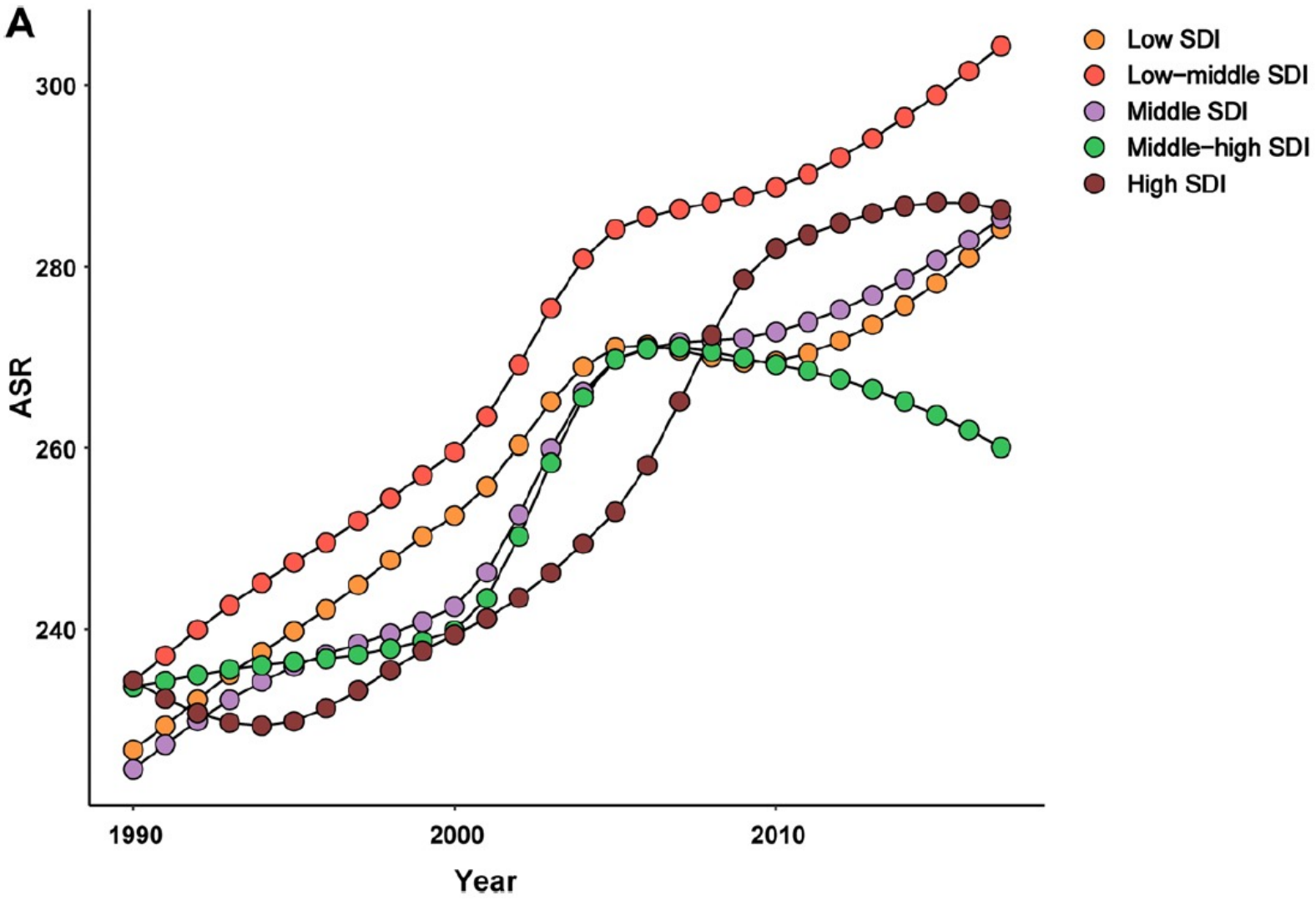


Fig. 1 The ASIR of diabetes mellitus caused by SDI regions, from 1990 to 2017. The data from five SDI regions are presented in the top-right panel. (ASIR, age-standardized incidence rate; SDI, socio-demographic index)

Global Health Crisis

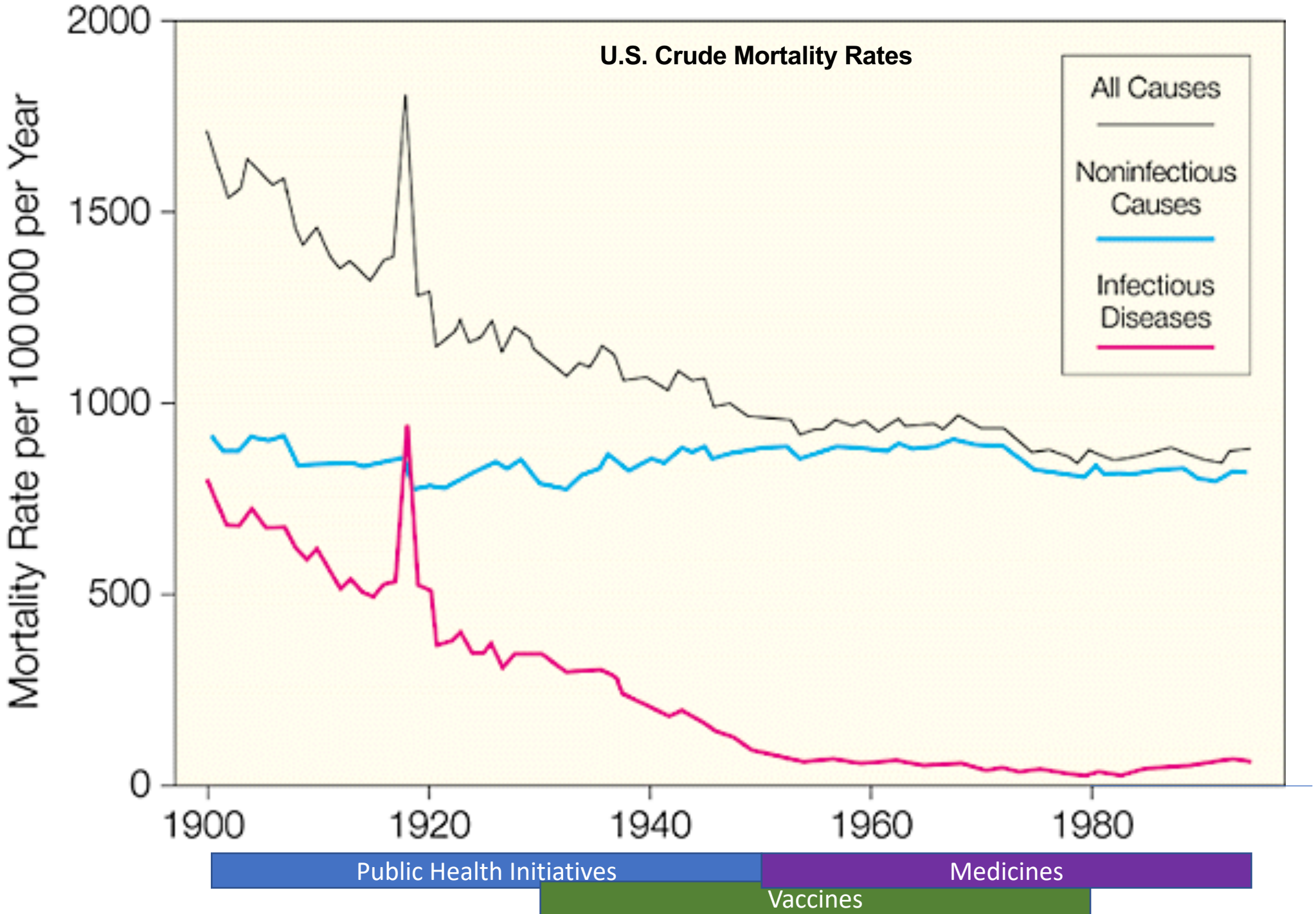
Most serious threats

- COVID and future pandemics
- Tuberculosis
- Malaria
- Parkinson's Disease
- Dementia
- Depression
- Diabetes

Greatest sources of inequality

- COVID and future pandemics
- Tuberculosis
- Malaria
- "Neglected diseases"
- HIV/AIDS
- Diarrhoeal Diseases
- Pneumonia
- Breast Cancer
- Prostate Cancer
- Diabetes

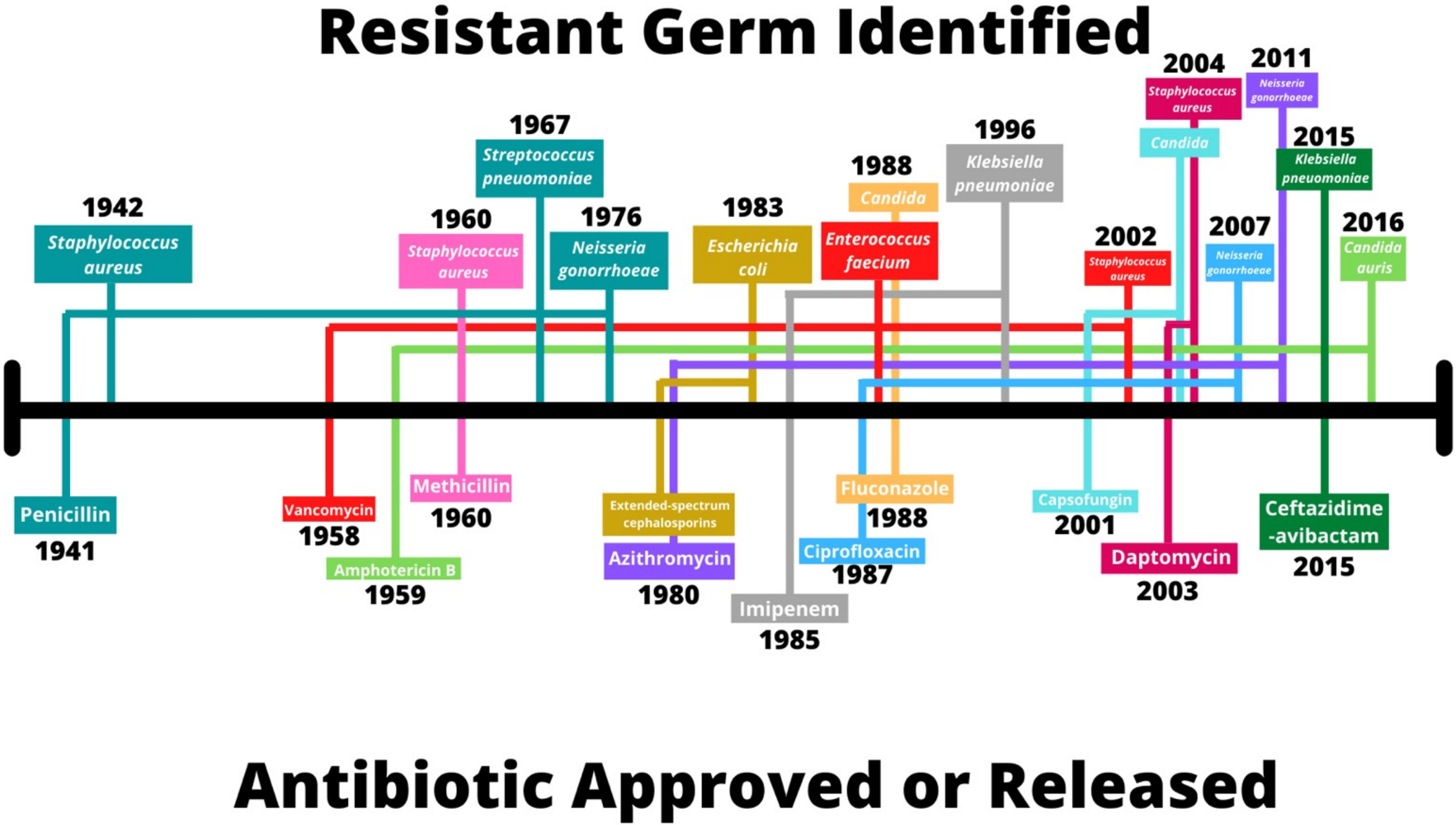
Part B:
The Roles of Pharmaceutical Products



Source: Armstrong, G. L. et al. JAMA 1999; 281:61-66

Major Vaccines in the U.S.

Disease	First Vaccine	Developed	First widely distributed in US
Tuberculosis	Bacillus Calmette-Guerin (BCG) vaccine	1921	1949
Diptheria	toxoid (inactivated toxin) vaccine	1923	mid-1940s
Pertussis ("Whooping Cough")	Whole-cell vaccine	1926	mid-1940s
Tetanus	toxoid (inactivated toxin) vaccine	1927	mid-1940s
Yellow Fever	17D vaccine	1932	1941
Influenza	Inactivated vaccine for types A and B	1942	mid-1940s
Polio	Salk inactivated vaccine	1952	late-1950s
Measles	Edmonston B strain live vaccine	1964	1974
Mumps	"Jeryl Lynn" strain	1967	1977
Rubella	Live non-human attenuated vaccines	1969	1970
Hepatitis B	Heptavax vaccine	1981	1980s
Varicella-zoster ("chicken pox")	Varivax	1984	1989
Haemophilus Influenzae type b	Bacterium capsular polysaccharide Hib vaccine	1985	1985
Rotavirus	Rotashield	1998	1998



Source: https://www.lgcstandards.com/GB/en/Resources/Blogs/Antibiotic_resistance

Public Health Initiatives in Developing Countries

- 71% of the global population now use what the WHO classifies as “safely managed drinking-water sources” (up from 52% in 1990)
- 37% of the populations in those countries now use “safely managed sanitation services.”
  - The only continent that lags is Africa, where the percentage of the population with safe drinking water is still only 26%. However, large amounts of development assistance (currently $2.4 billion per year) are currently being allocated to overcome this gap.

Vaccines in Developing Countries

Source: Source: Kristin VanderEnde et al., "Global Routine Vaccination Coverage — 2017," (2018), https://www.cdc.gov/mmwr/volumes/67/wr/mm6745a2.htm.

Vaccine	No. (%) countries with vaccine in schedule	Coverage* (%)						
		Global	African	Americas	Eastern Mediterranean	European	South-East Asia	Western Pacific
BCG	158 (81)	88	80	92	86	92	91	97
HepB BD	105 (54)	43	10	69	34	41	44	85
HepB3	188 (97)	84	72	90	81	82	88	93
DTP3	194 (100)	85	72	91	81	94	88	97
Hib3	191 (98)	72	72	91	81	76	86	28
Pol3	194 (100)	85	71	90	81	93	88	97
Rota_last	96 (49)	28	46	68	30	24	9	1
PCV3	139 (72)	44	68	82	52	70	12	16
MCV1	194 (100)	85	70	92	81	95	87	97
RCV1	162 (84)	52	26	92	46	95	21	97
MCV2	167 (86)	67	25	74	67	90	77	94

Abbreviations: BCG = Bacille Calmette-Guérin vaccine; DTP3 = third dose of diphtheria and tetanus toxoids and pertussis-containing vaccine; HepB BD = birth dose of hepatitis B vaccine; HepB3 = third dose of hepatitis B vaccine; Hib3 = third dose of *Haemophilus influenzae* type b vaccine; MCV1 = first dose of measles-containing vaccine; MCV2 = second dose of MCV; PCV3 = third dose of pneumococcal conjugate vaccine; Pol3 = third dose of polio vaccine; RCV1 = first dose of rubella-containing vaccine; Rota_last = final dose of rotavirus vaccine series (number of doses to complete the series varies among vaccine products).

(thousands)	Global Deaths	Global DALYs
HIV/AIDS	675	40147
Tuberculosis*	1208	66024
Malaria*	411	33398
STDs (excluding HIV/AIDS)		
Syphilis	43	3814
Chlamydia	1	324
Gonorrhoea	2	231
Trichomoniasis	0	282
Genital herpes	0	250
Other STDs	3	352
Diarrhoeal Diseases	1519	79311
Childhood Diseases		
Pertussis ("whooping cough")	111	9839
Diphtheria	5	420
Measles	165	14528
Tetanus	47	3474
Meningitis	233	16314
Encephalitis	78	4174
Hepatitis		
A	40	2102
B	36	1633
C	22	655
E	2	123

(thousands)	Global Deaths	Global DALYs
Parasitic and vector diseases (excluding Malaria)		
Trypanosomiasis*	2	102
Chagas*	8	217
Schistosomiasis	12	1628
Leishmaniasis*	6	722
Lymphatic filariasis (elephantiasis)	0	1616
Onchocerciasis (river blindness)	0	1210
Cysticercosis	7	988
Echinococcosis	9	461
Dengue	30	1952
Trachoma (infectious blindness)	0	194
Yellow fever	6	413
Rabies	47	2634
Intestinal nematode infections		
Ascariasis	2	749
Trichuriasis	0	232
Hookworm	0	962
Food-bourne trematodes	7	805
Leprosy	13	36
Other infectious diseases	370	19000
Totals	5101	311318

94.9% of 2002 revenue of U.S. pharmaceutical companies

5.1% of 2002 revenue of U.S. pharmaceutical companies

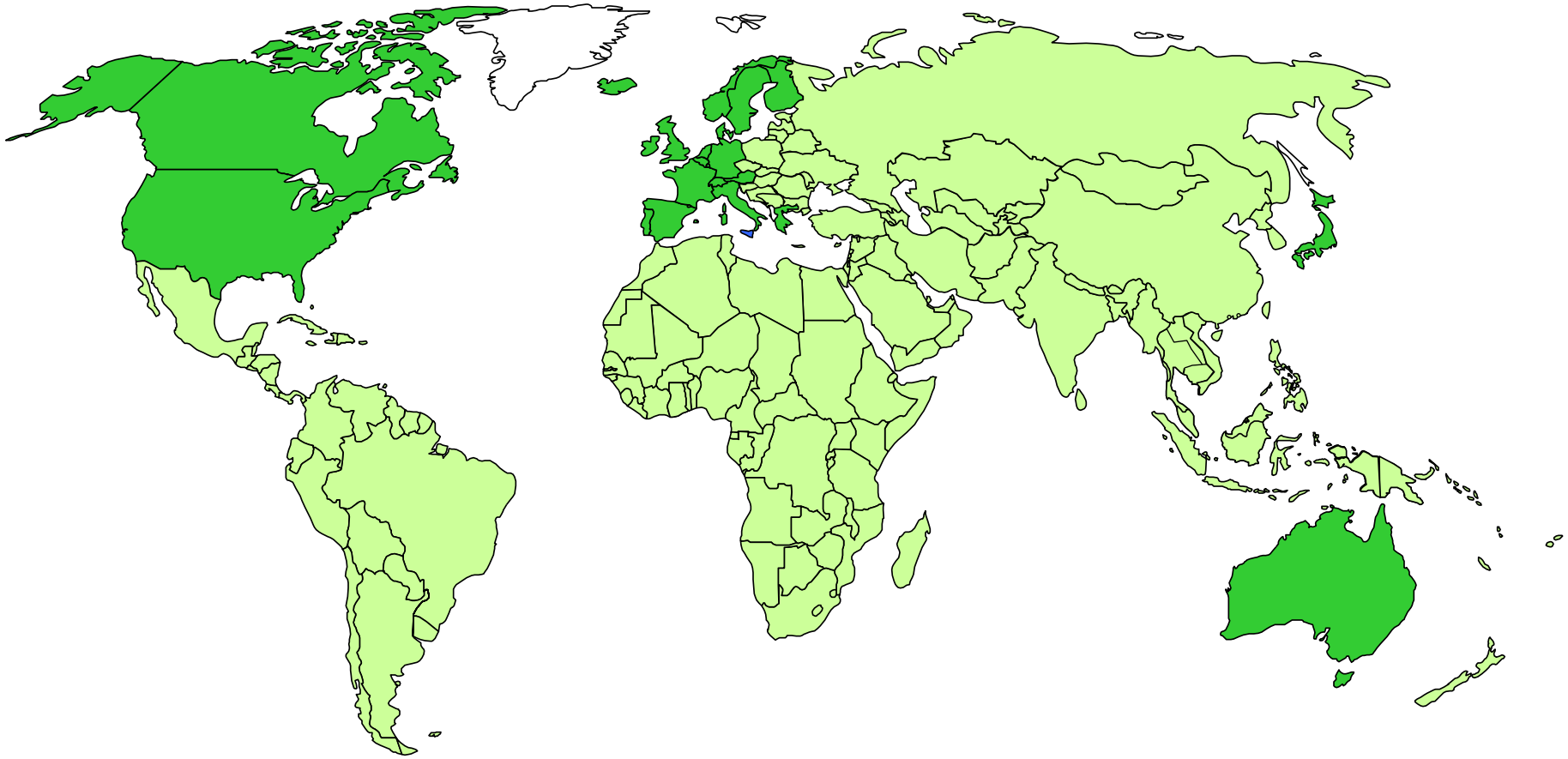
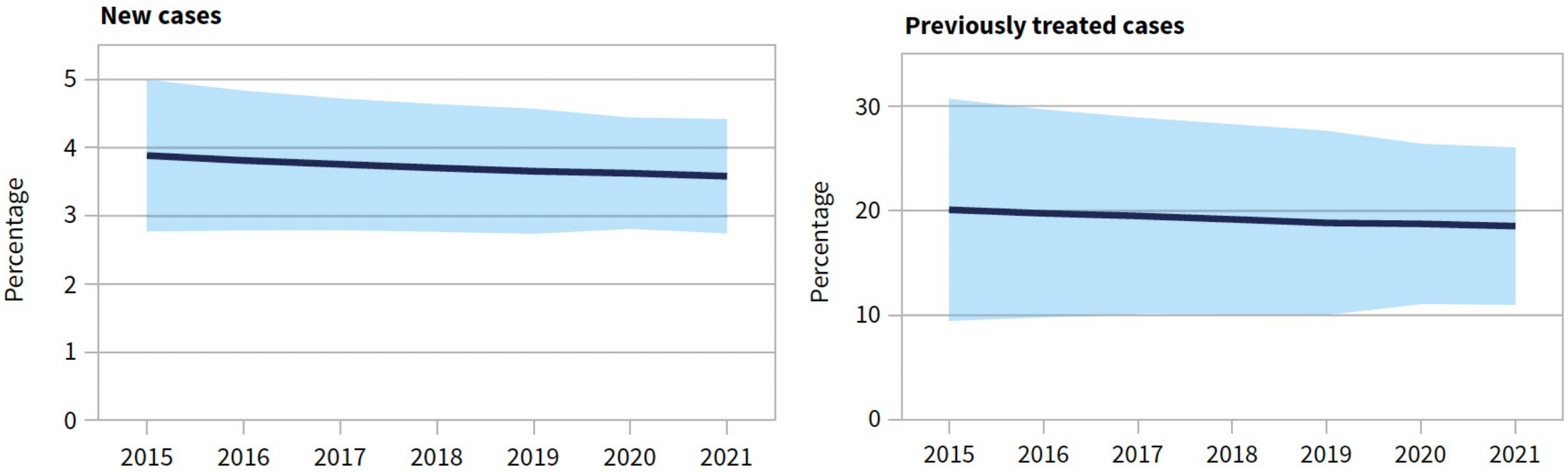


FIG. 16

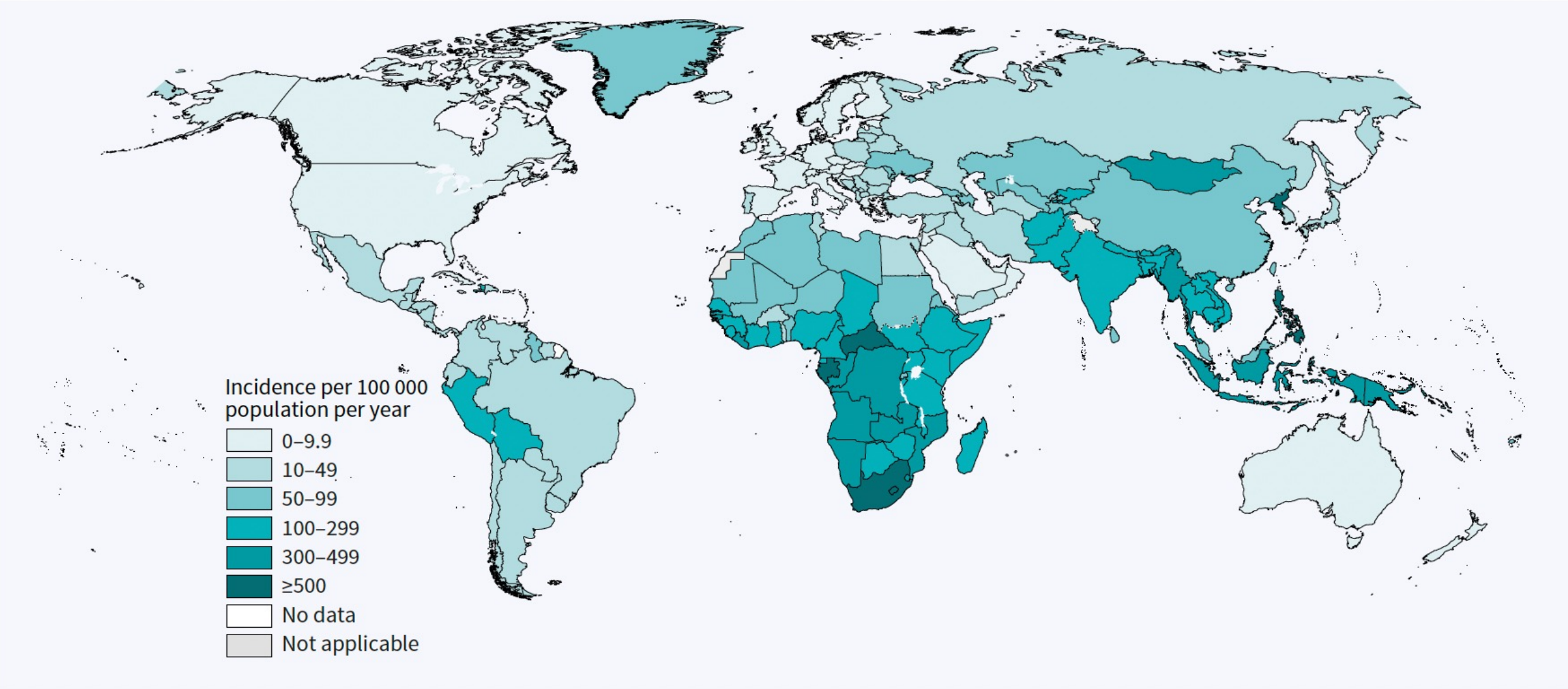
Global percentage of TB cases estimated to have MDR/RR-TB, 2015–2021

Shaded areas represent 95% uncertainty intervals.



Source: World Health Organization, Global TB Report (2022)

Estimated TB incidence rates, 2021

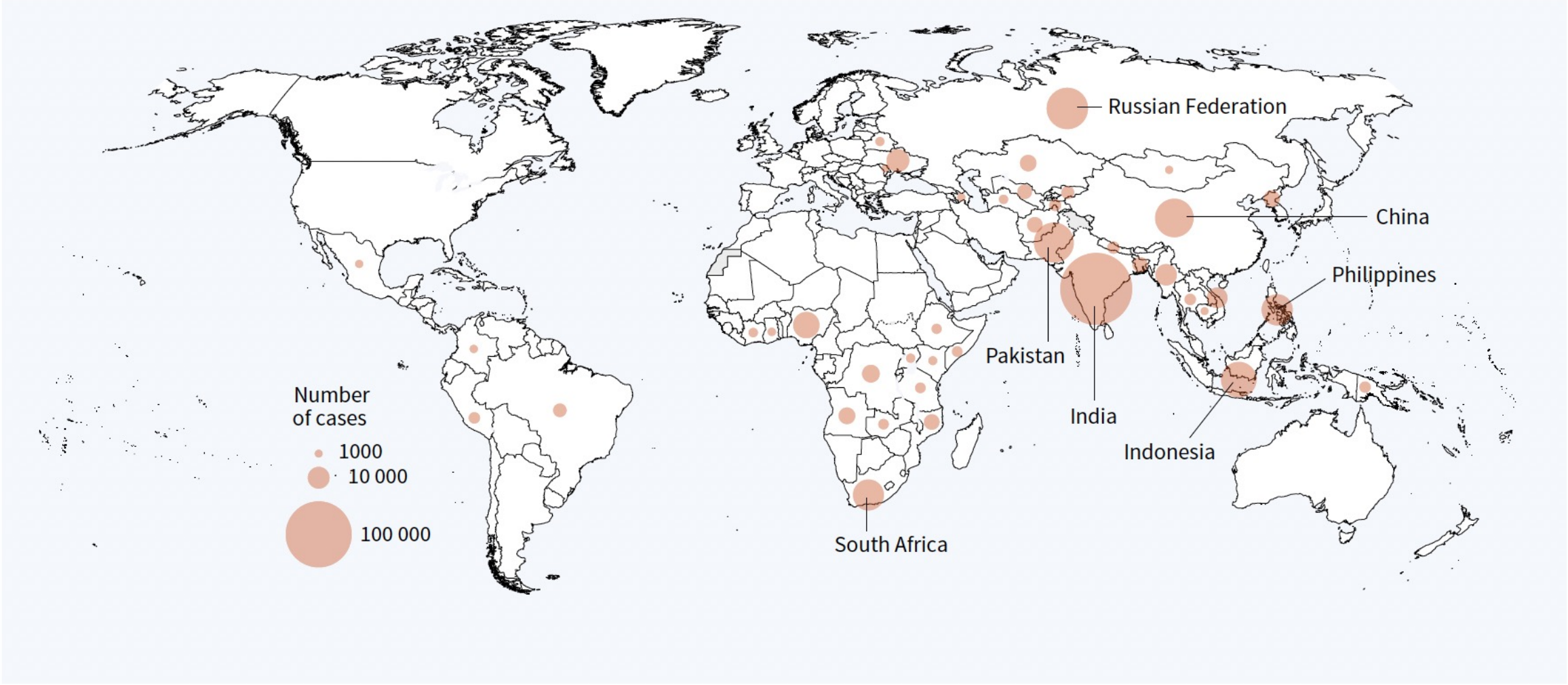


Source: World Health Organization, Global TB Report (2022)

FIG. 17

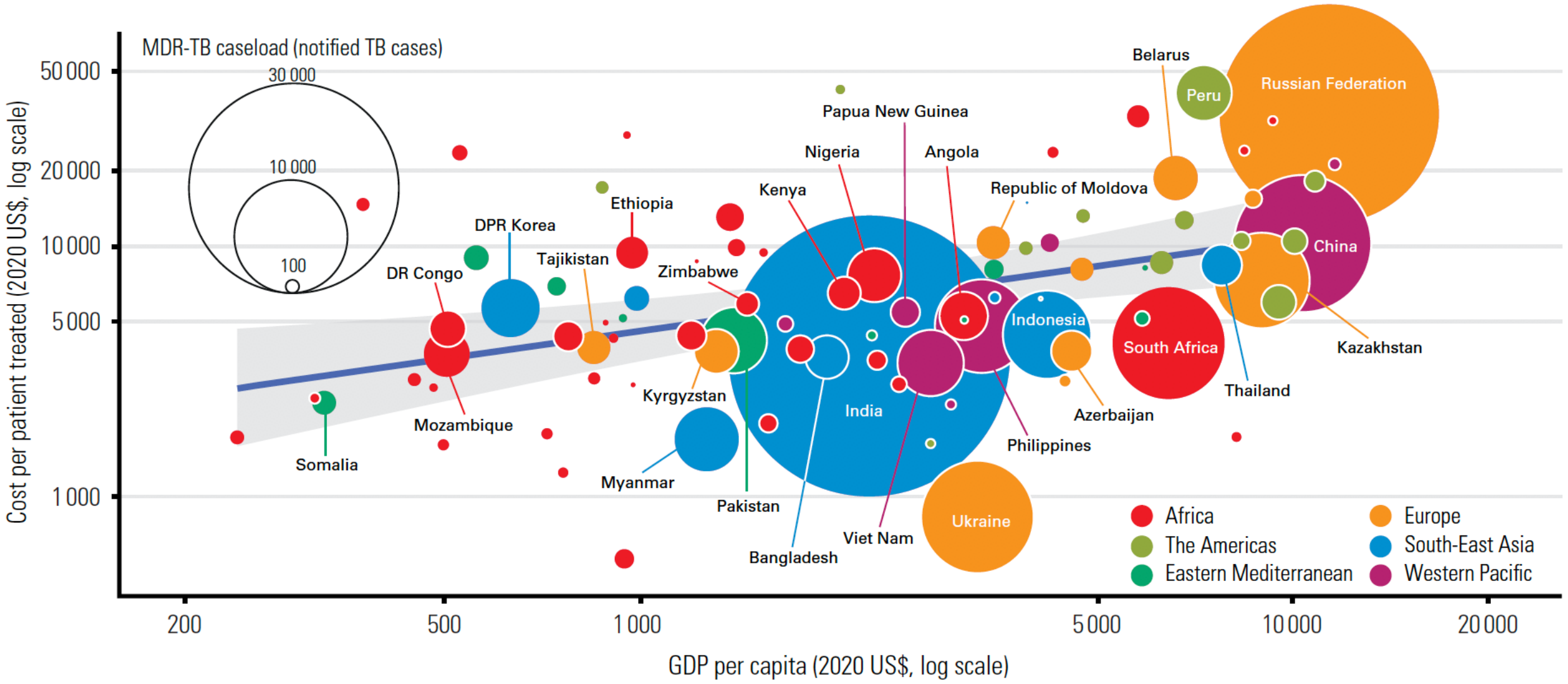
Estimated incidence of MDR/RR-TB in 2021, for countries with at least 1000 incident cases

The seven countries with the highest burden in terms of numbers of MDR/RR-TB cases, and that accounted for two thirds of global MDR/RR-TB cases in 2021, are labelled.



Source: World Health Organization, Global TB Report (2022)

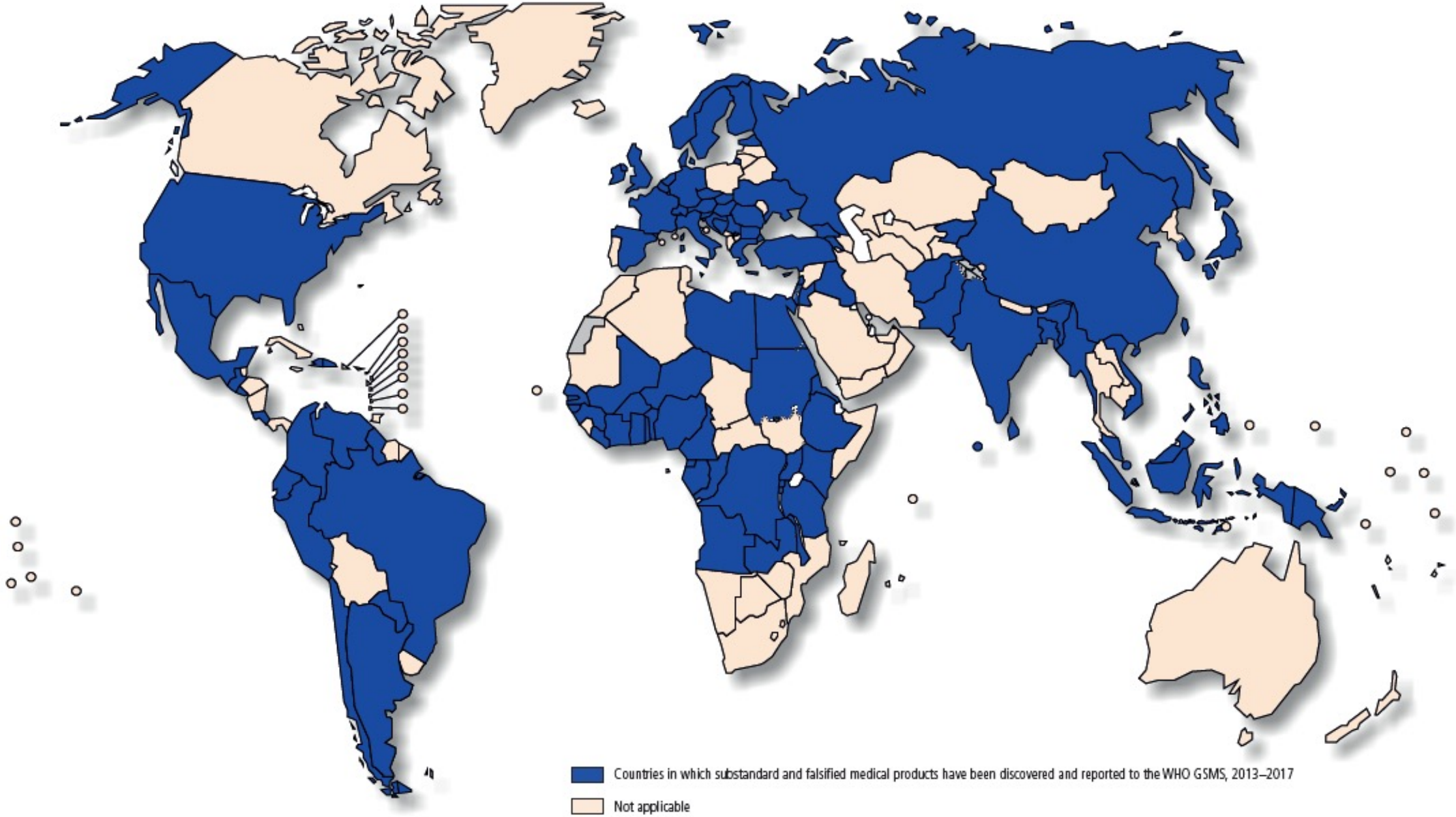
Estimated cost per patient treated for MDR-TB in 89 countries,[a] 2019



Affordability

- TB:
  - Roughly 3.5% of the 9 million new cases of active tuberculosis reported each year involve variants of the disease that are resistant to the standard course of antibiotics. Patients who contract those variants require special treatments – so-called DR-TB drugs. Whereas the costs of the standard TB treatments are now modest, the cost of a DR-TB regimen is not.
- AIDS:
  - First-generation ARVs are now affordable and reasonably available in most developing countries. However, second-generation ARVs are substantially more expensive, and the prices of third-generation drugs are higher still.
  - See Frontline AIDS, "The Problem with Patents: Access to Affordable Hiv Treatment in Middle-Income Countries," (2019), 6. (reporting that "The lowest prices (ppy) for third-line drugs that are widely patented were $664 ppy for darunavir, $439 for etravirine and $553 for raltegravir; the lowest combined prices were still in excess of $1500.
  - Outside sub-Saharan Africa, median prices for darunavir were $5180.
  - For salvage therapy (when standard treatment options no longer work), countries reported paying $6072 for tipranavir, $5190 for maraviroc and $17,700 for enfuvirtide."); Ellen 't Hoen et al., "Driving a Decade of Change: Hiv/Aids, Patents and Access to Medicine for All," *Journal of the International AIDS Society* 14, no. 15 (2011).
- Infections:
  - A simple course of antibiotics can cost in developing country more than the average resident earns in a month.

FIG. 1: COUNTRIES IN WHICH SUBSTANDARD AND FALSIFIED MEDICAL PRODUCTS HAVE BEEN DISCOVERED AND REPORTED TO THE WHO GSMS, 2013–2017



	Location	Date of sample collection	Drug tested	Method of testing	Obtained from	Sampling technique	Total samples tested	Samples that failed testing		Falsified*
								Chemical assay analysis	Packaging tests	
Southeast Asia										
Newton et al (2001)[9]	Cambodia, Laos, Myanmar (Burma), Thailand, Vietnam	1999–2000	Artesunate	HPLC, colorimetric testing (fast red dye), packaging analysis	Private pharmacies and outlets	Convenience	104	39/104 (38%)†	31/84 (38%)	39/104 (38%)
Newton et al (2008)[25]	Cambodia, Laos, Myanmar, Thailand-Myanmar border, Vietnam	1999–2005	Artesunate	HPLC, colorimetric testing (fast red dye), packaging analysis	Private pharmacies and outlets	Convenience and randomly‡	391	196/391 (50%)	195/391 (50%)	195/391 (50%)
Dondorp et al (2004)[26]	Cambodia, Laos, Myanmar, Thailand, Vietnam	2002–03	Artesunate, artemether, dihydroartemisinin, mefloquine	HPLC, colorimetric testing (fast red dye), packaging analysis	Public and private pharmacies and outlets and facilities	Convenience	303	103/303 (34%); 99/103 (96)†	99/303 (33%)	99/303 (33%)
Lon et al (2006)[27]	Cambodia	2003	Artesunate, quinine, chloroquine, tetracycline, mefloquine	HPLC, thin-layer chromatography, packaging analysis, disintegration analysis	Public and private pharmacies, and outlets and facilities	Convenience	451	122/451 (27%); 30/122 (25%)†	72/111 (65%)	88/111 (79%)§
Sengaloundeth et al (2009)[28]	Laos	2003	Artesunate	HPLC, colorimetric testing (fast red dye), mass spectroscopy, pollen analysis, X-ray diffraction, packaging analysis	Private pharmacies and outlets	Stratified random sampling	30	27/30 (90%)	26/30 (87%)	27/30 (90%)
United States Pharmacopeia (2004)[29]	China	2004	Artesunate, quinine, chloroquine, sulfadoxine-pyrimethamine, mefloquine	HPLC, thin-layer chromatography, visual inspection, dissolution analysis	NS	Convenience	39	2/39 (5%)†	Not tested	2 (5%)
Bate et al (2009)[30]	India	2008–09	Chloroquine	Thin-layer chromatography, disintegration analysis	Private pharmacies and outlets	Systematic random sampling	119	8/119 (7%)	Not tested	NA

(Continues on next page)

Source: Nayyar et al., "Poor-quality antimalarial drugs in southeast Asia and sub-Saharan Africa," 12 *Lancet Infectious Diseases* 488 (2012)

	Location	Date of sample collection	Drug tested	Method of testing	Obtained from	Sampling technique	Total samples tested	Samples that failed testing		Falsified*
								Chemical assay analysis	Packaging tests	
(Continued from previous page)										
Sub-Saharan Africa										
Ogwal-Okeng JO et al (2003)[31]	Uganda	2001	Chloroquine tablets and injections	HPLC	Private and public outlets	Convenience	92	57/92 (62%)	Not tested	NA
Basco et al (2004)[10]	Cameroon	2001	Chloroquine, quinine, sulfadoxine-pyrimethamine	Colorimetric test, thin-layer chromatography	Private pharmacies only	Convenience sampling from various vendors	284	112/284 (39%)	Not tested	49/284 (18%)
Amin et al (2005)[32]	Kenya	2002	Sulfadoxine-pyrimethamine, amodiaquine	HPLC, dissolution tests	Public and private outlets	Convenience	116	47/116 (41%)	Not tested	NA
Thoithi et al (2008)[33]	Kenya	2001–05	Artemether, dihydroartemisinin, quinine, sulfadoxine-pyrimethamine, amodiaquine	Tests of uniformity of weight, content of active pharmaceutical ingredient, dissolution	Public and private outlets	Convenience	41	11/41 (27%)	Not tested	NA
Atemnkeng et al (2007)[34]	Kenya and Democratic Republic of Congo	2004	Artemether, arteether, artesunate, dihydroartemisinin	HPLC with European pharmacopeia standards	Randomly, from both public and private pharmacies or outlets	Convenience sampling of different forms of drug	24	9/24 (38%)	Not tested	NA
Tipke et al (2008)[35]	Burkina Faso	2006	Artesunate, artemether lumefantrine, quinine, chloroquine, sulfadoxine-pyrimethamine, amodiaquine	Packaging analysis, disintegration analysis, colorimetric tests, thin-layer chromatography, ultraviolet-visible spectroscopy	Private and public pharmacies or outlets	Convenience	77	32/77 (42%); 1/32 (3%)†	28/77 (38%)	29/77 (38%)

Source: Nayyar et al., "Poor-quality antimalarial drugs in southeast Asia and sub-Saharan Africa," 12 *Lancet Infectious Diseases* 488 (2012)

US pharmacopeia (2009)[36]	Madagascar, Senegal, Uganda	2008	Artermisinin-combination treatment, sulfadoxine-pyrimethamine	Compendial quality testing according to US pharmacopeia standards	Private and public pharmacies and outlets	Convenience	197	64/197 (32%)	Not tested	NA
WHO (2011)[37]	Ghana, Kenya, Nigeria, Tanzania, Ethiopia, Cameroon	2008	Artermisinin-combination treatment, sulfadoxine-pyrimethamine	Compendial quality testing according to US pharmacopeia standards	Public and private outlets	Convenience	267	72/267 (27%)	Not tested	NA
Kibwage (2005)[38]	Kenya	Not provided	Sulfadoxine-pyrimethamine	Dissolution analysis	Public and private outlets	Convenience	33	23/33 (69%)	Not tested	NA
Jande et al (2006)[39]	Tanzania	Not provided	Sulfadoxine-pyrimethamine	Dissolution analysis	Public and private outlets	Convenience	9	5/9 (55%)	Not tested	NA
Taylor et al (2001)[40]	Nigeria	Not provided	Quinine, choroquine, sulfadoxine-pyrimethamine, proguanil	HPLC with British pharmacopeia, dissolution analysis	Private and public pharmacies and outlets	Random	284	119/284 (42%)	Not tested	NA
Smine et al (2002)[41]	Senegal	Not provided	Choroquine, sulfadoxine-pyrimethamine	US pharmacopeia standards for active pharmaceutical ingredient testing	Public and private outlets	Random	27	15/27 (56%)	Not tested	NA
Minzi et al (2003)[42]	Tanzania	Not provided	Sulfadoxine-pyrimethamine, amodiaquine	HPLC, dissolution tests	Public and private outlets	Convenience	33	10/33 (30%)	Not tested	NA
Maponga et al (2003)[43]	Gabon, Ghana, Kenya, Mali, Mozambique, Sudan, Zimbabwe	Not provided	Choroquine, sulfadoxine-pyrimethamine	HPLC, dissolution analysis, drug-specific assays	Private and public pharmacies and outlets	Convenience	278	5–100%¶	Not tested	NA
Gaudiano et al (2007)[44]	Congo, Burundi, Angola	Not provided	Quinine, choroquine, sulfadoxine-pyrimethamine, mefloquine	HPLC with US pharmacopeia standards, uniformity of mass, disintegration analysis	Mainly small, private pharmacies and outlets	Convenience	28	16/28 (57%); 1/16 (6%)†	Not tested	1/28 (4%)
Aina et al (2007)[45]	Nigeria	Not provided	Choroquine tablets, syrups, and injections	British pharmacopeia dissolution tests, active pharmaceutical ingredient assay, disintegration tests	Public outlet	Convenience	32	19/32 (59%)	Not tested	NA

(Continues on next page)

Source: Nayyar et al., "Poor-quality antimalarial drugs in southeast Asia and sub-Saharan Africa," 12 *Lancet Infectious Diseases* 488 (2012)

	Location	Date of sample collection	Drug tested	Method of testing	Obtained from	Sampling technique	Total samples tested	Samples that failed testing		Falsified*
								Chemical assay analysis	Packaging tests	
(Continued from previous page)										
Kaur et al (2008)[46]	Tanzania	Not provided	Artemisinins, quinine, antifolates, sulfadoxine-pyrimethamine, amodiaquine	HPLC and dissolution analysis with US pharmacopeia standards	Private and public pharmacies and outlets	Random	301	38/301 (12%)	Not tested	NA
Bate et al (2008)[47]	Ghana, Kenya, Nigeria, Rwanda, Tanzania, Uganda	Not provided	Artesunate, artemether, dihydroartemisinin, artemether-lumefantrine, sulfadoxine-pyrimethamine, mefloquine, amodiaquine	Thin-layer chromatography or dissolution analysis	Private pharmacies and outlets	Convenience	210	73/210 (35%)	Not tested	NA
Ofori-Kwakye et al (2008)[48]	Ghana	Not provided	Artesunate	Colorimetric tests, disintegration tests, EU pharmacopeia standards	Public and private outlets	Convenience	17	14/17 (82%)	Not tested	NA
Onwujekwe et al (2009)[49]	Nigeria	Not provided	Artesunate, dihydroartemisinin, chloroquine, quinine, sulfadoxine-pyrimethamine	HPLC and dissolution analysis with US pharmacopeia standards	Private and public pharmacies and outlets	Stratified random sampling	225	60/225 (27%)	Not tested	NA
Newton et al (2011)[8]	Burkina Faso, Chad, Cameroon, DR Congo, Ghana, Kenya, Nigeria, Rwanda, Senegal	2002-2010	Artesunate, dihydroartemisinin, dihydroartemisinin-piperaquine artemether-lumefantrine, artemether-amodiaquine, amodiaquine, halofantrine	HPLC, mass spectroscopy, pollen analysis, X-ray diffraction, packaging analysis	Pharmaceutical companies, private and public pharmacies	Convenience	59	35/59 (59%); 11/35 (31%)*¶	26/36 (72%)	14/59 (24%)

Data are n/N (%), unless otherwise indicated. Samples failing chemical assay analysis might have failed packaging analysis. HPLC=High-perfomance liquid chromatography. NS=not specified. NA=not applicable. *Falsified is used as a synonym for counterfeit. †Samples with no active pharmaceutical ingredient. ‡115 samples from Laos were randomly selected. §Only tetracycline, quinine, and artesunate were tested. ¶Varies substantially by drug and country; not included in analysis.

Table: **Reports of poor-quality antimalarial drugs by region in southeast Asia and sub-Saharan Africa, 1999–2011**

Source: Nayyar et al., "Poor-quality antimalarial drugs in southeast Asia and sub-Saharan Africa," 12 *Lancet Infectious Diseases* 488 (2012)

Source: "Post-marketing surveillance of anti-malarial medicines used in Malawi," Ibrahim Chikowe et al., Malaria Journal (2015) 14:127

Anti-malarial sample	Number of samples	Level of compliance of API content			Remarks	Number and rate of failing samples
		API	compliant	noncompliant		
ATS/SP	4	ATS	4	0	All the 4 samples were noncompliant	4 (100%)
		S	0	4		
		P	2	2		
ATS/SmP	5	ATS	2	3	Compliant APIs did not occur in the same samples therefore all the samples were noncompliant	5 (100%)
		Sm	1	4		
		P	2	3		
ATM/LUM	41	ATM	14	27	Only 2 samples had both APIs being compliant in the same sample.	39 (95.1%)
		LUM	11	30		
DHA/Pp	14	DHA	4	10	Pp API could not be assayed. Based on DHA alone, 4 out of 14 samples were compliant	10 (71.4%)
		Pp	-	-		
DHA/SP	12	DHA	0	12	All the samples were noncompliant even though P was 100% compliant	12 (100%)
		S	1	11		
		P	12	0		
SP	23	S	3	20	Only 2 samples had both APIs being compliant in the same sample	21 (91.3%)
		P	12	11		
QN	13	QN	5	8	5 out 13 samples were compliant	8 (61.5%)
Total	**112**		**73**	**145**		**99 (88.4%)**

Source: John P. Renschler et al., Estimated Under-Five Deaths Associated with Poor-Quality Antimalarials in Sub-Saharan Africa," 92 American Journal of Tropical Medicine and Hygiene 119 (2015)

TABLE 1

Estimated under-five deaths caused by poor-quality antimalarials

Country	Min	First quartile	Median	Mean	Third quartile	Max	Median as % of malaria deaths*
All countries	38,772	91,577	122,350	125,012	154,736	269,705	22.33
Nigeria	13,220	54,931	74,188	77,231	96,132	206,618	41.96
Uganda	1,589	7,374	10,138	10,811	13,556	31,419	53.45
DRC	1	3,178	6,501	7,399	10,596	32,251	7.99
Ghana	390	3,068	4,223	4,527	5,669	14,439	41.22
Cameroon	309	2,521	3,520	3,756	4,730	12,119	23.18
Burkina Faso	0	1,463	2,991	3,421	4,892	15,146	10.18
Coté d'Ivoire	0	1,102	2,277	2,591	3,703	10,317	11.08
Mali	0	998	2,050	2,325	3,332	10,414	10.59
Mozambique	0	738	1,491	1,746	2,484	7,489	6.63
Madagascar	0	886	1,240	1,339	1,695	4,314	46.69
Benin	0	528	1,053	1,207	1,713	5,368	11.76
Niger	0	440	904	1,048	1,507	4,556	6.34
Tanzania	0	596	933	1,038	1,373	4,431	5.99
Malawi	0	379	792	899	1,272	4,317	10.42
Chad	0	326	670	766	1,089	3,198	4.10
Guinea	0	262	547	637	911	2,856	4.19
Sudan	0	268	539	626	901	2,644	11.24
Togo	0	260	523	598	851	2,733	15.27
Sierra Leone	0	241	499	582	829	2,754	5.65
Angola	0	224	464	552	788	2,753	3.83
CAR	0	196	399	460	661	1,860	6.55
Kenya	0	109	215	249	353	1,462	4.53
Liberia	0	84	192	242	344	1,319	6.81
Senegal	0	162	225	238	301	739	6.28
Zambia	0	88	181	215	304	1,072	2.28
Congo	0	40	99	130	187	865	3.00
Burundi	0	43	87	102	148	507	6.42
Gabon	0	21	51	65	92	407	11.26
Rwanda	0	22	46	53	77	248	9.20
Somalia	0	20	43	50	72	234	1.06
Equatorial Guinea	0	4	22	35	52	341	3.57
Zimbabwe	0	6	14	16	23	79	0.60
Guinea-Bissau	0	5	10	13	18	62	0.66
Gambia	0	4	9	11	16	61	0.73
Mauritania	0	3	8	10	14	71	0.94
Namibia	0	1	3	4	6	25	75.00
Swaziland	0	0	0	0	0	0	0.00
Djibouti	0	0	0	0	0	0	0.00
Ethiopia	0	0	0	0	0	0	0.00

CAR = Central African Republic; DRC = Democratic Republic of Congo.

This table displays the results from 10,000 simulations run following the Latin hypercube sampling scheme discussed in the methodology. The values presented depict the estimated number of under-five malaria deaths caused by treatment with poor-quality antimalarials for 39 sub-Saharan countries. The countries are listed in descending order according to the medians of 10,000 simulations (with the cumulative nation totals in the top row).

*2010 WHO estimates of under-five malaria deaths (Supplemental Table 4).

Summary: Three Problems Limit our Ability to Use Drugs to Curb Infectious Diseases in Developing Countries

1) Incentives to develop appropriate vaccines and medicines are inadequate
2) Too often, existing drugs are not affordable
3) Many of the drugs currently distributed in developing countries are substandard or falsified