



International Health 2020; 00: 1–16  
doi:10.1093/inthealth/ihz112 Advance Access publication

# Health inequality in the tropics and its costs: a Sustainable Development Goals alert

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Received 2 April 2019; revised 10 September 2019; editorial decision 11 October 2019; accepted 11 October 2019

**Background:** It is known that health impacts economic performance. This article aims to assess the current state of health inequality in the tropics, defined as the countries located between the Tropic of Cancer and the Tropic of Capricorn, and estimate the impact of this inequality on gross domestic product (GDP).

**Methods:** We constructed a series of concentration indices showing between-country inequalities in disability-adjusted life years (DALYs), taken from the Global Burden of Disease Study. We then utilized a non-linear least squares model to estimate the influence of health on GDP and counterfactual analysis to assess the GDP for each country had there been no between-country inequality.

**Results:** The poorest 25% of the tropical population had 68% of the all-cause DALYs burden in 2015; 82% of the communicable, maternal, neonatal and nutritional DALYs burden; 55% of the non-communicable disease DALYs burden and 61% of the injury DALYs burden. An increase in the all-cause DALYs rate of 1/1000 resulted in a 0.05% decrease in GDP. If there were no inequality between countries in all-cause DALY rates, most high-income countries would see a modest increase in GDP, with low- and middle-income countries estimated to see larger increases.

**Conclusions:** There are large and growing inequalities in health in the tropics and this has significant economic cost for lower-income countries.

**Keywords:** inequality, macroeconomic costs, tropics

## Introduction

Health is a universal human right and basic human need.<sup>1</sup> Indeed, the development status of countries and regions is often judged by the quality of population health outcomes and how fairly health is distributed across the social spectrum. In 2008 the World Health Organization's (WHO) Commission on Social Determinants of Health noted that 'inequities in health, (or) avoidable health inequalities, arise because of the circumstances in which people grow, live, work and age, and the systems put in place to deal with illness. The conditions in which people live and die are, in turn, shaped by political, social and economic factors'.<sup>2</sup>

The relationship between health and economic growth is well established. Through its contribution to human and social capital, the health of a population has been identified in multiple studies to influence economic growth, and vice versa.<sup>3–5</sup> Health is thought to influence growth via the impact of health upon

working time<sup>6</sup> and also through the influence of health on productivity.<sup>5</sup> Yet this relationship between health and economic growth is more complicated than is often assumed. Theories of demographic transition suggest that economic growth may reduce the burden of communicable diseases but simultaneously increase the burden of non-communicable diseases. A growing evidence base also points to the way macroeconomic trends and global trade relations enable and promote unregulated commercialization, impacting differentially on population health in countries with stronger or weaker economies.<sup>7</sup>

Increasingly, the tropics is being recognized as a geopolitical and environmental entity in its own right.<sup>8</sup> The tropics is defined as the region between the Tropic of Cancer and Tropic of Capricorn. Countries in this region are home to almost half of the world's population, >50% of its young people, many of the world's fastest-growing economies and most of the world's biological and cultural diversity.<sup>9</sup> The trajectory of this region

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will be central to whether or not the world meets ambitious goals for global prosperity and equality as embodied in the 2030 Agenda for Sustainable Development and associated Sustainable Development Goals.<sup>10</sup>

Although some health outcomes have improved in the past 20 y, the tropics has historical trends of poor health outcomes<sup>9</sup> and weak economic performance and growth.<sup>11</sup> Gallup and Sachs<sup>12</sup> observed that macroeconomic growth varies greatly with geography, and Sachs<sup>13</sup> postulated that the underperformance of economies in the tropics was related to inferior agricultural and health technology as well as high fertility and high mortality rates.<sup>13</sup> Recent analysis demonstrates that 70% of the global infrastructure gap occurs in the tropics, 20% of people in the region to do not have access to clean water and 30% of people do not have access to reliable electricity.<sup>14</sup> Despite these figures, few analyses have been conducted to better understand how trends in health and economic growth intersect in the tropics.

This study aims to give an overview of the current state of health equality in the geographically and demographically significant region of the tropics. Using the results from the Global Burden of Disease Study,<sup>15</sup> we assess between-country health equality from 2000 to 2015. The article goes on to characterize the relationship between health and economic output in the tropics and estimate the level of gross domestic product (GDP) that could have been achieved had the current recorded levels of health inequality not been present.

## Materials and methods

### State of health inequalities

Using data from the Global Burden of Disease Study from 2000, 2005, 2010 and 2015,<sup>15</sup> we identified the number of disability-adjusted life years (DALYs) lost due to all causes; communicable, maternal, neonatal and nutritional diseases; non-communicable diseases and injuries for each country located at least partially in the tropics. Communicable, maternal, neonatal and nutritional diseases include conditions such as lower respiratory infections, diarrhoeal disease, malaria, preterm birth complications, human immunodeficiency virus/acquired immune deficiency syndrome and neonatal encephalopathy; non-communicable diseases include ischaemic heart disease, stroke, chronic obstructive pulmonary disease, cancer, diabetes, chronic kidney disease and Alzheimer's disease.

We utilized the list of 105 tropical countries contained within the 2014 State of the Tropics report.<sup>9</sup> To assess the level of economic-related inequality in health between countries within the tropics, as measured by DALYs lost, a series of concentration indices were constructed. A separate concentration index was constructed for each time point (2000, 2005, 2010 and 2015) to show the change in inequality over time. This was done separately for all-cause DALYs lost; communicable, maternal, neonatal and nutritional diseases DALYs lost; non-communicable diseases DALYs lost and injury DALYs lost.

The concentration index is a standard measure of health inequality, which assesses the distribution of health outcomes across economic groups.<sup>16</sup> The measure of a country's economic status used in this study was GDP per capita. Total GDP in 2011 international purchasing power parity (PPP) dollars for 2000,

2005, 2010 and 2015 was utilized<sup>17</sup> and divided by population estimates in the respective years<sup>18</sup> to obtain GDP per capita. Each country was then ranked from lowest to highest based on GDP per capita.

The concentration index reflects the cumulative proportion of health held by the cumulative proportion of the population, ranked by economic status. The concentration index has a range of  $-1$  to  $1$ , with a value of  $0$  denoting perfect equality in the distribution of the health outcome, a negative value denoting a distribution skewed towards groups of lower economic status and a positive value denoting a distribution skewed towards groups of higher economic status. The concentration index was computed as follows<sup>19</sup>:

$$\begin{aligned} \text{Concentration index} \\ = (p_1L_2 - p_2L_1) + (p_2L_3 - p_3L_2) + \dots + (p_{t-1}L_t - p_tL_{t-1}) \end{aligned} \quad (1)$$

where  $p_t$  is the cumulative percentage of the population in the tropics ranked by economic status (GDP per capita),  $L_t$  is the cumulative proportion of DALYs and  $t$  is the total number of countries.

The confidence intervals for the concentration index was calculated from the standard error and variance as follows<sup>20</sup>:

$$\begin{aligned} \text{var (concentration index)} \\ = \frac{1}{T} \left[ \sum_{t=1}^T f_i a_t^2 - (1 + \text{concentration index})^2 \right], \end{aligned} \quad (2)$$

where  $f_i$  is the cumulative proportion of the population in the  $i$ th group and

$$a_t = \frac{\mu_t}{\mu} (2R_t - 1 - \text{concentration index}) + 2 - q_{t-1} - q_t, \quad (3)$$

where  $\mu_t$  is the DALY rate of the  $t$ th country,  $\mu$  is the mean DALY rate of all countries,  $R_t$  is the cumulative proportion of the population up to the midpoint of each country's group interval (i.e.  $\sum_{k=1}^{T-1} f_k + \frac{1}{2}f_t$ ) and  $q_t$  is the cumulate DALY rate divided by  $\mu$ .<sup>20</sup>

### Cost of health inequalities

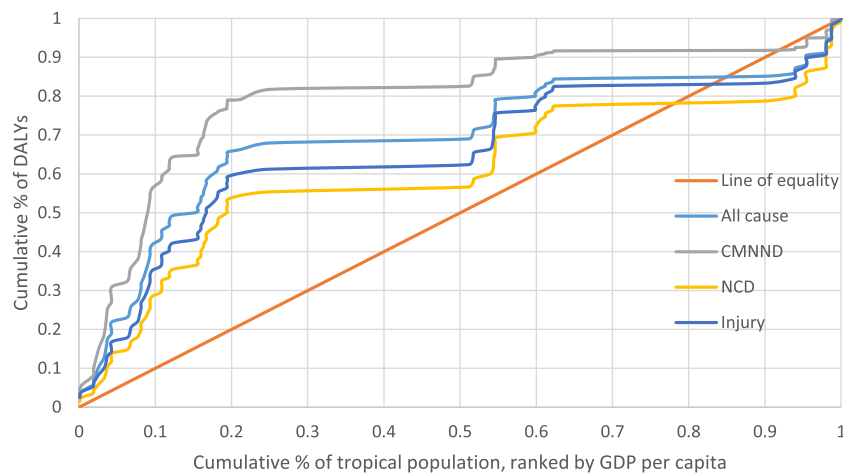
This study then undertook a counterfactual analysis to estimate the level of economic output (as measured by GDP) countries in the tropics could have achieved had they had the same all-cause DALYs rate as the best-performing country in the tropics.

### Measure of economic growth

We used the aggregate production function approach to measuring GDP proposed by Bloom and Canning<sup>21</sup>:

$$\log Y_{ij} = \alpha_{ij} + \alpha \log K_{ij} + \beta (\log L_{ij} + \varnothing_s s_{ij} + \varnothing_h h_{ij}), \quad (4)$$

where  $Y_{ij}$  is the total GDP of country  $i$  at time  $j$ , where  $i=1, \dots, 97$  and  $j=1995, \dots, 2015$ ,  $\alpha_{ij}$  is the level of total factor productivity (TFP),  $K_{ij}$  is the stock of physical capital,  $L_{ij}$  is the labour force,  $s_{ij}$  is years of schooling and  $h_{ij}$  is health. (In previous work in this field authors estimated TFP: however, TFP estimates are now available through the Penn World Tables.)



**Figure 1.** Concentration curve for DALYs in tropical countries, 2015. CMNND: communicable, maternal, neonatal and nutritional disease; NCD: non-communicable disease.

We obtained annual data on GDP, TFP, physical capital, labour force size and average years of schooling for countries in the tropics from 1990 to 2015. GDP data were obtained from the World Bank.<sup>17</sup> TFP and physical capital data for each of the countries were obtained from the Penn World Tables version 9.0.<sup>22</sup> GDP, TFP and physical capital data were all represented in 2011 international PPP dollars. Labour force data came from the World Bank and consisted of an estimated number of people in the labour force  $\geq 15$  y of age.<sup>23</sup> Education data for the average years of schooling were obtained from the United Nations Development Programme.<sup>24</sup> The measure of health was the all-cause DALY rate per 1000. Of the 105 countries located within the tropics, 97 had complete DALY data and were included in the analysis.

A non-linear least squares model of the log of GDP was constructed to estimate the coefficients of the independent variables log of capital, log of labour force, education and health, as shown in equation 4 above. Dummy time variables were included. Generalized method of moments was utilized to correct the models for heteroscedasticity,<sup>25</sup> and first-order autocorrelation structures for the errors were included in the model. This resultant equation was then used to estimate the counterfactual economic output (GDP) for all countries had they had the all-cause DALY rate of the best-performing country (Saudi Arabia, all-cause DALY rate of 170.56 per 1000).

All analysis was undertaken using SAS version 9.3 (SAS Institute, Cary, NC, USA).

## Results

There were 97 countries located in the tropics who had data on the total number of DALYs lost. The rate of lost DALYs due to all causes; communicable, maternal, neonatal and nutritional diseases; non-communicable diseases and injuries in 2000, 2005, 2010 and 2015 for each of these 97 countries is shown in Table A1. Overall, the DALY rate per 100 000 for all causes declined between 2000 and 2015. However, rates of decline varied between countries. There was a clear differential in DALYs rates by country income classification. High-income countries

in the tropics had an average all-cause DALYs rate in 2015 of 25 438 per 100 000 (standard deviation [SD]=5719), upper-middle-income countries 30 785 (SD=11 547), lower-middle-income countries 36 626 (SD=11 648) and low-income countries 58 315 (SD=13 935).

The unequal distribution of DALY in 2015 within countries in the tropics is illustrated in the concentration curves shown in Figure 1. As can be seen in Figure 1, the cumulative percentage of DALY lost exceeds the cumulative proportion of the population living in the tropics for poorer countries. For example, the poorest 25% of the tropical population had 68% of the all-cause DALY burden in 2015; 82% of the communicable, maternal, neonatal and nutritional disease DALY burden; 55% of the non-communicable disease DALY burden and 61% of the injury DALY burden. Appendix 2 shows countries ranked by their GDP per capita and the cumulative proportion of DALY lost.

Table 1 shows the concentration index for the distribution of DALY in 2000, 2005, 2010 and 2015. For all four DALY classifications, inequality appears to be increasing over time from 2000 to 2015. In 2000, the concentration index for the all-cause DALYs burden was  $-0.30$  (95% confidence interval [CI]  $-0.22$  to  $-0.08$ ), which by 2015 had increased to  $-0.39$  (95% CI  $-0.44$  to  $-0.35$ ). There was little evidence of economic-related inequality in DALY burden for non-communicable diseases in 2000. However, inequality based on economic status appeared in 2010 and grew in 2015. The increase in injury-related DALY inequality in 2010 appears to be driven by the spike in Haiti's injury-related DALY rate in 2010 (Appendix 1).

To estimate the cost of unequal all-cause DALY rates for countries within the tropics, we initially constructed a model to estimate GDP, with the results shown in Table 2. The model fitted the data well with an adjusted  $R^2$  value of 0.9667. The coefficient estimates shown in Table 2 relate to model 1 described in the Materials and methods section. This indicated that an increase in the all-cause DALY rate of 1 per 1000 resulted in a 0.03% decrease in GDP (from model 1 and coefficient estimates in Table 3,  $(-0.00057 \times 0.673191) \times 100 = -0.03\%$ ); conversely, a decrease in the all-cause DALY rate of 1 per 1000 resulted in a 0.03% increase in GDP.

**Table 1.** Concentration index showing the inequality in the distribution of DALYs by country income, measured by GDP per capita

DALY rate	Concentration index (95% CI)			
	2000	2005	2010	2015
All cause	-0.30 (-0.22 to -0.08)	-0.32 (-0.35 to -0.29)	-0.38 (-0.43 to -0.33)	-0.39 (-0.44 to -0.35)
Communicable, maternal, neonatal and nutritional diseases	-0.47 (-0.51 to -0.45)	-0.52 (-0.64 to -0.40)	-0.57 (-0.69 to -0.45)	-0.60 (-0.72 to -0.47)
Non-communicable diseases	0.00 (0.00 to 0.01)	-0.05 (-0.14 to 0.05)	0.14 (-0.20 to -0.07)	-0.20 (-0.25 to -0.16)
Injury	-0.23 (-0.20 to -0.26)	-0.15 (-0.21 to -0.12)	-0.41 (-0.58 to -0.23)	-0.31 (-0.32 to -0.30)

**Table 2.** Non-linear model of log GDP, tropical countries 1990–2015

Parameter	Estimate	Standard error	t-Value	p-Value
$\alpha$	0.256922	0.1709	1.5	0.1335
$\beta$	0.673191	0.1886	3.57	0.0004
$\varnothing_s$	0.142548	0.1005	1.42	0.1566
$\varnothing_h$	-0.00057	0.00048	-1.18	0.2393
Adjusted R <sup>2</sup>	0.9667			

Dummy time variables not shown; model:  $\log Y = a + \alpha \log K + \beta(\log L + \varnothing_s s + \varnothing_h h)$ .

Based on this estimated impact of all-cause DALY rates on GDP, the estimated change in 2015 GDP if each country had an all-cause DALY rate of 170.56 per 1000 is shown in Table 3. Most high-income countries were estimated to see a modest increase in GDP, with middle-income and low-income countries were estimated to see larger increases. For example, if the Central African Republic had an all-cause DALY rate of 170.56 per 1000, then they were estimated to have a GDP 28% higher than their actual GDP in 2015.

## Discussion

This study demonstrates large and growing economic-related inequalities in health in the tropics. The unequal distribution of poor health is such that populations in poorer countries experience a disproportionately larger burden of disease across most disease groups. Perhaps intuitively, economic-related inequalities in health were most pronounced in the communicable and maternal, neonatal and nutritional disease groups. However, of note, whereas in previous years (2000 and 2005) there was no related economic inequality for non-communicable diseases, inequality in this domain now exists and looks likely to increase.

Globally there has been a trend towards improvements in communicable and maternal, neonatal and nutritional disease DALY rates, a deterioration in non-communicable disease DALY rates and a stabilization of all-cause DALY rates between 1990 and 2015.<sup>26</sup> This study demonstrates more mixed results among countries in the tropics—with some seeing a decline in DALY rates in some domains and others seeing an increase. Such variation

makes it difficult to conclude whether the health status of the tropics, as measured by DALYs, is improving over time. What is clear, however, is that currently, health inequality in the region is increasing.

Findings from this study also demonstrate that health inequalities in the tropics come at a significant economic cost, probably compounding existing economic inequities. To our knowledge, this is the first study to use this framework to quantify the costs of health inequality and map them regionally. Results align with, but also extend, previous work such as that carried out by the Lancet Commission on Investing in Health, which noted that approximately 25% of economic growth from 2000 to 2011 in low- and middle-income countries was the result of value-added improvements to population health.<sup>27</sup> Health is a key form of human and social capital, and directly impacts upon the productivity of a nation's workforce, and thus economic growth.<sup>3</sup> Furthermore, through the 'health transition' effect, better health leads to declining fertility rates and slowing of population growth, which also positively influences economic growth per capita.<sup>13</sup> The WHO High-level Commission on Health Employment and Economic Growth stated that investment in health is an important pathway to economic growth, through increased life expectancy and healthier workers.<sup>28</sup>

Combined with the extant literature, our findings reinforce the importance of investing in equity-promoting health systems capable of providing universal health coverage. The recent Sustainable Infrastructure in the Tropics report highlighted a US\$30 trillion deficit in infrastructure in the region,<sup>14</sup> noting that the tropics has less health-related infrastructure per capita compared with non-tropical regions in all domains assessed

**Table 3.** Anticipated increase in GDP, based on the non-linear model of GDP shown in Table 2, had all countries had the same DALYs rate as the best-performing country, 2015

Country	GDP 2015	Increase in GDP	Growth in GDP, %
<b>High-income countries</b>			
Antigua and Barbuda	2 009 826 596	53 973 653	3
Australia	1 042 740 000 000	19 733 135 417	2
Barbados	4 374 192 583	235 393 539	5
Saudi Arabia	1 600 700 000 000	–	0
Singapore	447 738 000 000	1 570 525 125	>1
Seychelles	2 384 515 771	92 624 941	4
Trinidad and Tobago	42 548 380 978	2 615 256 373	6
<b>Upper-middle-income countries</b>			
Angola	173 593 000 000	28 445 172 261	16
Belize	2 896 339 797	100 610 214	3
Brazil	3 020 640 000 000	125 662 814 769	4
Botswana	33 925 440 081	5 095 779 561	15
China	18 607 300 000 000	563 322 801 665	3
Colombia	626 268 000 000	11 616 130 549	2
Costa Rica	71 705 298 733	821 713 412	1
Dominica	741 629 314	39 402 786	5
Dominican Republic	140 781 000 000	4 597 387 089	3
Ecuador	173 981 000 000	4 589 540 370	3
Fiji	7 811 978 867	694 874 614	9
Gabon	32 497 590 563	3 213 134 875	10
Equatorial Guinea	32 015 040 167	5 051 050 478	16
Jamaica	23 278 214 005	954 613 489	4
St. Lucia	1 892 096 825	79 873 600	4
Maldives	4 907 464 510	7 778 646	>1
Mexico	2 098 330 000 000	47 022 618 882	2
Marshall Islands	194 651 519	12 323 663	6
Mauritius	23 817 914 130	1 053 349 777	4
Malaysia	767 736 000 000	16 189 392 513	2
Namibia	24 043 436 006	2 457 382 668	10
Panama	82 061 443 521	1 845 225 450	2
Peru	369 226 000 000	4 211 555 598	1
Paraguay	57 357 253 470	1 717 492 382	3
Suriname	8 169 111 441	433 845 843	5
Thailand	1 046 120 000 000	53 454 404 761	5
<b>Lower-middle-income countries</b>			
Bangladesh	504 973 000 000	27 430 182 038	5
Bolivia	70 048 618 747	2 959 509 956	4
Cote d'Ivoire	75 129 288 986	12 845 710 270	17
Cameroon	68 302 439 597	11 290 836 272	17
Republic of the Congo	27 690 345 067	3 588 867 666	13
Djibouti	2 911 406 226	313 743 482	11
El Salvador	49 522 384 600	1 914 747 565	4
Federated States of Micronesia	343 060 704	14 522 270	4
Ghana	108 392 000 000	10 165 289 089	9

(Continued)

**Table 3.** Continued

Country	GDP 2015	Increase in GDP	Growth in GDP, %
Guatemala	118 524 000 000	4 942 459 994	4
Honduras	38 631 714 481	1 157 206 360	3
Indonesia	2 676 550 000 000	124 903 764 801	5
India	7 532 380 000 000	621 597 105 048	8
Kenya	133 945 000 000	13 117 888 814	10
Cambodia	51 067 798 981	2 678 798 779	5
Kiribati	210 624 150	21 358 824	10
Sri Lanka	231 923 000 000	5 662 135 378	2
Myanmar	265 745 000 000	18 162 993 447	7
Mauritania	15 063 179 361	1 125 289 804	7
Nigeria	1 027 420 000 000	163 607 465 290	16
Nicaragua	30 172 442 923	383 426 213	1
The Philippines	699 258 000 000	31 178 728 457	4
Papua New Guinea	20 327 000 425	2 301 254 260	11
Sudan	165 813 000 000	14 070 340 054	8
Solomon Islands	1 206 358 337	85 108 034	7
São Tomé and Príncipe	575 391 345	36 326 731	6
Timor-Leste	2 669 474 380	141 488 592	5
Tonga	551 908 322	22 472 648	4
Vietnam	519 777 000 000	14 915 212 610	3
Vanuatu	742 684 971	56 686 547	8
Samoa	1 077 065 956	27 862 590	3
Zambia	58 400 082 027	9 635 621 355	16
Low-income countries			
Burundi	7 634 578 343	1 095 034 646	14
Benin	21 016 184 357	2 725 580 341	13
Burkina Faso	28 086 807 428	4 854 308 341	17
Central African Republic	2 847 726 468	793 488 968	28
Comoros	1 098 546 195	74 493 053	7
Democratic Republic of the Congo	57 185 360 031	9 917 760 608	17
Ethiopia	153 116 000 000	14 294 035 761	9
Guinea	14 316 884 358	2 597 619 016	18
Guinea-Bissau	2 521 743 681	557 976 038	22
Haiti	17 686 408 605	1 831 466 588	10
Liberia	3 533 313 381	447 191 582	13
Madagascar	33 354 200 458	3 672 896 561	11
Mali	33 524 899 739	7 151 030 656	21
Mozambique	31 322 101 897	5 654 370 746	18
Malawi	19 132 417 662	3 005 945 469	16
Niger	17 857 377 171	3 647 931 415	20
Rwanda	19 954 999 667	1 877 316 666	9
Senegal	34 398 281 018	3 152 976 316	9
Sierra Leone	9 524 359 831	1 909 663 417	20
South Sudan	21 484 823 398	4 415 171 988	21
Chad	28 686 194 920	6 807 892 037	24
Togo	10 018 697 437	1 367 702 899	14
Tanzania	130 298 000 000	14 773 052 968	11
Uganda	67 946 377 419	9 254 472 937	14
Zimbabwe	29 831 655 630	4 221 552 678	14



(hospitals, hospital beds and physicians). This deficit is also likely to be an underestimate since the report contained no measures of primary care infrastructure, which is more likely to reach the poorest populations. Of concern, there is currently also no consolidated measure or database to help assess and compare countries' health system capacity (beyond infrastructure).<sup>29,30</sup> Together with our findings, these gaps in knowledge highlight a growing imperative to strengthen both our understanding of and investment in equity-promoting health systems.<sup>31</sup>

Beyond highlighting disturbing upward trends in economic-related health inequality in tropical countries, the impact of the 2010 Haiti earthquake on results reported in this study demonstrate how discrete environmental events can have long-lasting effects on the equity of health outcomes. Currently and moving forward it is predicted that countries within the tropics will bear an unequal burden of climate-induced natural disasters.<sup>14</sup> It has been previously noted that poorer countries within the tropics have the highest human impact associated with natural disasters.<sup>32,33</sup> Climate change-induced natural disasters are likely to increase in the tropics in coming decades,<sup>34</sup> contributing to and compounding health inequalities, particularly for injury-related health outcomes.

The results of the study must be considered in light of its limitations. The key source of uncertainty lies in the accuracy of the data utilized in this study. All macroeconomic data have a level of uncertainty associated with them and are reliant upon the accuracy of data collection institutions within each country.

## Conclusions

This study has demonstrated an important relationship between health and macroeconomic outcomes and the macroeconomic costs associated with health inequity in a geographically and demographically significant region. The results highlight concerning increases in health inequality and flag the compounding effect of this inequality on individual countries' macroeconomic performance. Improving the overall well-being of populations in the tropics will require investment in health, and social and economic determinants, to ensure that 'no one is left behind'. The WHO recognizes that health, while being a discrete and important goal worthy of prominence,<sup>35</sup> is inextricably linked to many of the other Sustainable Development Goals.<sup>36</sup> A multisector approach is thus likely to be a key to driving any future improvements in both health and macroeconomic outcomes. The 2030 Agenda for Sustainable Development and associated Sustainable Development Goals provide an unprecedented opportunity to address these issues.

**Authors' contributions:** EC conceived the study and undertook the analysis. ST contributed to the interpretation of the results. Both authors drafted the manuscript and edited and approved the final version.

**Acknowledgements:** None.

**Funding:** EC received funding from the National Health and Medical Research Council under the Career Development Fellowship scheme (APP1159536). The funder played no role in any aspect of the study.

**Competing interests:** None declared.

**Ethical approval:** Not required.

## References

- Marmot M. Commission on Social Determinants of Health. Achieving health equity: From root causes to fair outcomes. *Lancet*. 2007;370(9593):1153–1163.
- WHO Commission on Social Determinants of Health. Closing the gap in a generation: health equity through action on the social determinants of health: Commission on Social Determinants of Health final report. Geneva: World Health Organization, 2008.
- Bloom DE, Canning D, Sevilla J. The effect of health on economic growth: theory and evidence. Working paper 8587, National Bureau of Economic Research, Cambridge, MA; 2001.
- Bloom DE, Canning D, Sevilla J. Health and economic growth: reconciling the micro and macro evidence. Working paper 42, Center on Democracy, Development and the Rule of Law, Stanford, CA; 2005.
- Bloom DE, Canning D, Sevilla J. The effect of health on economic growth: a production function approach. *World Dev*. 2004;32(1):1–13.
- Grossman M. On the concept of health capital and the demand for health. *J Polit Econ*. 1972;80(2):223–255.
- Van Lerberghe W. The world health report 2008: primary health care: now more than ever. Geneva: World Health Organization, 2008.
- State of the Tropics. State of the tropics 2015 report. Townsville, QL, Australia: James Cook University, 2015.
- State of the Tropics. State of the tropics 2014 report. Townsville, QL, Australia: James Cook University, 2014.
- United Nations General Assembly. Transforming our world: the 2030 Agenda for Sustainable Development. New York: United Nations, 2015.
- Khawar M. Climate and economic development: further evidence in support of "the tropical effect". *J Econ*. 2014;2(4):77–89.
- Gallup JL, Sachs JD, Mellinger AD. Geography and economic development. *International regional science review* 1999;22(2):179–232.
- Sachs JD. Tropical underdevelopment. Working paper 8119, National Bureau of Economic Research, Cambridge, MA; 2001.
- State of the Tropics. Sustainable infrastructure in the tropics. Townsville, QL, Australia: James Cook University, 2017.
- Global Burden of Disease Study. Global Burden of Disease Study 2015 (GBD 2015). In: Results. Seattle, WA: Institute for Health Metrics and Evaluation, 2015.
- Wagstaff A, Van Doorslaer E. Equity in health care finance and delivery. In: Culyer AJ, Newhouse JP, editors. *Handbook of health economics*, Vol. 1. Oxford: Elsevier, 2000; p. 1803–1862.
- World Bank. GDP, PPP (current international \$). World Bank. International Comparison Program database. <http://data.worldbank.org/indicator/NY.GDP.MKTP.PP.CD?view=chart2017> [accessed 18 January 2019].
- World Bank. Population, total. World Bank Group. <https://data.worldbank.org/indicator/SP.POP.TOTL> [accessed 14 December 2019].
- Fuller MF, Lury DA. *Statistics workbook for social science students*. London: Phillip Allan, 1977.
- O'Donnell O, Van Doorslaer E, Wagstaff A, Lindelow M. Analyzing health equity using household survey data: a guide to techniques and their implementation. Washington, DC: World Bank, 2008.
- Bloom DE, Canning D, Sevilla J. Health and economic growth: reconciling the micro and macro evidence. Center on Democracy, Development and the Rule of Law Working Papers 2005;42.
- Feenstra RC, Inklaar R, Timmer MP. The next generation of the Penn World Table. *Am Econ Rev*. 2015;105(10):3150–3182.
- World Bank. Labour force, total. World Bank Group. <https://data.worldbank.org/indicator/SL.TLF.TOTL.IN> [accessed 14 December 2019].

- 24 United Nations Development Programme. Human development data (1990–2015): mean years of schooling (years). United Nations Development Programme. <http://hdr.undp.org/en/content/expected-years-schooling-children-years> [accessed 14 December 2019].
- 25 Erdman D, Little M. Nonlinear regression analysis and nonlinear simulation models. Cary, NC: SAS Institute. <https://support.sas.com/rnd/app/ets/papers/nonlinearmodels.pdf>.
- 26 Kassebaum NJ, Arora M, Barber RM, *et al.* Global, regional, and national disability-adjusted life-years (DALYs) for 315 diseases and injuries and healthy life expectancy (HALE), 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet*. 2016;388(10053):1603–1658.
- 27 Jamison DT, Summers LH, Alleyne G, *et al.* Global health 2035: a world converging within a generation. *Lancet*. 2013;382(9908):1898–1955.
- 28 World Health Organization. Working for health and growth: investing in the health workforce. In: Report of the High-Level Commission on Health Employment and Economic Growth. Geneva: World Health Organization, 2016.
- 29 Kruk ME, Pate M, Mullan Z. Introducing the Lancet Global Health Commission on high-quality health systems in the SDG era. *Lancet Glob Health*. 2017;5(5):E480–E481.
- 30 Abimbola S, Topp S, Palagyi A, Marais B, Negin J. Global health security: where is the data to inform health system strengthening? *BMJ Glob Health*. 2017;2:e000481.
- 31 Kieny MP, Bekedam H, Dovlo D, *et al.* Strengthening health systems for universal health coverage and sustainable development. *Bull World Health Org*. 2017;95(7):537–539.
- 32 Alcantara-Ayala I. Geomorphology, natural hazards, vulnerability and prevention of natural disasters in developing countries. *Geomorphology* 2002;47(2–4):107–124.
- 33 Kahn ME. The death toll from natural disasters: the role of income, geography, and institutions. *Rev Econ Stat*. 2005;87(2):271–284.
- 34 van Aalst MK. The impacts of climate change on the risk of natural disasters. *Disasters*. 2006;30(1):5–18.
- 35 Hill PS, Buse K, Brolan CE, Ooms G. How can health remain central post-2015 in a sustainable development paradigm? *Glob Health*. 2014;10:18.
- 36 World Health Organization. Health in 2015: from MDGs to SDGs. Geneva: World Health Organization, 2015.

## Appendix A



**Table A1.** DALYs rate per 100 000 for all tropical countries: 2000, 2005, 2010 and 2015

Country	All-cause				DALYs, Communicable, maternal, neonatal and nutritional diseases				Non-communicable diseases				Injuries			
	2000	2005	2010	2015	2000	2005	2010	2015	2000	2005	2010	2015	2000	2005	2010	2015
<b>High-income countries</b>																
Antigua and Barbuda	26 524.9	25 024.6	24 057.6	24 054.1	5596.42	4297.29	3671.97	3412.40838	18 877.2	18 658.2	18 502.9	18 945.5	2051.32	2069.08	1882.7	1696.26
Australia	23 650.7	22 627.5	22 029.4	21 987.4	1289.12	1247.63	1169.33	1073.80217	20 151.1	19 456.9	19 118.1	19 241.5	2210.51	1922.91	1741.6	1672.54
Barbados	30 207.7	29 564.8	30 350.2	31 079.9	5313.37	4339.17	4031.33	3708.01725	22 879.3	23 036.6	24 191.6	25 339.7	2015.94	2188.94	2127.29	2032.24
Bermuda	25 116.6	23 117.1	22 335.7	22 344.5	3720.71	2778.94	2470.83	2312.32345	19 405.3	18 270.7	18 011.7	18 427.9	1990.59	2068.2	1853.12	1604.3
Guam	24 430.6	26 793.1	31 000.6	32 404.5	3285.84	3659.81	4025.57	3802.48614	18 377.8	20 273.6	23 778.4	25 362.7	2766.99	2859.55	3196.72	3239.28
Puerto Rico	28 628.3	28 001.4	28 029.4	27 233.4	3791.11	3275.03	2858.26	2575.54054	21 633.8	21 743.1	22 137.5	21 976.4	3203.33	2983.33	3033.2	2681.5
Saudi Arabia	20 433.6	18 409.4	17 427.7	17 055.6	4708.18	3351.36	2649.51	2154.27876	12 370.4	12 069.2	12 098.8	12 468.6	3354.99	2988.84	2679.36	2432.69
Seychelles	29 242.1	28 238.4	27 683.7	27 178.7	4303.69	4187.7	3943.67	3662.45322	21 243.6	20 589.9	20 427.2	20 746.2	3694.72	3460.71	3312.8	2770.03
Singapore	18 263.1	17 681.8	17 535.9	17 969.7	1953.31	1805.02	1808.14	1897.71205	14 637.2	14 383.9	14 450.1	14 855.6	1672.64	1492.89	1277.68	1216.38
Trinidad and Tobago	32 696.1	32 344.2	32 881.2	33 073.9	6676.01	5133.24	4546.38	4134.96085	22 772.1	23 096.4	24 179.8	25 227.8	3247.93	4114.39	4155.77	3711.11
<b>Upper-middle-income countries</b>																
American Samoa	24 512.2	23 982.9	22 737.5	22 415.9	4417.97	3846.9	3258.61	2957.75179	17 210.8	17 367.8	17 024.5	17 196.7	2883.41	2768.21	2454.39	2261.49
Angola	101 982.7	84 178.7	71 493.9	59 759.4	71 206.6	57 053.5	44 072.1	34 373.3549	20 895.7	19 470.6	19 718.6	18 843.4	9880.19	7655.1	7703.26	6542.25
Belize	29 803.4	27 241.3	26 561.8	26 108.3	8475.31	7381.97	6242.76	5811.18316	16 466.2	15 347.2	16 062.8	16 320.4	4861.89	4512.08	4256.22	3976.72
Botswana	85 872.9	81 345.3	63 415.8	56 200.2	60 656.4	55 118.6	38 923.32	32 051.4053	19 316.2	19 971.3	18 967.9	19 077.3	5900.37	6255.36	5524.16	5071.45
Brazil	30 475.8	28 571.1	27 784.4	27 897.2	7121.69	5473.82	4523.49	3966.66974	18 419.2	18 477.1	18 834.6	19 803.8	4934.91	4620.19	4426.3	4126.74
China	29 492.6	27 931.3	26 031.7	24 945.3	4629.02	3142.74	2396.49	2036.21872	20 783.1	21 170.3	20 502.7	20 273.1	4080.49	3618.22	3132.57	2635.92
Colombia	26 229.9	23 900.8	22 958.8	21 889.3	4763.09	4078.78	3439.89	2763.48963	14 709.7	14 867.2	15 243.7	15 507.7	6757.11	4954.79	4275.86	3618.15

(Continued)



Table A1. Continued

Country	All-cause			DALYs, Communicable, maternal, neonatal and nutritional diseases			Non-communicable diseases					Injuries				
	2000	2005	2010	2015	2000	2005	2010	2015	2000	2005	2010	2015	2000	2005	2010	2015
Suriname	33 619. 1	33 646. 8	32 457 7	30 895. 9	10 044. 4	8807. 47	7734. 23	6624. 38348	19 242. 6	20 262. 1	20 305. 2	20 268. 3	4332. 06	4577. 26	4417. 54	4003. 24
Thailand	32 124 4	29 747. 4	29 348. 3	30 372 25	5835. 25	4737. 21	4412. 96	4209. 14851	20 594. 2	19 663. 7	20 452. 5	22 122. 8	5694. 55	5346. 51	4482. 75	4040. 09
Lower-middle-income countries																
Bangladesh	45 932. 9	38 902. 7	34 071. 7	31 211. 8	22 710 7	16 259. 7	11 725. 9	8971. 99065	17 883. 5	18 243. 9	18 672. 6	18 915. 7	5339. 38	4399. 11	3673. 23	3324. 07
Bolivia	41 372. 6	34 451 3	30 426. 3	28 066. 1	17 914. 2	12 919 83	9669. 83	7506. 91444	17 272. 7	16 412. 8	16 331. 1	16 678. 7	6185. 64	5119. 17	4425. 39	3880. 41
Cambodia	53 353. 8	41 764. 4	35 342. 4	30 725. 9	28 121. 1	18 337. 4	13 106. 5	9675. 06915	19 414. 5	18 682. 1	18 050. 7	17 538. 3	5818. 17	4744. 89	4185. 19	3512. 58
Cameroon	84 288. 4	79 463. 5	68 428. 1	60 135. 7	61 454. 2	57 659. 6	46 931. 9	38 887. 7988	18 205. 7	17 602 1	17 339. 1	17 062. 7	4628. 55	4201. 86	4157. 08	4185. 13
Congo, Rep.	81 550. 4	68 485 2	55 872. 2	50 832. 2	52 712 5	44 360. 5	32 562. 1	28 148. 6094	21 777. 7	19 233. 1	18 837. 4	18 691. 3	7060. 72	4891. 37	4472. 61	3992. 24
Cote d'Ivoire	90 286. 1	83 152. 4	71 229. 9	61 614. 6	65 902. 7	61 023. 5	50 342. 6	40 709. 9932	19 234 6	17 807. 6	16 944. 4	17 085. 2	5149. 33	4321. 35	3942. 83	3819. 36
Djibouti	57 669. 7	53 551. 5	48 695. 3	45 139. 5	35 347. 5	30 838. 1	25 631. 2	21 712. 3538	17 390. 4	17 963. 4	18 481. 1	18 990. 2	4931. 76	4750. 01	4582. 98	4436. 98
El Salvador	30 353. 6	28 336 8	27 436. 8	27 131. 8	7432. 17	5164. 61	4075. 3	3625. 69317	16 350. 5	16 612. 4	17 137. 1	17 631. 4	6570. 91	6558. 95	6224. 32	5874. 63
Federated States of Micronesia	31 351. 4	29 361. 4	28 458. 5	28 087. 5	8024. 07	5883. 62	4803. 15	4166. 35275	19 743. 4	20 118. 9	20 470. 5	20 799 5	3583. 97	3358. 96	3184. 92	3122. 06
Ghana	59 019. 7	55 264. 9	49 022. 2	41 496 4	39 098. 4	35 453. 5	29 513. 5	21 870. 1989	16 512. 7	16 515. 9	16 445. 1	16 578. 3	3408. 61	3295. 57	3063. 63	3047. 56
Guatemala	37 949. 6	34 347 6	30 505. 9	27 922. 9	18 271. 3	14 178. 4	10 514. 8	8080. 30516	14 934. 8	14 831. 3	15 037. 6	15 195. 5	4743. 45	5337. 24	4953. 39	4647. 12
Honduras	30 190. 8	27 507 8	25 925. 3	24 862 72	9317. 72	7284. 06	5812. 59	4721. 93882	16 989. 8	16 291. 1	15 993. 6	16 395 27	3883. 27	3931. 83	4119. 11	3745. 03
India	52 838. 3	47 216. 6	42 267 7	38 561. 7	27 343. 9	22 812. 7	18 055. 8	14 351. 8686	20 458. 6	19 868. 6	20 110. 1	20 390. 4	5035. 83	4535. 35	4101. 06	3819. 53
Indonesia	34 725. 3	32 489. 6	30 681. 5	29 217 9	13 963. 9	11 574 29	9554. 15976	7765. 15976	17 959. 6	18 319 3	18 705. 3	19 213. 2	2801. 81	2596. 54	2421. 86	2238. 7
Kenya	68 301. 2	62 412. 6	48 603. 4	42 578. 1	52 058. 7	46 478. 5	32 794. 1	26 612. 1447	12 900. 3	12 773. 6	12 649. 5	12 881. 5	3342. 21	3160. 43	3159. 79	3084. 46

(Continued)

Table A1. Continued

Country	All-cause				DALYs, Communicable, maternal, neonatal and nutritional diseases				Non-communicable diseases				Injuries			
	2000	2005	2010	2015	2000	2005	2010	2015	2000	2005	2010	2015	2000	2005	2010	2015
Kiribati	51 888. 6	48 855. 5	46 289. 8	43 483	21 926. 1	19 402. 2	16 650. 7	13 957. 952	25 464. 3	24 919. 8	25 071	25 210. 8	4498. 18	4533. 5	4568. 02	4314. 32
Mauritania	54 921. 5	48 741. 6	41 514	36 524. 1	35 849. 5	30 975 6	24 525. 6	19 527. 8138	15 264. 2	14 292. 1	13 941	14 135. 9	3807. 76	3474. 53	3047. 34	2860. 45
Myanmar	50 600. 4	44 678. 3	38 381. 9	34 867. 4	24 660. 4	19 208 4	13 295. 4	9590. 64588	22 230. 8	22 029. 4	21 865. 4	22 261. 7	3709. 15	3440. 86	3221. 09	3015. 06
Nicaragua	24 640. 6	22 211. 5	20 824. 5	20 367. 3	8793. 77	6207. 89	4592. 77	3555. 60593	12 778. 5	13 223. 9	13 744. 3	14 457. 5	3068. 27	2779. 72	2487. 51	2354. 23
Nigeria	96 329. 5	87 680. 4	72 288. 9	58 555 8	74 128. 1	68 051. 4	54 088. 8	40 929. 8867	17 822. 1	16 128. 8	15 028. 2	14 366. 7	4379. 42	3500. 21	3171. 77	3258. 43
Papua New Guinea	58 681. 4	56 298. 4	51 681. 8	46 559. 4	26 797. 1	24 088. 9	20 000. 9	16 086. 9777	25 380. 5	25 919. 4	25 833. 1	25 188. 2	6503. 81	6290 79	5847. 79	5284. 21
Philippines	32 085. 3	31 140. 9	30 078. 4	28 675. 6	12 751. 5	11 052. 5	9224. 12	7532. 24641	16 099 3	17 000. 3	18 041. 1	18 523. 9	3234. 79	3088 15	2813. 41	2619. 41
Samoa	25 681. 7	24 977. 3	24 252. 3	23 797. 2	5517. 37	4830. 07	4122. 65	3572. 32355	17 343. 3	17 547. 6	17 652. 1	17 909. 4	2821. 04	2599. 59	2477. 5	2315. 47
São Tomé and Príncipe	49 629. 5	43 500. 7	37 504 7	33 508. 7	26 733. 7	21 538. 1	16 792. 7	13 712. 1931	19 409. 1	18 792. 7	17 898. 6	17 252. 5	3486. 67	3169. 82	2812. 73	2544. 09
Solomon Islands	40 735. 4	40 654. 4	38 166. 5	35 441. 3	13 320. 9	12 466. 7	10 066 10332	7820. 10332	22 499. 3	23 469. 2	23 631. 6	23 480. 5	4915. 18	4718. 55	4468. 89	4140. 69
Sri Lanka	28 599. 6	26 703. 2	26 112. 7	23 418 76	4828. 76	4442. 09	3315. 07	2653. 95399	17 577. 9	17 888. 9	17 432. 9	17 515. 5	6192. 94	4372. 14	5364. 71	3248. 49
Sudan	59 603. 6	50 482. 2	44 325. 9	39 169. 8	32 150. 5	24 844. 5	19 559. 1	15 498. 8885	20 301 15 600.	19 425. 5	18 930. 2	18 485. 7	7152. 01	6212. 18	5836. 59	5185. 24
Timor-Leste	69 235. 5	42 718. 4	36 547. 6	30 868. 4	41 289. 9	24 303 7076.	18 035. 6407.	13 421. 5401.	15 600. 19 169.	14 488 19 545.	15 022. 19 194.	14 502. 19 062.	12 345. 3823.	3927. 3732.	3489. 3488.	2943. 3203.
Tonga	30 700 6	30 354. 6	29 090. 9	27 667 16	7707. 16	7076. 53	6407. 77	5401. 06297	19 169. 4	19 545. 4	19 194. 6	19 062. 1	3823. 43	3732. 64	3488. 53	3203. 83
Vanuatu	40 640. 8	40 375. 8	38 655. 9	36 946. 8	13 148. 5	12 524. 7	10 163. 8	8350. 7508	22 760. 4	23 219. 9	24 053 1	24 261. 1	4731. 89	4631. 23	4439. 12	4334. 98
Vietnam	27 148. 2	26 044. 2	25 039. 7	24 533. 8	7211. 31	5713. 99	4544. 97	3662. 28856	16 372. 8	16 848. 5	17 182. 1	17 793. 5	3564. 14	3481. 67	3312. 55	3078. 04
Zambia	11 0822 4	95 243. 4	73 234. 8	60 054 8	86 367. 9	70 677. 8	49 598. 6	37 715. 9298	19 129. 6	19 305. 9	18 681. 3	17 874. 2	5324. 79	5259. 77	4954. 84	4463. 91

(Continued)

Table A1. Continued

Country	All-cause			DALYs, Communicable, maternal, neonatal and nutritional diseases			Non-communicable diseases			Injuries						
	2000	2005	2010	2015	2000	2005	2010	2015	2000	2005	2010	2015				
Low-income countries																
Benin	80 646.1	69 702.4	58 762.8	50 853.6	57 861.6	48 652.9	38 334.8	30 293.3	17 508.1	16 817.9	16 587.5	16 865.7	5276.38	4231.54	3840.47	3694.52
Burkina Faso	10 2890.1	88 377.2	73 301.5	62 096.9	81 970.7	69 628.5	55 308.9	43 456.0	16 079.6	14 566.6	14 185.1	14 658.2	4839.96	4182.06	3807.47	3982.67
Burundi	10 7396.1	77 060.9	59 089.9	54 434.7	79 638.8	55 135.8	39 647.2	33 872.5	19 715.9	16 624.2	15 237.8	16 013.8	8041.22	5300.05	4205.73	4548.36
Central African Republic	11 4723.3	10 9973.3	98 280.3	89 671.1	83 101.9	79 072.1	66 544.7	57 371.9	23 828.6	23 449.2	23 878.2	24 141.4	7792.5	7451.91	7857.44	8158.14
Chad	11 3487.3	10 3286.7	89 623.3	78 903.7	89 948.8	81 418.2	66 928.7	56 914.4	16 635.1	16 029.5	16 576.9	16 249.2	6903.24	5838.47	6118.12	5740.11
Comoros	53 569.6	43 926.8	38 006.8	34 727.5	33 666.7	26 294.8	20 876.2	17 463.1	15 987.6	14 231.2	14 109.9	14 373.1	3914.71	3400.59	3021.55	2891.29
Democratic Republic of the Congo	96 698.3	84 675.7	73 007.3	62 253.2	73 746.7	63 482.8	52 356.3	41 068.3	17 087.2	16 290.2	16 146.4	16 673.2	5864.56	4902.73	4504.47	4511.64
Eritrea	147 296.7	84 675.1	53 433.1	49 227.8	37 620.9	34 286.2	32 201.7	27 990.4	14 578.2	15 614.8	16 194.8	16 466.1	95 097.79	5134.79	5036.6	4771.16
Ethiopia	91 781.4	55 035.8	51 540.7	41 384.4	68 520.7	50 186.2	32 643.5	23 087.9	17 960.1	16 482.1	15 187.6	14 970.6	5300.57	4425.34	3709.64	3327.02
Guinea	96 183.2	71 093.7	73 001.1	64 339.5	71 104.3	61 571.9	50 557.6	42 202.4	19 964.7	18 543.3	18 423.3	18 395.1	5114.21	4256.71	4020.26	3742.01
Guinea-Bissau	96 538.7	84 371.9	82 888.8	74 719.1	70 317.4	63 816.9	55 242.7	48 023.9	20 016.6	20 832.4	21 252.7	20 932.7	6204.66	6367.91	6393.47	5762.61
Haiti	60 968.6	91 017.2	187 344.4	44 042.2	32 998.5	29 190.1	23 011.9	17 138.9	22 022.1	21 553.9	21 933.5	21 751.9	5947.93	5420.19	142 398.94	5151.94
Liberia	90 101.9	56 164.1	59 506.9	50 039.2	70 426.3	55 887.3	41 285.1	32 470.2	15 258.8	14 714.9	14 871.7	14 561.7	4416.83	3593.55	3350.47	3007.21
Madagascar	67 233.6	74 195.3	50 353.3	45 753.1	45 882.4	35 340.6	30 285.3	25 391.1	17 797.2	16 968.2	17 106.6	17 456.4	3554.16	3039.77	2961.67	2905.6
Malawi	115 647.6	55 348.3	73 752.2	58 000.3	93 996.4	75 419.9	55 477.8	39 821.0	16 885.4	15 609.5	14 759.4	14 719.3	4765.8	3938.15	3515.86	3459.93
Mali	10 9769.5	94 967.8	82 559.8	72 644.4	85 293.9	74 473.9	62 405.6	53 393.3	17 595.1	15 648.1	15 385.7	14 895.8	6880.13	4976.42	4768.58	4355.29
Mozambique	98 628.9	95 098.5	76 691.8	64 101.3	76 310.1	67 542.8	55 877.6	43 459.3	17 205.9	16 365.5	16 680.7	16 677.7	5112.88	4195.85	4133.49	3964.93

(Continued)

Table A1. Continued

Country	All-cause					DALYs, Communicable, maternal, neonatal and nutritional diseases					Non-communicable diseases					Injuries						
	2000	2005	2010	2015	2020	2000	2005	2010	2015	2020	2000	2005	2010	2015	2020	2000	2005	2010	2015	2020	2015	
Niger	12 6772	88 104.	82 349.	70 292.	10 4637	81 977.	63 758.	51 265.	16 073.	15 189.	14 305.	14 467.	6061.	5117.	4286.	6061.	5117.	4286.	4559.	4559.	4559.	4559.
Rwanda	96 403.	102 285	46 763.	41 572.	68 421.	43 716.	27 811.	22 324.	19 282.	14 660	13 918	14 560	8699.	6056.	5033.	8699.	6056.	5033.	4687.	4687.	4687.	4687.
Senegal	67 156.	64 432.	47 345.	40 943.	47 840.	37 410	29 067.	22 734.	15 323.	15 153.	14 928.	15 035.	3992.	3745.	3349.	3992.	3745.	3349.	3173.	3173.	3173.	3173.
Sierra Leone	115 035	56 309.	82 915.	69 308.	84 772.	72 121.	56 975.	44 685.	23 178.	22 351.	21 461	20 514.	7082.	4917.	4479.	7082.	4917.	4479.	4108.	4108.	4108.	4108.
Somalia	104 699	99 391.	94 454.	78 851.	78 099.	69 011.	67 654	53 115.	19 119.	17 892.	18 344.	17 757.	7480.	6732.	8456.	7480.	6732.	8456.	7978.	7978.	7978.	7978.
South Sudan	86 956.	93 635.	73 398.	70 610.	65 322	57 992.	51 906	46 476.	16 517.	16 009.	16 559.	17 215.	5116.	4684.	4933.	5116.	4684.	4933.	6918.	6918.	6918.	6918.
Tanzania	81 186.	78 686.	56 858.	46 603	62 093.	51 378.	37 906.	27 531.	15 455.	15 302.	15 430	15 672.	3637.	3546.	3521.	3637.	3546.	3521.	3399.	3399.	3399.	3399.
Togo	73 669	70 227.	62 911.	52 632.	51 510.	49 387.	42 394.	32 456.	17 899.	17 169.	16 790.	16 708.	4259.	4444.	3726.	4259.	4444.	3726.	3467.	3467.	3467.	3467.
Uganda	97 965.	71 001.	65 370.	52 551	74 556.	58 373.	44 575.	31 735.	17 875.	17 206.	16 189.	16 436.	5533.	5060.	4605.	5533.	5060.	4605.	4378.	4378.	4378.	4378.
Zimbabwe	82 571.	80 640.	81 502.	53 934.	63 658.	72 972.	61 351.	36 162.	15 274	16 383.	16 223.	14 367.	3638.	3842.	3926.	3638.	3842.	3926.	3405.	3405.	3405.	3405.
	3	8	2	8	8	8	8	1499	1	1	8	5	41	27	56	41	27	56	15	15	15	15



**Table A2.** Cumulative proportion of the population living in the tropics and cumulative proportion of the DALYs burden, 2015

Country	Cumulative % of tropical population	Cumulative % of DALYs, all	Cumulative % of DALYs, communicable, maternal, neonatal and nutritional diseases	Cumulative % of DALYs, non-communicable diseases	Cumulative % of DALYs, injury
Central African Republic	0.0009	0.0249	0.0348	0.0148	0.0249
Burundi	0.0029	0.0400	0.0554	0.0246	0.0388
Democratic Republic of the Congo	0.0182	0.0573	0.0804	0.0349	0.0526
Liberia	0.0191	0.0712	0.1001	0.0438	0.0618
Niger	0.0231	0.0907	0.1312	0.0527	0.0758
Malawi	0.0266	0.1068	0.1554	0.0617	0.0863
Mozambique	0.0322	0.1246	0.1818	0.0720	0.0985
Guinea	0.0346	0.1424	0.2074	0.0832	0.1099
Sierra Leone	0.0361	0.1617	0.2346	0.0958	0.1225
Togo	0.0375	0.1763	0.2543	0.1061	0.1331
Madagascar	0.0424	0.1890	0.2697	0.1168	0.1419
Comoros	0.0425	0.1986	0.2803	0.1256	0.1508
Guinea-Bissau	0.0429	0.2193	0.3095	0.1385	0.1684
Ethiopia	0.0629	0.2308	0.3235	0.1477	0.1786
Burkina Faso	0.0665	0.2481	0.3499	0.1567	0.1907
Haiti	0.0686	0.2603	0.3603	0.1700	0.2065
Uganda	0.0767	0.2749	0.3796	0.1801	0.2199
Rwanda	0.0790	0.2864	0.3932	0.1890	0.2342
South Sudan	0.0814	0.3060	0.4214	0.1996	0.2553
Kiribati	0.0814	0.3181	0.4299	0.2151	0.2685
Zimbabwe	0.0846	0.3330	0.4518	0.2239	0.2789
Mali	0.0880	0.3532	0.4843	0.2330	0.2923
Benin	0.0902	0.3673	0.5027	0.2434	0.3035
Chad	0.0930	0.3892	0.5372	0.2533	0.3211
Solomon Islands	0.0931	0.3991	0.5420	0.2678	0.3337
Timor-Leste	0.0933	0.4076	0.5501	0.2767	0.3427
Senegal	0.0963	0.4190	0.5640	0.2859	0.3524
Tanzania	0.1071	0.4319	0.5807	0.2955	0.3628
Papua New Guinea	0.1087	0.4449	0.5905	0.3110	0.3790
Vanuatu	0.1087	0.4551	0.5955	0.3259	0.3922
Kenya	0.1182	0.4669	0.6117	0.3338	0.4017
São Tomé and Príncipe	0.1182	0.4762	0.6200	0.3443	0.4094
Cameroon	0.1228	0.4929	0.6436	0.3548	0.4222
Bangladesh	0.1550	0.5016	0.6491	0.3664	0.4324
Djibouti	0.1552	0.5141	0.6623	0.3781	0.4460
Cote d'Ivoire	0.1598	0.5312	0.6870	0.3886	0.4576
Federated States of Micronesia	0.1599	0.5390	0.6895	0.4013	0.4672
Cambodia	0.1630	0.5475	0.6954	0.4121	0.4779
Mauritania	0.1638	0.5577	0.7073	0.4208	0.4867
Zambia	0.1670	0.5743	0.7302	0.4317	0.5003
Marshall Islands	0.1670	0.5837	0.7343	0.4460	0.5110
Ghana	0.1726	0.5952	0.7476	0.4562	0.5203
Sudan	0.1803	0.6060	0.7570	0.4675	0.5361
Honduras	0.1821	0.6129	0.7599	0.4776	0.5476
Nicaragua	0.1833	0.6186	0.7620	0.4865	0.5548

(Continued)

**Table A2.** Continued

Country	Cumulative % of tropical population	Cumulative % of DALYs, all	Cumulative % of DALYs, communicable, maternal, neonatal and nutritional diseases	Cumulative % of DALYs, non-communicable diseases	Cumulative % of DALYs, injury
Myanmar	0.1938	0.6283	0.7679	0.5001	0.5640
Tonga	0.1938	0.6360	0.7711	0.5118	0.5738
Republic of the Congo	0.1948	0.6501	0.7882	0.5233	0.5860
Samoa	0.1948	0.6567	0.7904	0.5343	0.5931
Vietnam	0.2132	0.6635	0.7926	0.5452	0.6025
Nigeria	0.2494	0.6797	0.8175	0.5540	0.6124
India	0.5113	0.6904	0.8262	0.5666	0.6241
Angola	0.5169	0.7070	0.8471	0.5781	0.6441
Bolivia	0.5190	0.7148	0.8517	0.5884	0.6560
Philippines	0.5393	0.7228	0.8562	0.5997	0.6640
Guatemala	0.5426	0.7305	0.8611	0.6090	0.6782
El Salvador	0.5439	0.7380	0.8633	0.6199	0.6961
Belize	0.5439	0.7453	0.8669	0.6299	0.7083
Jamaica	0.5445	0.7530	0.8696	0.6426	0.7160
Paraguay	0.5458	0.7599	0.8723	0.6531	0.7261
Fiji	0.5460	0.7711	0.8766	0.6713	0.7367
Namibia	0.5465	0.7832	0.8926	0.6797	0.7484
Dominica	0.5465	0.7918	0.8956	0.6938	0.7569
Indonesia	0.5982	0.7999	0.9004	0.7056	0.7638
St. Lucia	0.5982	0.8077	0.9027	0.7188	0.7721
Ecuador	0.6014	0.8143	0.9054	0.7286	0.7824
Sri Lanka	0.6056	0.8208	0.9070	0.7394	0.7923
Peru	0.6119	0.8264	0.9096	0.7478	0.7986
Maldives	0.6120	0.8312	0.9114	0.7555	0.8050
Colombia	0.6216	0.8373	0.9131	0.7650	0.8161
Dominican Republic	0.6237	0.8444	0.9168	0.7751	0.8254
China	0.8980	0.8513	0.9180	0.7875	0.8334
Brazil	0.9392	0.8590	0.9204	0.7997	0.8460
Suriname	0.9393	0.8676	0.9244	0.8121	0.8583
Costa Rica	0.9403	0.8732	0.9256	0.8219	0.8648
Thailand	0.9540	0.8816	0.9282	0.8355	0.8771
Botswana	0.9545	0.8972	0.9476	0.8472	0.8926
Barbados	0.9545	0.9058	0.9499	0.8628	0.8988
Mexico	0.9797	0.9122	0.9516	0.8733	0.9072
Gabon	0.9801	0.9241	0.9640	0.8847	0.9192
Mauritius	0.9803	0.9320	0.9654	0.8997	0.9253
Antigua and Barbuda	0.9804	0.9387	0.9674	0.9113	0.9305
Panama	0.9812	0.9450	0.9699	0.9210	0.9394
Malaysia	0.9873	0.9513	0.9722	0.9311	0.9471
Seychelles	0.9873	0.9589	0.9744	0.9438	0.9556
Equatorial Guinea	0.9875	0.9750	0.9944	0.9559	0.9724
Trinidad and Tobago	0.9878	0.9842	0.9969	0.9714	0.9837
Australia	0.9926	0.9903	0.9975	0.9832	0.9888
Saudi Arabia	0.9989	0.9950	0.9988	0.9909	0.9963
Singapore	1.0000	1.0000	1.0000	1.0000	1.0000