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International Climate Migrant Policy and Estimates of Climate Migration

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Abstract: The architecture of international aid and climate finance should be reformed to address the needs of climate migrants. While humanitarian aid agencies that support some climate migrants are increasingly overburdened, climate migration has been underestimated and largely neglected by the United Nations Framework Convention on Climate Change (UNFCCC). The policy community has based a high-end estimate of 216 million potential climate migrants by 2050 on *Groundswell* (2021), but *Groundswell* does not address all drivers. It uses statistical methods to estimate internal migration from slow-onset drivers including crop yields, water supplies, and sea level rise, but the state of knowledge only permits rough, "back-of-the-envelope" estimates for other forms and drivers. Working out such estimates for sudden-onset drivers and for the remaining slow-onset drivers, if mitigation and adaptation are weak, I find that there could be about 500 million climate migrants by 2050. While the UNFCCC classifies climate migration under adaptation, few adaptation resources are devoted to migrants' needs. Based on humanitarian aid expenses for other kinds of migrants, I estimate it could cost around $7000 per person to help climate migrants to rebuild their lives. At this rate, support for climate migrants would be a significant part of the total climate finance, and with organizational needs for supporting climate migrants being quite different from those for adaptation proper, it would make sense for the UNFCCC to address climate migration as a separate category on par with mitigation and adaptation.

Keywords: climate migrants; UNFCCC; adaptation; sea level rise; climate finance; humanitarian aid

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1. Introduction

Although climate migration has been recognized since at least the early 1990s as a serious consequence of climate change, climate migrants have largely been neglected by the United Nations Framework Convention on Climate Change (UNFCCC). As climate change policy has been constructed under headings of "mitigation" and "adaptation", climate migration has been classified under adaptation, but adaptation programming has mostly neglected climate migrants. In practice, most international support for people forcibly displaced by climate change has come from traditional humanitarian agencies [1].

This, I argue, is a mistake. While climate migrants represent perhaps the most substantial body of victims of the climate crisis besides those who lose their lives, the statist structure of the UNFCCC privileges the interests of national governments, but interests of climate migrants tend not to be well represented by their governments [2]. In light of harms experienced by climate migrants and potential political consequences of climate migration, supporting climate migrants should be a UNFCCC priority.

Like many other areas of climate change policy, the scale of challenges in supporting climate migrants involves great uncertainties. The standard source for estimating potential numbers of climate migrants is the World Bank's *Groundswell* [3], estimating up to 216 million climate migrants by 2050, but I will show that its estimates are too low. A more reasonable high-end estimate is up to 500 million climate migrants by 2050. Also, programs to support climate migrants are different enough from adaptation proper that it makes

programmatic sense to classify them separately. At this writing, advanced countries have committed $100 billion/year to support mitigation and adaptation in developing countries (all financial figures in this paper are in U.S. dollars). I argue that costs for reasonable support for climate migrants are likely to rise from around $49 billion/year in the 2020s to around $175 billion/year in the 2040s.

Given weaknesses in the body of evidence for estimating numbers of future climate migrants and costs for supporting them, and given complexities in their causes, best estimates at this point remain quite rough. Estimates also depend on definitions as to who counts as a climate migrant, and these definitions inevitably include arbitrary elements. Climate policy, however, requires that estimates should be made, and those I shall offer improve on those available in the literature. Foundations for policy are advanced as much by clarifying issues with definitions and the underlying causal structures as by specific numbers proposed.

This paper proceeds as follows. Section 2 discusses the UNFCCC's neglect of climate migrants. Section 3 proposes a categorization of climate migration appropriate for international climate policy and discusses the availability of data for each category. Sections 4 and 5 develop estimates, respectively, of potential numbers of climate migrants by 2050 driven by sudden- and slow-onset weather events, and Section 6 combines their estimates and discusses other relevant factors for an overall high-end estimate. Section 7 develops estimates of potential costs for supporting climate migrants based on experience with various kinds of migrant support. Section 8 discusses the importance of supporting climate migrants, and Section 9 concludes by proposing changes to the climate policy architecture for implementing this support.

2. The UNFCCC Has Neglected Climate Migrants

Climate change first became a focus for international policy with the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988 and the UNFCCC in 1992. It was clear from basic climate science that continued increases in greenhouse gas (GHG) emissions would cause significant human displacement, most apparently from rising sea levels. Policy makers and the general public needed a sense of the potential scale of the problem in the policy-relevant future, and Norman Myers' 1993 article, "Environmental Refugees in a Globally Warmed World", served this purpose [4]. His estimates of 150 million possible displaced persons by 2050, updated to 212 million in 2001 [5], became standard references. Both papers projected that most potential displacements would be due to sea level rise—100 million in the 1993 paper and 162 million in the 2001 paper—with 50 million in each paper attributed to droughts and "other climate dislocations" (p. 611). He emphasized that his estimates were preliminary, and at the times the articles were published, 2050 was far enough away that likely numbers of climate migrants could be expected to be greatly reduced by effective mitigation. In any case, his estimates did not inspire significant international support for climate-displaced persons.

From the establishment of the UNFCCC in 1992 through to the 2015 Paris Agreement, international negotiations on climate change policy focused on efforts to reduce GHG emissions (mitigation) and efforts to reduce direct harms from effects of climate change (adaptation). The Paris Agreement included a first official gesture of support for climate migrants, calling for the establishment of a Task Force on Displacement. It was only authorized to develop recommendations [6], however, with only thirteen members and with no program budget [7]. The UNFCCC had launched support for adaptation planning in developing countries as early as 2001 with the establishment of a Least Developed Countries Fund [8]. The UNFCCC's 2009 Copenhagen Accord committed $10 billion a year from developed countries to support mitigation and adaptation in developing countries, which was to rise to $100 billion a year by 2020 [9], although this target was not met until 2022 [10].

In principle, needs of climate migrants could be addressed under adaptation, but in practice, adaptation has generally been understood as addressing more direct effects

of climate change. As of 2023, developing countries' adaptation actions reported to the UNFCCC fall in the following sectors:

Cross-cutting	31%
Agriculture and livestock	19%
Biodiversity and ecosystems	19%
Transport and infrastructure	12%
Water security	7%
Human health and well-being	6%
Fisheries	2%
Forestry	2%
Energy	1%
Multiple	1% [11]

None of 513 priority projects from National Adaptation Programs of Action [12], 229 projects supported by the UNFCCC's Adaptation Fund [13], or 2459 climate change projects in the Global Environment Facility's projects database [14] has a title indicating support for climate migrants or persons displaced by climate change. (The Adaptation Fund supports a project titled "Increasing the resilience of both displaced persons and host communities to climate change-related water challenges in Jordan and Lebanon", but it supports people displaced by conflict.) In 2023, the UNFCCC launched a Loss and Damage Fund that aims to "provide support for responding to economic and non-economic loss and damage associated with the adverse effects of climate change". While its terms of reference include addressing challenges from displacement, relocation, and migration, they also include challenges from climate-related emergencies, sea level rise, insufficient climate information and data, and climate-resilient reconstruction and recovery [15]. Also, with only $661 million in commitments as of March 2024 [16], the institutional strength of this fund remains uncertain.

Most developed country support for mitigation and adaptation in developing countries has been channeled through pre-established multilateral and bilateral development agencies such as the World Bank's Global Environment Facility, the European Bank for Reconstruction and Development, Germany's KfW, and the Japanese International Cooperation Agency. Alongside the increase in international climate finance since 2009, this period has also seen an increase in total numbers of people recorded as displaced from their homes from all causes, including conflict and violence and weather and geophysical disasters. From 1993 through 2004, the number of international refugees and other people listed by UNHCR (the UN Refugee Agency) as being displaced internationally and within their own countries mostly by conflict and violence remained roughly stable around 25 million, but since then it has risen almost every year to an all-time high over 120 million in 2023 [17]. The Internal Displacement Monitoring Center (IDMC) began tracking people displaced within their own countries by weather and geophysical hazards in 2008. From 2008 to 2023, these numbers fluctuated between 15 and 38 million per year with a fairly stable average around 25 million [18]. International support for displaced people has mostly been channeled through pre-established humanitarian agencies such as UNHCR, the International Committee of the Red Cross, and the International Rescue Committee.

In sum, in the architecture of international aid, climate change mitigation and adaptation are supported mostly by established development assistance institutions, while displaced persons are supported mostly by humanitarian aid. Whereas development assistance agencies distinguish between traditional development assistance and climate finance, humanitarian aid agencies have not tracked persons displaced by climate change. While

the $100 billion per year climate finance commitment from developed countries does not include humanitarian aid agencies' support for climate-displaced persons, there also has been no systematic effort to identify total numbers of persons displaced by climate change or costs for supporting them.

3. Categories and Available Data Related to Climate Migration

The literature on climate migrants typically distinguishes between displacements caused by slow- and sudden-onset climate change-driven events or disasters. According to UNFCCC, "slow onset events evolve gradually from incremental changes occurring over many years or from an increased frequency of recurring events", including sea level rise, temperature increase, ocean acidification, glacial retreat, salinization, land degradation and deforestation, loss of biodiversity, and desertification. A rapid or sudden-onset event "may be a single, discrete event that occurs in a matter of days or even hours [19]". According to the Platform on Displacement, "Sudden Onset Disasters refers to a 'serious disruption of the functioning of a community or society involving widespread human, material, economic or environmental losses and impacts, and which exceeds the ability of the affected community or society to cope using its own resources'. . . . [D]isasters refer to disruptions triggered by or linked to hydro-metrological and climatological natural hazards, including anthropogenic global warming, as well as geophysical hazards [20]". It is also widely recognized that effects of climate change can increase the incidence and/or intensity of conflict, increasing numbers of persons displaced by conflict. People forced by climate change to leave their homes can be divided into four categories:

1. People displaced by sudden-onset weather events who return to their homes (we assume that most people displaced by slow-onset events are unable to return to their homes).
2. People displaced by slow- or sudden-onset events who find new homes in their country of residence.
3. People displaced by slow- or sudden-onset events who leave their country of residence.
4. Additional people displaced by conflict due indirectly to climate change.

IDMC tracks numbers of people displaced by disasters and by conflict and violence within their home countries, so-called internally displaced persons or IDPs. According to IDMC, "Internally displaced persons are persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters, and who have not crossed an internationally recognized State border [21]". It tracks IDPs displaced by weather and geophysical disasters separately, so its numbers for IDPs displaced by weather disasters is the primary source for our first category of displaced persons. IDMC does not distinguish, however, between people who are able to return to their homes and those forced to find new homes. In principle, one might want to distinguish between displacements due to anthropogenic climate change (that is, climate change caused by humans) and those that would have occurred due to natural weather events, but this does not appear to be feasible.

Groundswell estimates numbers of persons displaced by slow-onset events who remain in their countries of residence. As noted above, since its publication, *Groundswell* has been the standard reference on potential numbers of climate migrants due to slow-onset causes. A recent review article on "The impact of climate change on migration: a synthesis of empirical insights", cites Myers (2001) [5] and Biermann and Boas (2010) [22], who also estimate potential climate migration by 2050 as "around or over 200 million". It identifies *Groundswell*, however, as its only example of a sophisticated modeling effort, and it notes that confidence in all estimates of future climate migration is low [23] (p. 282). I argue below that due to its focus on only three of many drivers of slow-onset displacements and due to problems with its data on displacements due to sea level rise, *Groundswell* under-estimates this category of climate migration. Neither *Groundswell* nor IDMC offers

global estimates of numbers of people displaced by sudden-onset events who find new homes in their country of residence. Since these numbers are likely to be quantitatively significant and important for policy, I make a first rough estimate below.

As far as I know, there also has been no systematic effort to estimate global numbers of climate-displaced persons who leave their country of residence, nor has there been one to estimate indirect contributions from climate change to displacements due to conflict and violence. Having no basis for estimating these variables, I include them as significant but unknown factors.

Although total numbers of people displaced from their homes by climate change are not known, they are already significant, and they are sure to increase in coming years. Adaptation programs have largely neglected climate migrants, and humanitarian aid agencies are already struggling to support the greatly increasing numbers of displaced people [24]. Since developed countries have caused the majority of GHG emissions, they bear a degree of responsibility to climate migrants that is generally greater than their responsibility to other categories of migrants. Climate change harms everyone, but harms from losses of home, livelihood, and community that often come with climate migration are particularly severe. In order to consider what it would mean for the UNFCCC to include support for climate migrants within its mandate, it may be helpful to develop a clearer picture of potential numbers of climate migrants and costs for supporting them.

4. How Many People Are Displaced by Sudden-Onset Weather Events?

As noted above, IDMC began to monitor world-wide internal displacement associated with disasters in 2008. From 2008 to 2020, it finds an average of 24.6 million new internal displacements due to disasters a year. From 2008 to 2018, 87.3% of these displacements were due to weather-related disasters and 12.7% to geophysical disasters, mainly earthquakes and tsunamis. Weather-related displacements, therefore, averaged about 21.5 million a year. Through 2018, 98.7% of these were attributed to floods (58.0%) and storms (40.7%) and the remainder to drought, wildfires, landslides, and extreme temperatures [25–27]. Since anthropogenic climate change causes floods to become more frequent and severe, storms to become stronger, and other weather-related events also to become more extreme, other things equal, we expect weather-related displacements to increase through to 2050 and beyond [28].

IDMC's estimates for displacements in a given year include all new recorded and verified displacements in that calendar year, including secondary and subsequent displacements. It does not collect primary data itself, relying instead on around 2000 unique sources, mainly governments, disaster relief organizations, UN agencies, and the media [29]. Hence, its estimates are contingent on their ability to gather data and willingness to share them. Major forms of reporting bias that IDMC reports include:

- Unequal availability of data: Displacement data availability tends to be found [*sic.*] in large events in a small number of countries where international agencies, funding partners, and media have a substantial presence, or where there is a strong national commitment and capacity to collect and report on displacement information.
- Under-reporting: Small-scale events are far more common but less reported on. In addition, events that occur in isolated, insecure, or marginalized areas tend to be under-reported because of limited access or media coverage.
- "Invisible" IDPs: There tends to be significantly more information available on IDPs who take refuge at official or collective sites than on those living with host communities and in other dispersed settings. As the vast majority fall into the second category, figures based on data from collective sites are likely to be substantial underestimates [30].

An "Independent review of the humanitarian response to internal displacement" finds that "[M]ost IDPs are not in camps . . . Camps therefore represent just the 'tip of the iceberg' with most IDPs either staying with family and friends, taken in by and living with strangers, renting private accommodations if they can afford to do so, living in official or unofficial emergency shelters (often schools or community centers), or living in makeshift

settlements, for example, on the side of the road, under bridges, in train cars, in destroyed buildings, or even in caves. This is true in both rural, including remote, and urban areas [31] (p. 24)". Cardona-Fox argues that "IDPs living outside formal settlements, where they are not registered or counted, in fact, constitute the majority of the displaced population" and that "[G]overnments, with the primary responsibility to collect data on displacement, often have incentives not to do so . . . Governments routinely minimize displacement estimates even blocking attempts by international organizations to collect and publish more accurate information [32] (p. 627)". As one example, India, with 4.9 million new displacements due to disasters reported by IDMC in 2021, only keeps track of displaced people who live in camps and register themselves [33] (p. 75).

IDMC subtracts net outflows of displaced persons to other countries and does not report net outflows. While people who are displaced more than once in a year may be counted more than once, unreported IDPs are likely to be far more numerous than double- or triple-counted IDPs, and IDMC recognizes that it tends to underestimate true numbers of IDPs.

We have no quantitative basis to estimate how far IDMC's reported IDPs due to weather-related disasters underestimate total numbers of people these disasters displace. Considering, among other factors, that where governments are less effective in collecting data, people are likely to be more vulnerable to displacement, it seems that true numbers of displaced people are likely to exceed IDMC's reported numbers by at least ten percent. This gives a conservative estimate of about 24 million current average annual displacements from sudden-onset weather disasters (21.5 + 2.15, rounded up).

4.1. How Many People Displaced by Sudden-Onset Events Return Home and How Many Find New Homes in Their Country of Residence?

The most significant gap in data on IDPs from our perspective is the number who do not return to their homes and are permanently displaced. With 24 million average annual displacements from sudden-onset weather disasters, even a small proportion becoming permanently displaced contributes significantly to the stock of climate migrants. Relief agencies typically report on total persons in their care but cease reporting when people leave their camps or other sites. One method IDMC uses to estimate numbers of IDPs is to multiply numbers of homes destroyed or seriously damaged by a weather event by the country's average household size [29] (p. 21). For some households, however, the destruction of their home and other property exceeds a threshold beyond which they are unable or unwilling to re-establish their home and/or livelihood at the same location.

To estimate permanent climate migration due to sudden-onset causes, I first consider three examples. The impacts of Hurricane Katrina that hit New Orleans in 2005 are well studied. With floodwaters submerging 80% of the city, sixteen months later, only 58% of former residents had returned. Of households whose homes were undamaged, however, 96% had returned, compared to only 30% of households whose homes were completely destroyed [34]. These floods were largely due to breached levees that were subsequently rebuilt to a higher standard, and threats to New Orleans from climate change were not of grave concern to the general public in the years immediately following Hurricane Katrina. Despite widespread property damage, ten years later, the population had returned to 87% of its 2005 level [35]. We would only expect part of the increase from 2006 to 2015 to have been made up of returnees, so we can conservatively estimate permanent displacements at 20%.

Typhoon Haiyan's impacts on the Philippines (known there as Typhoon Yolanda) are more typical of future climate risk but less well quantified. It hit the Philippines in 2013 with wind speeds of more than 300 km per hour and storm surges of up to four meters, causing unprecedented damage across 44 provinces. "About 16 million persons . . . were affected, of which approximately 4 million (about 890 thousand families) were displaced". The typhoon damaged 1.1 million houses, with more than 550,000 of these reported as destroyed [36] (p. 5). Hundreds of government offices and international agencies were involved in relief

efforts with no comprehensive monitoring. The national government initially promoted a 40 m "no build zone" along affected coastlines, but residential construction in these zones was eventually made subject to the discretion of local authorities. The government planned to build 219,000 housing units to relocate about a million people [37] (p. 7), but as of 2021, eight years later, only 140,000 had been completed [38].

Difficulties in quantifying permanent migration due to Typhoon Haiyan are typical of most sudden-onset climate disasters. No one knows how many people whose homes were destroyed left the region immediately, and, of those housed temporarily by government or international agencies, how many were able to rebuild at or close to the site of their earlier residences. How many moved away is also unknown. If we take the 140,000 housing units the government eventually provided as a conservative basis for estimating permanent displacements, this gives a total of about 640,000 permanent climate migrants or about 16% of the number originally counted as displaced.

Bangladesh suffers both from rising sea levels and from inland floods. Storm surges from hurricanes are becoming increasingly harmful, and it is not unusual for a third of the country to flood as monsoon rains cause rivers to rise. From 2001 to 2011, based on household survey data from the Bangladesh Bureau of Statistics, Ahmed finds 64% of Bangladesh's 13.5 million people who migrated permanently within Bangladesh to be due to economic causes, 72% of this economic migration to be due to environmental hazards, and 33% of this environmental migration to be related to climate change. Of these estimated 2 million permanent climate migrants over 11 years, according to survey responses, 54% were due to coastal hazards and 43% to river erosion and flooding [39]. According to IDMC, from 2008 to 2018, Bangladesh had about 627,000 average annual internal displacements from weather disasters [40]. At a first approximation, then, Bangladesh appears to have had about 182,000 permanent climate migrants a year over the 11-year period of Ahmed's study (2 million migrants due to coastal hazards and river erosion and floods divided by 11 years), or roughly 29% of 627,000 annual IDPs from weather disasters reported by IDMC. (This implies that the remaining 71% returned to their homes.) We do not know how these permanent migrants would be divided between slow- and sudden-onset causes. At a 50-50 split, this gives about a million permanent climate migrants due to sudden-onset causes in 11 years, roughly 15% of total climate migrants in this period.

These three cases—New Orleans, the Philippines, and Bangladesh—are not representative of internal displacements globally due to weather disasters. The selection of both Hurricane Katrina and Typhoon Haiyan over-emphasizes extreme storms, and victims of weather disasters in the Philippines and Bangladesh may be more vulnerable than average, with less-than-average institutional support. Our rough estimates that 20% of total displacements from New Orleans were permanent, as well as 16% from the Philippines and 15% from Bangladesh, are probably above the international average. On this basis, however, it seems reasonable to estimate that permanent displacements world-wide from sudden-onset weather events are likely to exceed 10% of annual displacements. This suggests that the 24 million average annual worldwide displacements we found for the thirteen years from 2008 through 2020 led to a cumulative total of at least 31 million permanent displacements, with the remaining 281 million (or so) returning to their homes.

4.2. How Many People Could Be Displaced by Sudden-Onset Weather Events by 2050?

In 2015, IDMC estimated that after adjusting for population growth, the likelihood of being displaced by a disaster at that time was 60% higher than it was in the 1970s, which we can take to be before the onset of significant climate change [41] (p. 8). For a high-end estimate that assumes weak mitigation and weak adaptation, let us estimate that future displacements from sudden-onset events increase by 40% each decade. In the absence of data that would allow for scientific estimates and in light of the widely observed acceleration in the frequency and intensity of extreme weather events, this is not unreasonable. In this scenario, we expect an average of 33.6 million annual displacements from 2021 to 2030, 47 million in the decade to 2040, and 66 million in the decade to 2050.

With permanent displacements at 10% of annual displacements, the stock of permanent climate migrants increases by the same numbers: 33.6 + 47 + 66 = 146.6 million. Added to the 31 million permanent displacements from 2008 to 2020, this gives a total of 177.6 million, which we round up to 180 million. We also estimate in this scenario that about 59 million people will be displaced by sudden-onset weather disasters and return to their homes in the year 2050 (90% of 66 million).

5. How Many People Could Be Displaced by Slow-Onset Weather Events by 2050?

As suggested above, for the most part, the policy role of estimates of potential climate migration by 2050 has been to convey a sense of the scale of the problem, particularly if mitigation and adaptation are weak. Papers discussing long-term policy related to climate migration such as for the United Nations [42], the European Union [43], and the United States government [44] have often anchored their discussions with estimates of the potential number of migrants in 2050, often with little care for fine points of definition. The public media also routinely anchor discussions of the potential scale of climate migration with estimates for 2050, and, unsurprisingly, the media usually express definitions and methodologies in broad and imprecise terms.

The first statistically rigorous estimates of potential climate migration by 2050 came from the World Bank's two *Groundswell* reports. The first, published in 2018, addressed internal climate migration in Sub-Saharan Africa, South Asia, and Latin America [45]. The second, in 2021, extended the analysis to include North Africa, East Asia and the Pacific, and Eastern Europe and Central Asia (hence excluding North America and Western Europe) [3]. Prior to 2018, Myers' 2001 estimate, often rounded to 200 million, was often cited, although it was also criticized in the academic literature for being methodologically weak as Myers himself had acknowledged.

Groundswell includes three drivers of displacements:

i. water availability in terms of cubic meters per second of river discharge;
ii. crop production in terms of yields in tons per hectare of maize, wheat, rice, and soybeans; and
iii. sea level rise in terms of population living on land up to one and two meters above sea level, respectively, for low- and high-end climate change scenarios.

For measures of water availability and crop yields, *Groundswell* employs a "gravity" model in which continents are divided into grided cells with sides of 0.5 degrees, roughly 55 km at the equator. It uses effects of variations in water availability and crop production on population movements among cells from 1970 to 2010 to predict climate change-driven movements up to 2050. This methodology implicitly defines displacement as movement from one cell to another within a national territory. *Groundswell* bases estimates of displacements due to sea level rise on IPCC (2013) estimates of from 0.157 to 0.322 m sea level rise above current levels by 2050 [46]. Its estimates of population in the one- and two-meter bands are based in part on topographical data from NASA's Shuttle Radar Topography Mission (SRTM) satellite data.

For total displacements from all three drivers, *Groundswell* estimates three scenarios with varied levels of climate action (implying levels of mitigation) and socioeconomic development (implying, among other things, levels of adaptation): an optimistic climate-friendly scenario, an inclusive development, less climate-friendly scenario, and a pessimistic reference scenario. The pessimistic reference scenario assumes weak mitigation and unfavorable socioeconomic development. For each scenario, from its statistical model, *Groundswell* presents central estimates and lower and higher 95th percentile estimates. The widest range of estimates, therefore, of from 44 million to 216 million internal climate migrants by 2050 in the second *Groundswell* report, is from the lower 95th percentile for the climate-friendly scenario to the upper 95th percentile for the pessimistic reference scenario.

Groundswell's upper 95th percentile estimate of 216 million for its pessimistic reference scenario, or 143 million from the 2018 analysis for fewer regions, is the figure that the policy community and the media have generally adopted for the potential number of climate

migrants by 2050. For example, a 2021 U.S. White House "Report on the Impact of Climate Change on Migration" finds that:

> Migration in response to climate impacts may range from mobility as a proactive adaptation strategy to forced displacement in the face of life-threatening risks. This mobility may occur within or across international borders. Specifically, one model forecasts that climate change may lead to nearly three percent of the population (totaling more than 143 million people) in three regions—Sub-Saharan Africa, South Asia, and Latin America—to move within their country of origin by 2050. To date, this mobility has been mostly internal and increasingly an urban phenomenon, with many of those displaced and migrating moving to urban areas. Although most people displaced or migrating as a result of climate impacts are staying within their countries of origin, the accelerating trend of global displacement related to climate impacts is increasing cross-border movements, too, particularly where climate change interacts with conflict and violence. [44]

A 2022 story from the U.S. public broadcasting station entitled "Climate change is already fueling global migration. The world isn't ready to meet people's changing needs, experts say", states that "[o]ver the next 30 years, 143 million people are likely to be uprooted by rising seas, drought, searing temperatures and other climate catastrophes [47]", and Al Jazeera has a 2021 story entitled, "Climate change could displace 216 million by 2050: Report [48]". In the academic literature, noting that at 3 °C warming, "Large parts of the planet would in effect be rendered uninhabitable, prompting a wave of conflict and mass migration that could destabilize the entire world", Chandler writes in a footnote that "According to the World Bank, on our current path more than 200 million people are likely to be displaced within their own countries due to water shortages, crop failure and sea level rise by 2050 [49]".

Groundswell's figures of 143 or 216 million climate migrants by 2050, as upper 95th percentiles for a pessimistic reference scenario, should not be taken as "likely". In a context in which *Groundswell* is mistakenly taken as estimating total internal climate migration, these figures are also high for policy anchors. When we consider all forms and drivers of climate migration, however, it becomes clear that as general high-end estimates, numbers for potential climate migration from *Groundswell*'s pessimistic reference scenario are far too low.

One reason that they are too low is that *Groundswell* data for sea level rise are problematic. While NASA's SRTM was a standard source in 2018, in 2019, Kulp and Strauss point out in a widely cited article that "SRTM models the elevation of upper surfaces and not bare earth terrain", leading to positive global mean bias in the 1–20 m elevation band of at least 1.9 m [50] (p. 2). With a new digital elevation model employing a neural network that reduces vertical bias to between 0.01 and 0.11 m, Kulp and Strauss find populations exposed to dangerous coastal water levels that are at least three times higher than SRTM-based estimates for all scenarios and models they consider. Given that the positive bias they find in land elevation is about six times greater than high-end projections of sea level rise by 2050, their results indicate that prior expectations of population displacements are too low. *Groundswell* does not disaggregate the proportions of its estimates for climate migration that are due to sea level rise as compared to crop yields or water flows, but SRTM's over-estimate of the elevation of land adjacent to the sea will have caused *Groundswell's* estimates to fall below accurate values. If we assume that with better data, *Groundswell*'s estimates would increase by 20%, their high-end estimate of 216 million would rise by 43 million to 259 million.

A second reason that figures from *Groundswell* should not be taken as estimates of total potential climate migration is that it does not include many slow-onset drivers of climate migration. As "the world's definitive source of data and analysis on internal displacement [51]", IDMC distinguishes between "drivers" and "triggers" of internal displacement due to climate change. Like UNFCCC, it identifies the drivers as sea level rise, desertifica-

tion, glacial melt, increasing temperatures, land/forest degradation, loss of biodiversity, ocean acidification, and salinization. It identifies the triggers as loss of livelihoods, food and water insecurity, sudden-onset hazards, and loss of territory [52]. The slow-onset drivers from IDMC's list that *Groundswell* does not consider are desertification (independent of river discharge), glacial melt, increasing temperatures (independent of reductions in yields of maize, wheat, rice, and soybeans), land/forest degradation, loss of biodiversity, ocean acidification, and salinization. Reductions in crop yields other than maize, wheat, rice, and soybeans and reductions in livestock due to degraded pastures can be considered triggers due to slow-onset drivers from IDMC's classification that *Groundswell* neglects.

A central dilemma in estimating future climate migration is starkly apparent in considering migration driven by increasing temperatures. It is only recently that increasing temperatures are significantly increasing health risks, so past studies of effects of temperature on migration, most of which focus on rural areas and use crop yields as an intervening variable (see, e.g., [23]), are unlikely to have strong predictive value. Khavarian-Garmsir et al. argue persuasively, based partly on survey evidence, that increasing heat has contributed to shrinking populations in the cities of Iran's Khuzestan province, where some of Iran's highest temperatures have been recorded, but they do not offer general quantitative estimates [53]. While data from current experience on the response particularly of urban migration to increasing temperatures are inadequate, heat and humidity are likely to rise to unprecedented levels in coming decades. It is reasonable to expect increasing heat and humidity to drive significant migration, but the magnitude is uncertain.

In this context, it is helpful to offer tentative estimates incorporating the pattern of increase it is reasonable to expect. High temperatures influence health and the quality of life, reduce the hours a person can work outdoors, and, particularly when they coincide with high humidity, are directly life-threatening. Extreme heat may be particularly harmful in cities where "heat islands" can raise temperatures up to 9 °C above the surrounding countryside and where pollution and other environmental stressors can exacerbate harms from heat [54,55]. At 1 °C global warming, the number of people exposed to life-threatening combinations of heat and humidity at least one day per year had risen from 97 million to 279 million. It is projected to rise to 508 million at 1.5 °C and 789 million at 2 °C [56]. It is reasonable to expect rates of migration to accelerate as levels of heat and numbers of days in which heat and humidity are life-threatening increase. As temperatures rise to 1.5 °C, we might expect 5% of the 279 million people already experiencing life-threatening heat and humidity to be displaced from their homes, about 14 million people. Should temperatures rise to 2 °C by 2050, as now seems plausible [57,58], we might expect 10% of the 494 million people (508 − 14) newly vulnerable at 1.5 °C, about 49 million, to be displaced, for a high-end estimate of 63 million people (14 + 49). While many heat-driven migrants are likely to be low-income laborers, there are also likely to be disproportionate numbers of elderly migrants in this category due to their greater sensitivity to extreme heat and their greater mobility. Also, heat-driven migrants may on average have greater assets than other categories of climate migrants.

Among drivers and triggers of slow-onset climate migration not considered by *Groundswell*, this leaves declines in other crops and pasturage, desertification, glacial melt, land/forest degradation, loss of biodiversity, ocean acidification, and salinization, insofar as they are independent of factors already addressed. Loss of pasturage and desertification are already driving significant climate migration in a swath of Africa from the Senegalese Sahel in the west to Somalia in the east [59]. Ocean acidification and warming are bleaching corals and reducing fish yields in many places across the tropics, often where fish is the main protein in local diets [60]. Melting permafrost, a form of land degradation, is driving migration in the far north [61]. Many slow-onset drivers are likely to overlap, exacerbating one another's effects, and, as Simpson et al. point out, the scientific literature has not yet come to terms with "the complexity of interactions of multiple drivers of climate change risk and of how multiple risks compound or cascade [62] (p. 489)". If we consider all these factors together, it seems reasonable to suggest that they could cause a high-end

estimate of 37 million climate migrants by 2050, bringing the total for slow-onset drivers not included in *Groundswell* to 100 million. This is obviously very tentative, but it seems to be a reasonable order of magnitude based on general knowledge of these factors. The round number total, 100 million, signals the tentative nature of the underlying estimates.

6. What Is a Reasonable High-End Estimate for Potential Climate Migrants by 2050?

A third reason that figures from *Groundswell* should not be taken as estimates of total potential climate migration is that they only count slow-onset drivers, excluding sudden-onset causes. Above, we estimate potential climate migration from sudden-onset weather disasters at 180 million by 2050, with an additional 59 million short-term migrants in that year. Of course, *Groundswell* makes no claim to include sudden-onset or additional slow-onset drivers. Taking these factors into account and adjusting *Groundswell's* high-end estimate with better data for sea level rise gives a revised high-end estimate of 539 million (180 + 259 + 100). Considering *Groundswell's* 95th percentile estimate for its pessimistic reference scenario to be unreasonably high for policy makers, we adjust our total down to 500 million. This is obviously a very rough estimate, but it is more reasonable for policy makers than 200 or 216 million.

Several other factors could influence this estimate or should otherwise be taken into consideration. This estimate does not consider international climate migration, and it excludes the portion of conflict-driven migration that is indirectly due to climate change. Recall that IDMC does not report numbers of victims of sudden-onset weather disasters who leave their countries of residence. It is widely noted that most climate migrants do not leave their home countries (e.g., [63]), but the proportion that does is likely to increase as climate change causes conditions in some particularly vulnerable countries to deteriorate greatly. *Groundswell's* estimates of slow-onset climate migration due to sea level rise are likely to include some migrants from coastal land driven by sudden-onset weather disasters such as storms, and these would be counted twice in our total estimate (once under sudden-onset and again under slow-onset).

All our sources for estimates of climate migration employ IPCC estimates of potential warming and sea level rise, but a significant minority of climate scientists find these IPCC estimates to be conservative. Notably, James Hansen places greater emphasis on climate patterns from Earth's paleo-history and less emphasis on computer models than the IPCC, and this leads him to arrive at higher estimates for potential warming and for sea level rise [58]. Hansen also finds a cooling effect from anthropogenic aerosols such as sulfur dioxide greater than that found by the IPCC. As countries transition to renewable energy and this cooling is decreased, this factor also leads to greater warming than in IPCC projections. If IPCC estimates turn out to be too low, we can expect greater numbers of climate migrants.

In 2020 the Institute for Economics & Peace (IEP) published a report entitled, "Ecological Threat Register 2020: Understanding Ecological Threats, Resilience, and Peace", stating that "Approximately one billion people live in countries that do not have the resilience to deal with the ecological changes they are expected to face between now and 2050 [64]". In presenting their key findings, IEP states that "Over one billion people live in 31 countries where the country's resilience is unlikely to sufficiently withstand the impact of ecological events by 2050, contributing to mass population displacement [65]". Some media outlets interpreted this finding to mean that there could be over a billion climate migrants by 2050, and this figure subsequently entered the wider public discourse. Although this is an overly simplistic interpretation of IEP's finding, the range of causes underlying IEP's analysis point to plausible interactions between climate change, conflict, and societal breakdown that could significantly increase climate migration above our estimates.

We should also note the ambiguity in terms such as "return home" and "find new homes". We have noted that *Groundswell* implicitly defines climate migration as movement from one 0.5 degree grided cell (about 55 km at the Equator) to another. When someone's home is destroyed by a storm or they have to abandon their farm due to salinization caused

by sea level rise, they may move to a nearby community. They may retain some social connections, access to services, and relevant livelihood skills but still face significant losses. Different definitions of migration applied to a given case could yield significantly different findings and policy conclusions.

Also, we have not taken account of how many displacements due to sudden-onset weather disasters would have occurred in the absence of anthropogenic climate change. Advanced countries arguably bear less responsibility for these displaced persons.

From the present international policy perspective, however, such fine points of distinction are hardly relevant. Humanitarian aid agencies are already over-burdened, and the family of agencies around the UNFCCC that address climate change devote few resources to climate migrants. Climate change has already displaced millions of people. Without great improvements in mitigation and adaptation, the number is likely to rise to closer to 500 million than to 216 million by 2050.

7. What Would It Cost to Support Climate Migrants?

While some climate migrants plan far in advance for the move, it is reasonable to assume that on average, whether driven by slow- or sudden-onset events, climate migrants possess fewer assets than most other classes of migrants. They are likely to need new homes and livelihoods, and host communities that receive many migrants are likely to need to strengthen service infrastructures.

Current international support for displaced persons is found in three main forms:

- people displaced by conflict or disasters who remain in their home country are supported as IDPs, mostly in IDP camps;
- displaced people who cross borders may be supported as refugees, mostly in refugee camps; and
- some refugees recognized as having been displaced by war or persecution and as having a well-founded fear of returning home (but not those identified as displaced by climate change alone) are resettled in new home countries.

Programmatic requirements for helping climate migrants to resettle in their home countries are likely to fall between those for supporting refugees in refugee camps and in new home countries. In 2019, about 71 million people were reported as IDPs [26], 26 million people were supported in refugee camps [66], and 108,000 refugees were resettled in new home countries [67]. In that year, official development assistance allocated to humanitarian aid was reported at $24 billion [68], and $13 billion of this was reported as flowing to refugee-hosting countries. Assuming that most of the remaining humanitarian aid went to support IDPs, this implies $11 billion mostly for IDP camps. In 2019 in-donor-country costs for resettling refugees were about $10 billion [69]. Although these figures involve rough estimates for one year only and do not account for all international funds devoted to supporting displaced persons, they are likely to express reasonable orders of magnitude for official international expenses. Average expenses were about $93,000 per resettled refugee, $500 per camp-based refugee, and somewhat less than $155 per IDP. One should bear in mind when interpreting these expenses that IDPs typically remain in camps for a matter of months while camp-based refugees often remain for many years and may find employment.

In their broad program logic, successful mitigation reduces adaptation needs, successful adaptation reduces numbers of climate migrants, and successful resettlement of climate migrants in home countries is likely to reduce the need for resettlement in other countries. The extent to which climate migrants will be accepted to resettle in new countries depends on host government policies that are hard to predict. Estimating costs for supporting resettlement in home countries obviously involves great uncertainties, but assuming the goal includes securing livelihoods, housing, and basic social services, and acknowledging great variation in costs among countries, the figure is likely to fall between $500 for camp-based refugees and $93,000 for resettling someone in a new country. An estimate of $7000 per climate migrant, or $7 billion for a million climate migrants, does not appear unreasonable as a starting point. We can assume either that the full $7000 per migrant is spent in one year

or that $7000 for each migrant is spread over several years. Costs are likely to be higher in middle- and high-income countries, but they are likely to need less international support.

By way of comparison, IDMC finds that economic costs for the average person living in internal displacement rose from $310 in 2019 to $380 in 2021, with costs in 2021 ranging from $114 in Colombia to $869 in Syria. These costs include the loss in income when people are forced to flee their homes, as well as costs for meeting basic needs in security, housing, health, and education, and they do not distinguish between costs borne by the international community and those borne by host country governments [70]. The Humanitarian Coordination Task Team in Bangladesh, coordinating government, United Nations, and other humanitarian actors, budgets $60 per household per month for complementary multi-sector assistance after a weather disaster, of which 20% is for anticipatory action [71] (p. 55). The Government of Bangladesh's main resettlement program, *Ashrayan*, that supports some Rohingya refugees as well as some Bangladeshis internally displaced by extreme weather events, spends about $4000 for its most basic two-room brick house with a tin room on land it owns, suitable for a small family (other designs are more elaborate and costly [72,73]). Considering that prices in Bangladesh are likely to be below average, altogether, these data support our rough estimates of costs, on average, of less than $155 per IDP and $7000 to resettle a climate migrant.

Recall that about 31 million of 500 million potential climate migrants by 2050 were already displaced by sudden-onset weather events by 2020. Rounding the remainder to 470, this might lead to a distribution such as 70 million people permanently displaced in the 2020s, 150 million in the 2030s, and 250 million in the 2040s. Although it is unreasonable to expect that all climate migrants would remain in their home countries, this assumption establishes a reasonable floor estimate. Under these assumptions and without correcting for inflation, average annual costs would be about $49 billion, $105 billion, and $175 billion in the respective decades. With average annual numbers of people displaced by sudden-onset weather events who return home rising from around 30 million a year in the 2020s to around 59 million a year in the 2040s, average costs for supporting them would rise from below $4.6 billion to below $9.1 billion a year.

8. Discussion

These estimates are obviously rough and can be improved as better data become available. Given the current state of knowledge, best estimates of numbers of current and future climate migrants and of costs for supporting them inevitably depend on "back of the envelope" calculations. All told, without significant improvements in mitigation and adaptation, it is more likely that there will be around 500 million climate migrants by 2050 than around 200 million. Costs for helping migrants to rebuild their lives would likely constitute a significant proportion of advanced countries' financial support for climate action in developing countries.

We can speculate that the UNFCCC has categorized climate migrants under adaptation and largely ignored them partly due to the political sensitivity of immigration in advanced countries, partly to advanced countries' general aversion to taking responsibility for harms beyond their borders from their carbon pollution, and partly to the political weakness of actual and potential climate migrants in developing countries [32]. It should not be surprising if developing country governments have prioritized adaptation needs that appear more immediate and that respond to requirements of established government departments.

Most climate migrants who abandon their homes receive little support from the international community, but among all victims of climate change, harm to their well-being is likely to be particularly great. They generally would not have chosen to leave their homes if not forced by climate change, and many arrive destitute in urban slums. As the future they anticipated is no longer possible, it is important for them and for the wider society that they should gain new livelihoods. They are often likely to arrive in communities that are already stressed, and, as their numbers increase, they may more often give rise to political unrest. If, as IEP hypothesizes, climate migration and other effects of climate change cause

already fragile polities to break down, waves of refugees are likely to be released. Not only do advanced countries bear obligations to climate migrants due to their disproportionate responsibility for climate change, helping climate migrants to rebuild their lives in their home countries is also in advanced countries' political interest.

9. Conclusions and Future Directions

From an institutional perspective, there are good reasons to distinguish support for climate migrants from established UNFCCC categories of "adaptation" and "loss and damage". Up to now, adaptation has largely been understood as adapting existing social and environmental sectors to effects of climate change. The Loss and Damage Fund has largely been conceptualized from a statist or governmental perspective, but needs of climate migrants warrant attention independently from challenges facing established government ministries. Strategies for supporting climate migrants possess an analytic and institutional coherence distinct from protecting agriculture, infrastructure, and other established areas of adaptation. Consequences for urban receiving communities are likely to be institutionally diffuse, crossing jurisdictional and departmental boundaries of service institutions that are already likely to be stressed. To build the unified perspective essential for coherent policy, it makes sense to establish new institutions that have the well-being of climate migrants as their mandate.

It is widely accepted that at a basic organizational level, form should follow function, see, e.g., [74,75]. When, in the late 1980s, the World Bank was found to give inadequate attention to environmental concerns, it led to the establishment of the Global Environment Facility [76] (pp. 709–711). Later, in the early 2000s, when acquired immunodeficiency syndrome (AIDS) was breaking out across the developing world, it led to the establishment of the U.S. President's Emergency Plan for AIDS Relief (PEPFAR) [77]. Functional requirements of environmental protection and of combatting AIDS were distinct enough from established development activities to justify creating new organizations. Considering requirements for supporting climate migrants to rebuild livelihoods compared to approaches of organizations supporting climate change mitigation and adaptation and those of traditional humanitarian aid agencies, the same logic applies.

I do not wish to underestimate political challenges inherent in establishing reasonable support for climate migrants. Since the formation of the UNFCCC, advanced countries have avoided taking direct responsibility for harms from their carbon pollution [1]. Not only budgetary requirements but also institutional challenges in implementing coherent programs are formidable. While large-scale climate migration once appeared as a distant possibility, today, it is upon us. Without diminishing the urgency of mitigating climate change, the human and political costs of continuing to neglect climate migrants have simply become too great.

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