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Nature-dependent people: Mapping human direct use of nature for basic needs across the tropics

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ABSTRACT

Understanding where people depend the most on natural resources for their basic human needs is crucial for planning conservation and development interventions. For some people, nature is a direct source of food, clean water, and energy through subsistence uses. However, a high direct dependency on nature for basic needs makes people particularly sensitive to changes in climate, land cover, and land tenure. Based on more than 5 million household interviews conducted in 85 tropical countries, we identified where people highly depend on nature for their basic needs. Our results show that 1.2 billion people, or 30% of the population across tropical countries, are highly dependent on nature. In places where people highly depend on nature for their basic needs, nature-based strategies that protect, restore or sustainably manage ecosystems must be carefully designed to promote inclusive human development alongside environmental benefits.

1. Introduction

Nature provides people everywhere with multiple benefits that help maintain their quality of life. These benefits include food provision, water purification, construction material, and recreation opportunity (Díaz et al., 2018; MEA, 2005). Although all people depend on nature for their well-being, some population groups more directly depend on nature to satisfy basic human needs than others. For these population groups who lack the assets needed to escape poverty, the benefits directly derived from nature are indispensable (Bennett et al., 2015). For many others, nature represents an irreplaceable cultural value (Díaz et al., 2018). Improving understanding of environmental changes and their effects on people has been the goal of recent global scientific assessments on biodiversity and climate change (IPCC, 2014; IPBES, 2019). Likewise, prioritizing populations who are “most vulnerable and in need” is a global political and moral objective as expressed in the Sustainable Development Goals (UNGA, 2015: preamble and paragraph 8), the Paris Agreement (UNFCCC, 2015: preamble and article 7.2) and ongoing negotiations around the post-2020 Global Biodiversity Framework to be ratified under the Convention on Biological Diversity (CBD) in 2021. However, studies on the connections between nature and people usually focus on the benefits that can be provided by nature rather than on people’s needs for maintaining their well-being, which has not been consistently evaluated to date across multiple countries (Chaplin-Kramer et al., 2019; Isbell et al., 2017).

Although billions of people worldwide are estimated to satisfy at least part of their basic needs by using nature as a primary source of livelihood, energy, water, or food (MEA, 2005), we lack detailed information on where they are and how much they depend on nature. While previous studies have demonstrated the magnitude of people’s dependency on nature, they are not spatially explicit (Chaplin-Kramer et al., 2019), cannot be aggregated or are not consistently estimated globally (Newton et al., 2016; Yang et al., 2013). For example, around 40% of the world’s population, or 3 billion people, depend solely on biomass (e.g. wood or leaves) for cooking and heating (Openshaw, 2011; WHO, 2006). Around 500 million people live directly from the proceeds of smallholder farming activities (IFAD and UNEP, 2013) that together with forestry and fishing activities represent 70% of the income of households in tropical rural areas (Angelsen et al., 2014). Over 800 million people live without improved sources of drinking water, such as pipes or pumps (WHO, UNICEF, 2010) and directly rely on rivers, streams or groundwater. Meanwhile, more than 1.3 billion people build

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their homes using forest products (FAO, 2014).

Here, we provide the first globally consistent assessment of the number of people who are highly dependent on locally available natural resources to meet their basic needs, as well as their location, based on household surveys representative at the sub-national level. We defined nature-dependent people as those that directly depend on locally available natural resources for at least three of the four basic needs considered, i.e. housing materials, water, energy, and occupation (see Methods). Traditional development pathways have often overlooked people's relationships with nature (IPBES, 2019) and a limited understanding of the importance of nature in directly supporting people's basic needs risks perpetuating poor or unsustainable development outcomes. Nature-based strategies can provide positive benefits for both nature and people. Therefore, quantitative information about the critical role that nature plays for some populations is urgently needed to develop targeted and effective nature-based strategies that promote equal and just adaptation to climate change and sustainable development for all (Chaplin-Kramer et al., 2019; Guerry et al., 2015; Yang et al., 2013). Although nature-based strategies are often assumed to provide social benefits, especially for the most vulnerable people, they rarely explicitly distinguish the dependencies of different groups on nature (Woroniecki et al., 2019) and potential trade-offs with development interventions (McShane et al., 2011). Identifying populations that directly depend on nature for their basic needs and, therefore, are most sensitive to environmental change, can help guide the prioritization and design of more effective, equal and just nature-based strategies that can support the well-being of people while conserving nature (Daw et al., 2015a; Erbaugh et al., 2020).

2. Methods

2.1. Study design

Identifying the contribution of nature to basic human needs requires locally specific datasets that capture multiple social-ecological interactions and are comparable across countries. We used publicly available datasets from three main sources: the USAID's Demographic Health Survey (DHS), UNICEF's Multiple Indicator Cluster Surveys (MICS), and national statistics offices' household surveys or census (NHS). These surveys use standardized questions to record socio-demographic characteristics. When multiple sources for the same country were available, our criteria for selection were based on the most complete dataset publicly available, the most recent release date, and the highest subnational level representativity (see SI Appendix, Table S2). Although the surveys were primarily designed for assessing health or living conditions, many questions included information related to the uses of nature for basic human needs. We focused on countries in the tropics because people in this region are usually more vulnerable to changes driven by climate and land uses and are dependent on nature for their livelihoods. The combined dataset included more than 5 million surveyed households from 85 countries or territories (hereafter referred to as 'countries') and 1,111 sub-national regions (see Table S2). The selected surveys were conducted between 2010 and 2018, mostly by the DHS (44) and the MICS (23) programs, followed by national statistic offices' surveys. The combined dataset is based on samples that represent 98% of the population of the tropics (i.e. the remaining 2% were related to data missing or collected before 2010 in Venezuela, Malaysia, Equatorial Guinea, Cuba, and Eritrea). We used weighted observations that are representative at the national and sub-national levels (usually the first sub-national administrative level such as regions, departments, or states), which were calculated by the survey designers based on the household selection probability (e.g. see Rutstein and Kiersten, 2004 for DHS).

2.2. Basic human needs

In our analysis we focused on those aspects of human well-being that nature can directly help fulfill and are considered essential for basic needs. While basic human needs are claimed to be universal, they can be satisfied differently depending on cultures and time (Doyal and Gough, 1984; Max-neef, 1992). There have been many definitions of human well-being, for a review see Alkire (2002) and Table S2. Based on some of these studies, the Millennium Ecosystem Assessment (2000) showed how nature can contribute to all the components of human well-being, including "basic material for good life" (e.g. adequate livelihoods and income, enough food and water, shelter, and energy). Subsequently the IPBES embraced this view and highlighted the multidimensional perspectives of human well-being that include material, non-material and intrinsic values (Díaz et al., 2015).

Our four selected dimensions of basic needs cover especially the provisioning services of ecosystems, but also some regulating services. Due to high local specificity and lack of comparable indicators we did not include cultural services in our global study, even though they are also important aspects of nature contributions to human well-being and possibly basic human needs. For example, nature can provide sources of inspiration that are essential for education or mental health (Millenium Ecosystem Assessement, 2005).

2.3. Mapping direct use of nature and nature-dependent people

Although all humans depend on nature for their well-being, some population groups more directly and immediately depend on locally available nature to satisfy basic needs than others. We argue that the amount of direct use of natural resources for basic needs by certain households is an expression of how dependent they are on nature, and therefore can be a suitable proxy indicator for identifying their dependencies on natural resources. Other studies have used such proxy indicators to explore people's dependence on ecosystems at national or lower levels (Balbi et al., 2019; Hamann et al., 2015; Raudsepp-Hearne et al., 2010). Here we consider nature-dependent people as those that directly rely on locally available natural resources to fulfill their basic needs. The nature-dependent people indicator is composed of four dimensions related to the direct use of nature for basic human needs and includes the sources of 1) housing materials, 2) drinking water, 3) fuel for cooking (energy) and 4) main occupation. Variables for each dimension were chosen based on their importance in supporting basic human needs, information availability and comparability across all the surveys used (see Table S2 and Data S1 for harmonization table). The selected indicators are widely recognized in assessing the relations between human well-being and nature and have been used in local studies to assess the direct use of nature (Balbi et al., 2019; Hamann et al., 2015). The four selected indicators cover several aspects of the "basic material needs" component of well-being as described by the Millenium Ecosystem Assessement (2005) and other studies on human well-being (see section above).

We assessed the level of dependency of people on nature by using the answers from household surveys that referred to the use of nature-based sources for each of the four selected dimensions (see Table 1). We focused on sources of water, energy, housing materials and occupation that were provided directly by nature and locally available. For classifying nature-dependent households we only included answers related to each of the four dimensions that were based on a direct use of nature without technological improvements (see specific household survey questions and categorization in Table 1). For example, nature-dependent for energy included households that used natural materials or biomass as a main source of energy for cooking (i.e. wood, charcoal, agricultural crop residue or straws/grass/shrubs). We harmonized the possible answers related to the four dimensions across all the surveys (see Data S1). The number of possible answers related to each four dimensions varied across survey type. For example, for energy sources

Table 1
Summary of the household survey questions and answer categories used to calculate the dependency of the household on nature for energy, water, housing and occupation. For an exhaustive list of variable codes and their harmonization see Data S1.

Variable	Household survey question	Answers related to/dependent on nature	Other answers (not exhaustive)
Energy ($energy_h$)	*What type of fuel does your household mainly use for cooking?*	wood, charcoal, agricultural crop residue, straws/shrubs/grass, dung	electricity, butane/Liquefied Petroleum Gas (LPG), kerosene, biogas
Water ($water_h$)	*What is the main source of drinking water of members of your household?*	surface water (rivers, stream lake, …), rainwater collection, spring (protected or unprotected), well (protected or unprotected)	piped water into dwelling, piped water into compound, piped water into neighbor, boreholes, tank tracker or cart, bottled water
Housing ($floor_h$)	*What is the main material of the dwelling floor (observation)?*	wood, earth/sand, mud, clay, bamboo or palm, dung	cement/concrete, vinyl, ceramic tiles, parquet, briks, carpet
Occupation($occup_h$)	*What is your occupation? That is, what kind of work doyou mainly do?* (DHS and NHS only) *What is your (husband's/partner's) occupation? That is,what kind of work does he mainly do?* (DHS and NHS only) *Does any member of this household own land that can be used for agriculture? Does this household own any livestock, herds, other farm animal or poultry?*	agricultural, forestry and fishery workers (skilled or unskilled)	technical professionals, managers and administration, clerical support workers, services and sales, industrial workers, domestic services

there were 10 possible answers on average, for water sources 13 answers, for housing materials 9 answers, and for occupation 11 answers. Since respondents could only choose one answer, we simply aggregated the nature-based answers to assess each dimension (see Table 1).

With a few exceptions, the questions regarding the household characteristics are very similar across all the surveys (Mexico, Fiji and French territories -French Guyana, Guadalupe, Martinique and La reunion), and therefore did not require any additional treatment. However, the information regarding individuals' main occupation is not collected systematically in the surveys. For instance, in the MICS surveys there is no information about occupation. To account for this, we used the combination of two other variables in the MICS dataset, namely the ownership of land used for agriculture and the ownership of livestock. Since these questions were also included in the DHS surveys, we estimated the correlation coefficient using a probit model, controlling by households' characteristics (e.g. sex of the head of the household, number of household members). We also included country and sub-national regions as random effect variables to account for unobserved characteristics that may alter the results. The specification of the probability function is provided below:

$$Pwa_{hj} = \beta_0 + \rho_1 agriculture_{hjc} + \delta_i X_{ihjc} + \sigma_c + \sigma_r + \varepsilon_{hj}$$

$$\widehat{Pwa}_{hj} = \widehat{\beta_0} + \widehat{\rho}_1 lnd_{hj} + \widehat{\delta}_i X_{ihj} + \widehat{\sigma_c} + \widehat{\sigma_r}$$

Where $agriculture_{hjc}$ corresponds to the agricultural land or livestock ownership variable, X_{ihjc} are the control variables at the household level,σ_r and σ_c are the country and sub regional random effect variables. $\widehat{Pwa}_{hj}$ is the predicted probability used to determine whether a household has a member working in agriculture. The results of the marginal effect of the *probit* estimations are presented in the Table S2.

2.4. Nature-dependent people indicator

To compute the nature-dependent people indicator, we categorized households depending on their characteristics related to the four dimensions of basic human needs based on the surveys. The unit of analysis was the household, but we aggregated information at the sub-national region (usually the first sub-national administrative level), testing to ensure that data were representative. To calculate the level of nature dependency of a household, we added each human basic need dimension that the household directly derived from nature as follows:

$$levelofnaturedependency_h = water_h + energy_h + floor_h + occupation_h$$

Where $water_h$, $energy_h$, $floor_h$, and $occupation_h$ take value of either 0 (not directly derived from nature-based sources) or 1 (directly derived from nature-based sources). The level of nature dependency (l) takes values from 0 (very low level or no dependency on nature) to 4 (very high level of dependency on nature). We computed the total proportion of households with a given level of dependency (l) in each sub-national level by dividing the count of households at this level by the number of households in a sub-national level. To quantify the proportion of households highly dependent on nature we summed the proportions of categories 3 and 4, which account for high and very high level of dependencies respectively.

2.5. Geospatial analysis

We conducted spatial analyses using qGIS 3.01 combining information on nature-dependent people with administrative regions, population counts, and land uses (protected areas and anthromes). The most recent shapefiles for the different administrative boundaries were downloaded from the GADM v.3.6 database (GADM, 2020). We used the population numbers data in 2015 from the Gridded Population of the World database v4 (CIESIN, 2018) with populations estimates at different sub-national levels adjusted according to official United Nations World Population Prospects information from national census. For the protected areas we used the World Database of Protected Areas and followed their methodology to analyze protected areas by country (WDPA, 2020). For the analysis of land uses we used information on the anthropogenic biomes for 2015 that are derived from an overlay of population, land use and land cover data (Ellis et al., 2020). We calculated the proportion of wild and semi-natural lands, as well as the other anthrome types. For the comparison with poverty-related indicators we used the wealth index that is included in DHS and MICS surveys as well as human development index (UNDP, 2019).

3. Results

Our results indicate that around 1.2 billion people in the tropics, or 30% of people living in tropical countries, are highly dependent on nature to meet their basic human needs, defined here as directly relying on locally available natural resources for at least three of the four basic needs considered: housing materials, water, energy and occupation (Table S4). This number increases to 2.7 billion (or 69%) when we consider the people that are dependent on nature for at least one basic need (Fig. S6). There are important variations in the proportion of people that depend on nature across continents, countries, and sub-national regions (Figs. 1 and 3). At the continental level, the largest number of highly nature-dependent people live in tropical Asia-Pacific (636 M or 27% of the total population in that region), followed by Africa (478 M or 48%) and the Americas (48 M or 9%).

The largest proportion of people who highly depend on nature per country is found in Africa (Fig. 1). A vast majority of people (greater than 75%) in several African countries highly depend on nature, especially in the central and eastern regions, including Burundi, the Democratic Republic of Congo, Chad, Ethiopia, Rwanda, Central African Republic, Niger, and Madagascar. In South-East Asia, a large proportion of people per country (greater than 40%) are nature-dependent, especially in Papua New Guinea, Cambodia, Laos and Timor-Leste. Another region in which countries have a large proportion of nature-dependent people (greater than 25%) is Central America, particularly in Nicaragua, Guatemala, and El Salvador. Africa has the largest continuous area with a high proportion of nature-dependent people, as more than 50% of people in all sub-national regions in many countries are highly dependent on nature (including Guinea, Guinea Bissau, Chad, Congo, Central African Republic, Ethiopia, Burundi and Rwanda). In contrast, several countries outside the African continent have many sub-national regions with a low proportion of highly nature-dependent people (e.g. in Indonesia and Brazil).

Moreover, the combination of basic needs derived from nature that underpin the dependency relationship also varies globally and across continents (Figs. 2-3). Most people who depend on nature in the tropics do so for energy sources (31% of total people in the tropics categorized as nature-dependent or 1.19 billion) followed by occupation (29% or 1.11 B), housing materials (29% or 1.10 B), and water (16% or 633 M). At the continental level, in tropical countries in Africa, the most important basic need derived from natural sources is energy, in the Americas, occupation and in Asia, housing materials (Fig. S1). In Africa, most nature-dependent people (53% or 249 M) rely on nature for all four basic needs.

The proportion of nature-dependent people across different land uses and human development profiles reveal mixed patterns (Fig. 4A and B). Regarding land uses, there is no significant association ($r^2 = 0.004$, $p < 0.0001$) between the proportion of nature-dependent people per country and the proportion of their wild- and seminatural lands (based on the classification of anthropogenic biomes or anthromes) (Fig. 4A). However, there is a positive association when considering Asia-Pacific countries only ($r^2 = 0.30$, $p = 0.18$), a small positive association for countries in Africa ($r^2 = 0.12$, $p < 0.001$) and a small negative association for countries in the Americas ($r^2 = 0.03$, $p < 0.001$). In addition, there was no significant pattern regarding the proportion of nature-dependent people and the area under nature protection at the sub-national level (Fig S2). Information on the proportion of nature-dependent people and the proportion of semi-natural and natural areas reflects the past land use strategies and can indicate appropriate nature-based policy and management strategies for current and future situations. For example, depending on the condition and extent of natural areas, different strategies (nature protection, sustainable management, restoration, or hybrid approaches) can be implemented to support nature-dependent people (Fig. 4A).

We found a negative correlation between nature-dependent people and the human development index, which combines life expectancy, education, and income per capita indicators (see Fig. 4B). This negative correlation is clearer for countries in the Americas ($r^2 = 0.51$) and Africa ($r^2 = 0.47$), but less for those in Asia-Pacific ($r^2 = 0.23$). This result empirically supports the generally acknowledged positive association between high poverty and high human dependency on nature, which has not been previously shown at the global level. In addition, our analysis also shows that households with the same level of poverty can have heterogenous level of dependency (see Fig. S4).

4. Discussion

4.1. Shifting towards more just and sustainable development

The crucial contribution of nature to the development of vulnerable population groups is at the core of global sustainable development efforts (e.g. SDGs), yet we lack information on where such contributions are the highest. Sustainable development requires strategies that avoid or mitigate negative environmental and social sustainability issues (Hamann et al., 2015) and exclusion of vulnerable population groups (FAO, 2020; Newton et al., 2016). As shown by our analysis, in several regions in the tropics, nature is the primary resource for meeting basic needs for a high proportion of people (30% of the population or 1.2 billion people). This figure is similar to the World Bank's estimates of 1.6

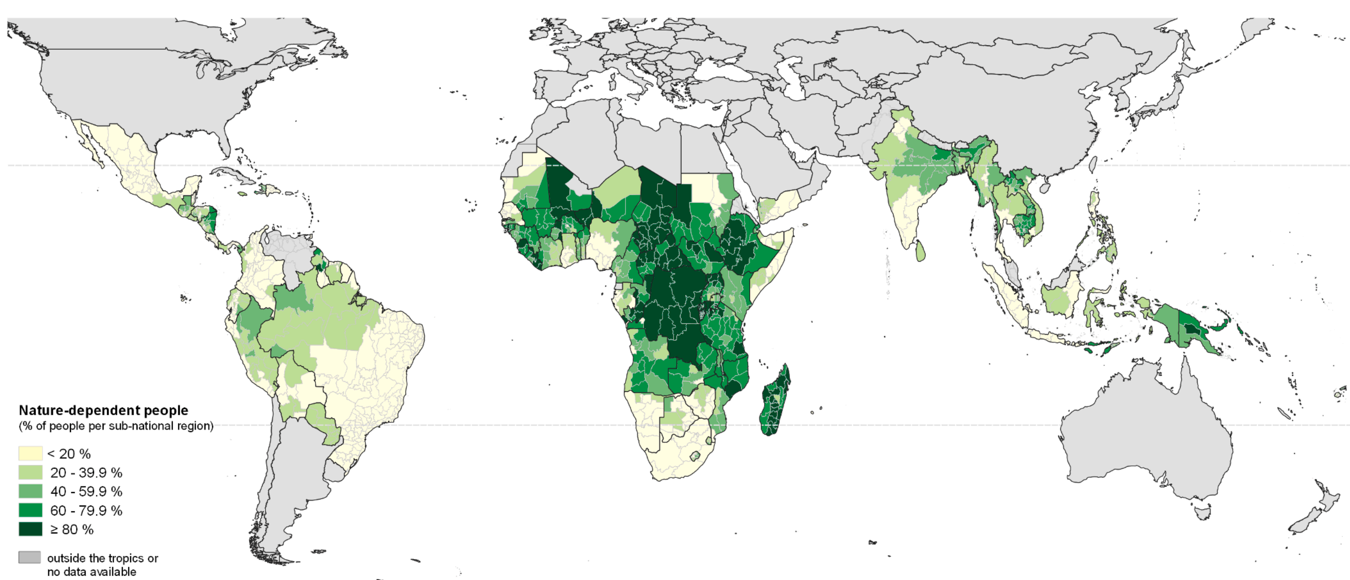

Fig. 1. Proportion of people that highly depend on nature to fulfill their basic human needs at sub-national level across the tropics (30% on average across the tropics). Nature-dependent people are defined as those that directly use natural sources for at least three of the four basic needs considered: housing materials, water, energy, occupation.

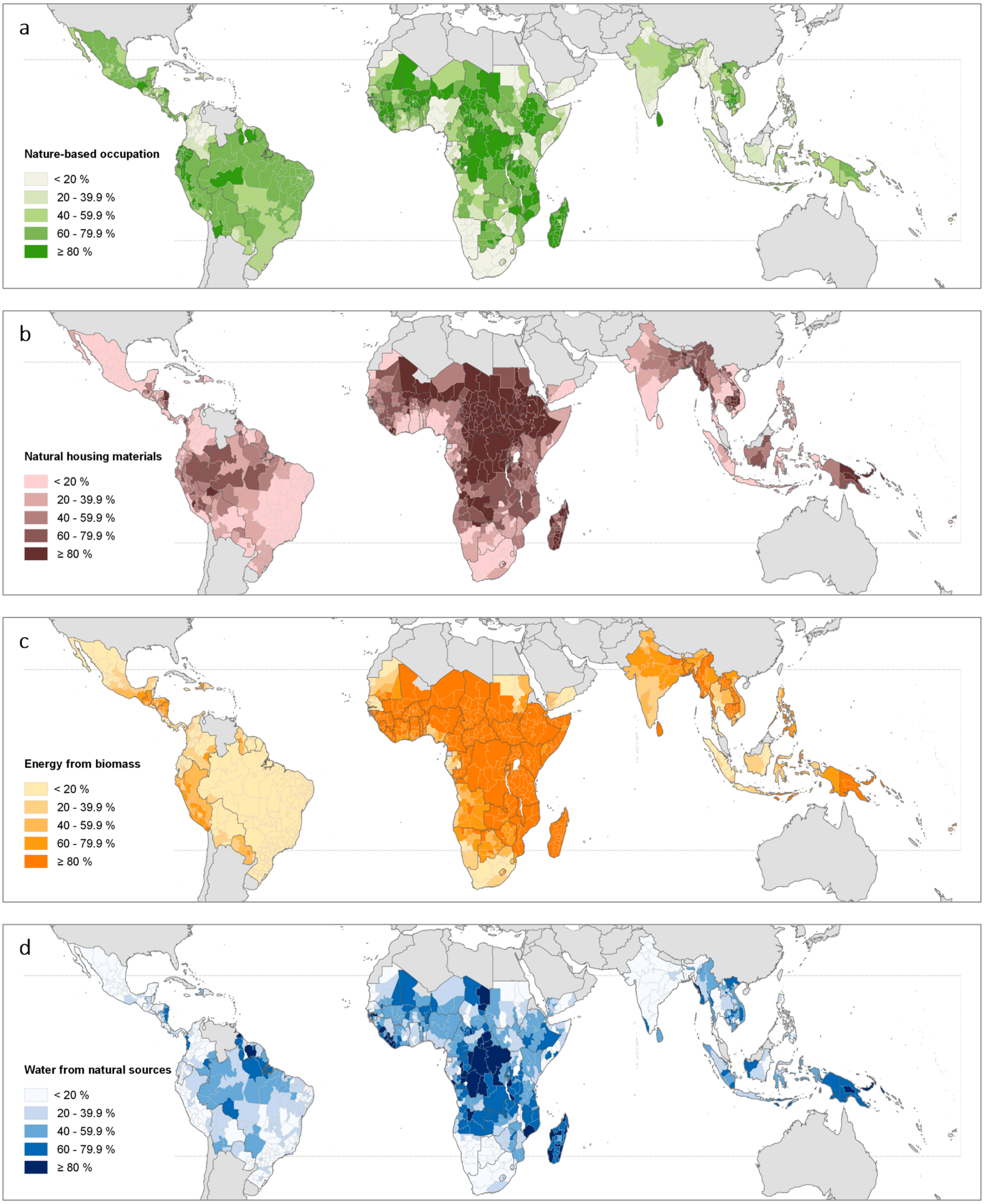

Fig. 2. Proportion of people at sub-national level that use nature as a primary source for (a) occupation (e.g. agriculture, forestry, fishery) 40% on average across the tropics, (b) housing materials (e.g. wood, bamboo, dung) 36% on average, (c) energy (e.g. wood, charcoal, straws) 55% on average, or (d) water (e.g. rivers rainwater, spring) 22% on average. For details on the nature-based sources used by households to meet each basic need considered see Table 1 and for the percentages see Supplementary Data 2.

billion people globally that depend on forests for their livelihoods to some extent, and of 1.2 billion people that rely on agroforestry systems in developing countries (World Bank, 2002). We identified high proportions of nature-dependent people in Central and East Africa and parts of the north-west Amazon and South-East Asia. These places are also among those most lagging in pursuit of their economic development and in meeting their populations' basic needs (UNDP, 2019). As indicated by our results, in several countries in central and eastern Africa, more than 75% of the population depend on nature for their basic needs.

As societies develop economically and transition to urbanization, they tend to reduce their direct dependence on nature to meet basic needs (Cumming et al., 2014; Sanderson et al., 2018). Changes in the nature dependency of people over time is commonly observed in the poverty–environment literature (Cavendish, 2000; Vedeld et al., 2007)

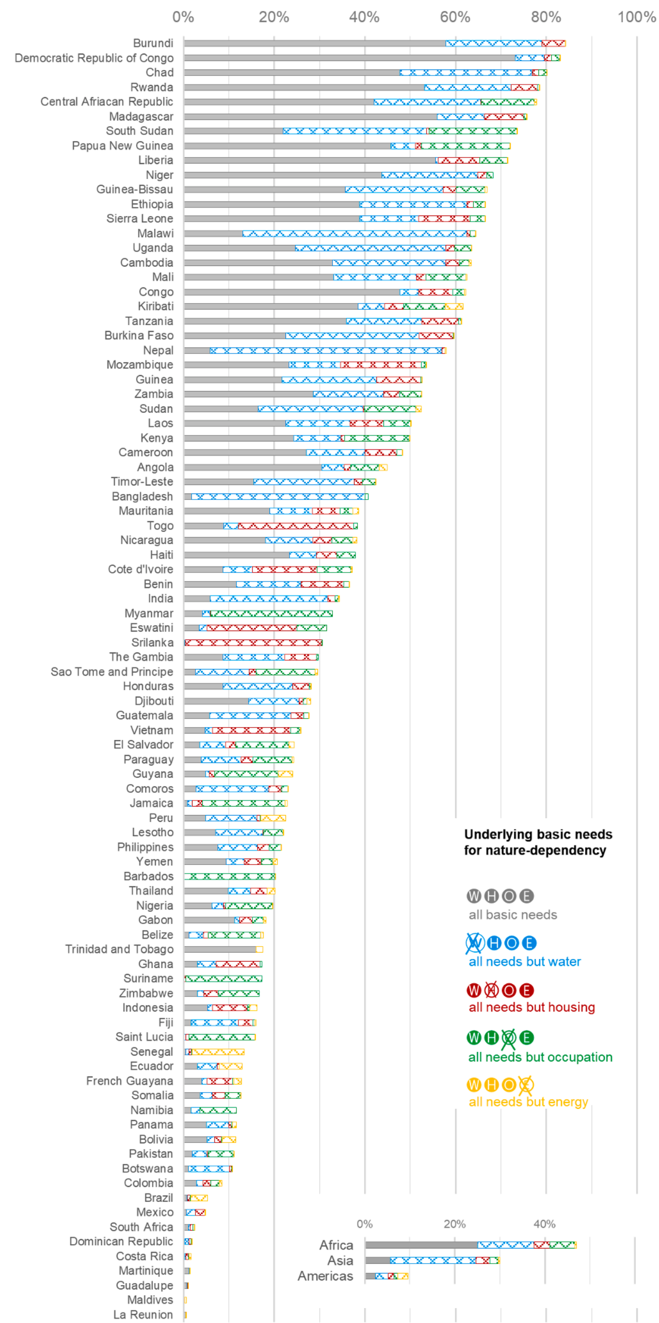

Fig. 3. Proportion of nature-dependent people per country. The colours indicate the underlying basic needs that are derived from nature, either 4 needs (solid bar in grey = all four basic needs) or 3 needs (striped bars, blue = all basic needs but water sources, yellow = all but energy sources, red = all but housing materials, green = all but occupation). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and is explained by several drivers that either push or pull households towards diversifying livelihood strategies (Ellis, 2000). In some cases, the degradation of nature and the resulting reduction of benefits provided to people push them out of direct use or dependency on nature. In other cases, attractive alternative opportunities arise and people choose to replace the direct use of nature with those alternative options. Nevertheless, according to our analysis, there are many places, regions, or countries where people still primarily use natural resources for their basic needs (totaling 30% of people in the tropics). These places may often represent “green-loop” systems, i.e. systems with high direct dependence on local ecosystems in which populations rely on and sustainably manage local ecosystems to provide their resources (Cumming et al., 2014). However, some places with “green-loop” could transition towards unsustainable uses of natural resources (e.g. due to high demands, destructive management practices). Systems in a ‘green-loop’ may also transition away from this stable state when they start relying on natural resources or alternatives produced somewhere else due to markets that provide more attractive options or needed replacements to insufficient local supply (Cumming et al., 2014; Grimm et al., 2008), which could result in improved sustainable uses of the remaining nature in those places.

4.2. Assessing complex relationships between nature, land use and human development

Our analysis of nature dependency and human development provides empirical evidence of the association between poverty and natural resources acknowledged in other studies (e.g. Hamann et al., 2015; Schleicher et al., 2018; Vedeld et al., 2007) – but rarely, if ever, at the global scale. Information on the type and degree of dependency of people on nature can complement commonly used development and environmental indicators, and adds deeper equity and sustainability perspectives (Alkire and Santos, 2014; UNDP, 2019). The negative correlation between nature-dependent people and the human development index demonstrated in this study reflects the interdependencies between human development and nature (Fig. 4B). The geographic co-location of people who are highly dependent on nature and have a low human development ranking, highlights both the lack of alternative options to meet basic needs, but also the importance of natural resources for meeting those needs. This is in line with previous studies indicating how high levels of direct use of natural resources are usually associated with people who have limited market access, high poverty rates, and strong cultural ties to nature (Berkes et al., 2001; Angelsen et al., 2014). These dependencies result in closely coupled social-ecological systems in which the sustainable use of natural resources is often hard to achieve or maintain.

Our results indicate that the proportion of people highly dependent on nature for basic human needs is not systematically correlated with the proportion of wilderness areas (Fig. 4A). The relationships between people and nature are influenced by multiple drivers and feedbacks that can explain the lack of correlation as people are pushed or pull towards different livelihood strategies (as described in the previous section). Modified or non-natural systems (e.g. gardens, croplands, and rangelands) also provide some basic needs for people, as defined in our study. For example, agriculture for subsistence needs, burning wood from plantations, crop residues and dung for energy needs, and using earth, mud or clay for housing needs are met through nature-based sources, but they do not necessarily come from semi-natural or wild areas. In addition, there might be some time lag between the conversion of natural areas into more highly modified landscapes and the reduction of some of nature’s benefits and uses. Another possible explanation is that in some places, particularly in more economically developed ones, people may not highly depend on nature because they have access to alternative sources to fulfill their basic needs (e.g. technologies, services, or non-nature-based income), and hence can afford to conserve some wild or semi-natural areas for recreation or other less extractive uses. This could also help explain the lack of correlation between the proportion of nature-dependent people and wilderness areas in countries in the Americas compared to countries in Africa and Asia-Pacific, where there was a small positive correlation.

4.3. Leveraging nature’s potential to support human development

In regions where people have a high dependency on nature, implementation of appropriate strategies that protect, sustainably manage, and restore natural and modified ecosystems (i.e. nature-based

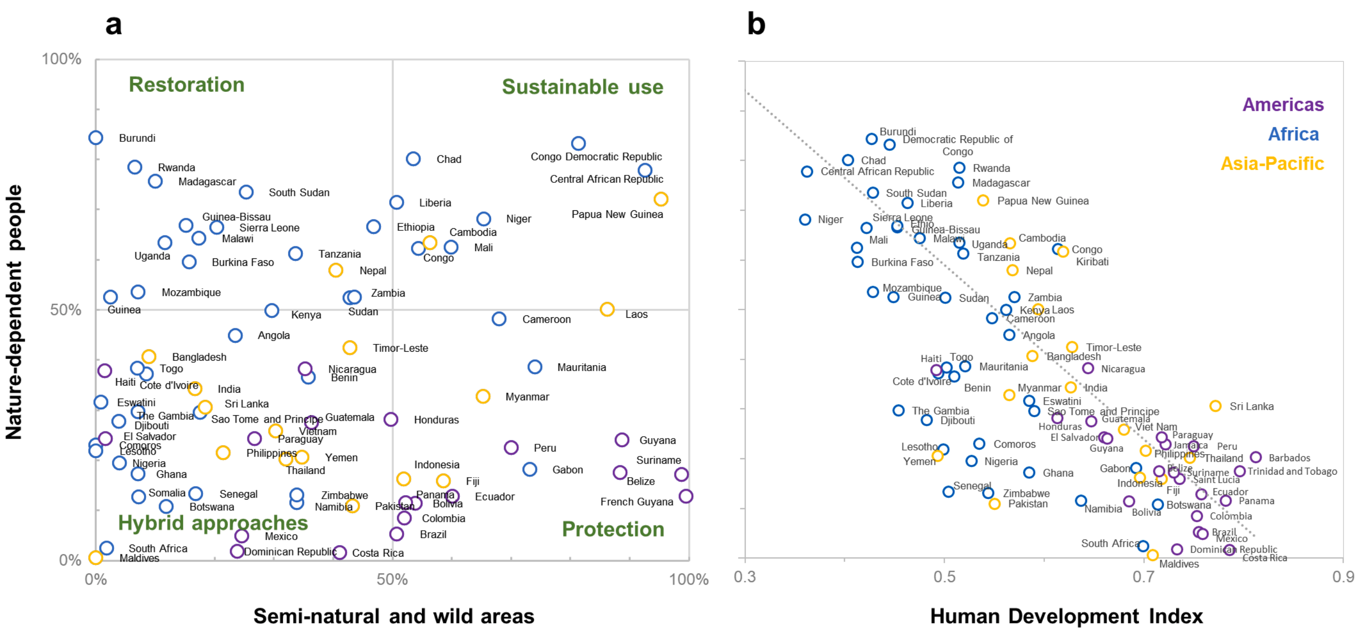

Fig. 4. Country-level proportion of highly nature-dependent people by the proportion of natural areas (A) and human development (B). A: proportion of nature-dependent people per semi-natural and wild lands, which are areas with low population density and land-use intensity as per classification of anthropogenic biomes (Ellis et al., 2020). Depending on the combination of nature-dependent people and land conditions, different nature management strategies can be most appropriate to balance social and environmental needs (in green). B: proportion of nature-dependent people in per country by their human development index (HDI), which combines life expectancy, education, and per capita income indicators, displaying a significant negative association ($r^2 = 0.56$, $p < 0.0001$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

strategies Cohen-Shacham et al., 2016) may represent the best option for achieving multiple local development outcomes while maintaining or improving the extent and condition of nature (Fig. 4A and B). For example, protecting patches of old-growth forests for climate mitigation can also provide forest products (e.g. wild fruits, honey) and flood protection benefits for communities, contributing to their livelihood needs (Donatti et al., 2020; Jones et al., 2012). Such nature-based strategies are likely relevant in places like northern Peru, where there are still a high proportion of wilderness areas but low proportion of people who directly depend on nature for basic needs (e.g. Fig. 4A, quadrant 'protection'; Pyhälä et al., 2006). Sustainably managing coastal ecosystems and mangroves for coastal protection can also provide firewood, which many people depend on for cooking, and would be relevant in central Papua New Guinea and other places with a high proportion of nature-dependent people and wilderness areas (e.g. Fig. 4A, quadrant 'sustinable use'; Page et al., 2016). Restoring grasslands to improve livestock production can also support water regulation services and help people that rely on rivers or springs for clean water, especially during extended dry periods. These type of nature-based actions could help people in eastern Kenya, where wilderness areas are scarce, but a high proportion of people still directly depend on nature for their basic needs (e.g. Fig. 4A, quadrant 'restoration'; Leauthaud et al., 2013).

The recognition of the needs of nature-dependent people in international policy fora and by funding agencies that help address global environmental challenges, such as climate change and land degradation, can strengthen the transition towards more just and sustainable development. Indeed, multilateral environment-related funds, such as the Green Climate Fund and the Global Environmental Facility, have begun requiring demonstration of how their investments directly benefit people, especially the most vulnerable. Multilateral environmental agreements such as the Paris Climate Agreement (under the UNFCCC) and the new global biodiversity framework in negotiation under the CBD, both include references to human rights and equitable uses of natural resources. In addition, the proposal to increase the protection of 30% of the lands and seas for biodiversity conservation by 2030 has gained attention in CBD negotiations (Dinerstein et al., 2019). Our findings support calls of previous studies for such proposal to consider the potential social and economic implications when deciding the areas to protect and the governance arrangements because they can restrict natural resources uses (Schleicher et al., 2019), for example for nature-dependent people. Strategies that protect, restore and manage nature sustainably to address societal challenges represent a promising approach to improving human development, but only if they can demonstrate positive impact for the most vulnerable groups.

4.4. *Understanding human dependencies to design locally appropriate nature-based strategies*

Recent studies have identified global priority areas for nature-based solutions for climate change mitigation — areas where nature can be protected or restored to preserve high carbon stocks (Brancalion et al., 2019; Goldstein et al., 2020; Griscom et al., 2020). It can be tempting, however, to focus on places offering the most cost-efficient or most feasible outcomes based on a single priority, like carbon stock (Holl and Brancalion, 2020). Using narrow nature management approaches that focus on a few (and particularly global) benefits increases the risk of overlooking trade-offs (Otto-Portner et al., 2021). Appropriately managing the environment, for example, by protecting areas for biodiversity or carbon stocks in places with nature-dependent people, must also involve multiple-use considerations, including that of human needs under various scenarios of development and drivers of changes (Armitage et al., 2012; Daw et al., 2015b).

The methodological approach to assess the use of nature for basic needs applied in this study can be scaled down using similar survey questions to those used here but implemented at low administrative levels. Local studies can also use more specific questions targeting other basic needs from and uses of nature, which can be retrieved from censuses or collected through ad-hoc surveys that are representative at low administrative levels. In these surveys the direct use of nature for cultural or spiritual reasons can also be included, as well as other locally specific needs. The information on the direct use of natural resources can also be combined with other datasets to spatially assess synergies or trade-offs between the different contributions of nature to people (e.g. biodiversity conservation, carbon sequestration, water regulation).

5. Conclusion

We have identified, for the first time, places where people primarily use nature to meet their basic needs, adding an environmental dimension to issues of human development and vulnerability. We found that around 1.2 billion people in the tropics, or 30% of the population in that region, are highly dependent on nature for their basic needs. There are high proportions of nature-dependent people in relatively continuous areas in Central and East Africa, and parts of the north-west Amazon and South-East Asia. Our study highlights that business-as-usual development practices that overlook people's relationships with nature risk exacerbating the burden on population groups that are extremely vulnerable to environmental changes. Likewise, nature conservation and management practices that do not consider people's dependencies on nature can fail or overlook an opportunity to contribute to human development and well-being. Considering nature's contribution to basic human needs in the design of environmental policies and management interventions ensures that they not only support global priorities on climate or biodiversity, but also help meet the local needs of the most vulnerable people, resulting in more effective and just nature-based solutions to address societal challenges.

6. Data and materials availability

All data are available in the Supplementary materials or in the publicly accessible databases of the organizations that conducted the household surveys. Summary data and interactive visualizations are available at ndp.resilienceatlas.org.

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CRediT authorship contribution statement

Giacomo Fedele: Conceptualization, Methodology, Software, Formal analysis, Data curation, Visualization, Writing – original draft. **Camila I. Donatti:** Formal analysis, Writing – original draft. **Ivan Bornacelly:** Software, Formal analysis, Data curation, Writing – review & editing. **David G. Hole:** Conceptualization, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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