Tools4LDN Technical Report on Monitoring Progress Towards UNCCD Strategic Objective 2

A Review of Publicly Available Geospatial Datasets and Indicators in Support of UNCCD Strategic Objective (SO) 2:

To Improve Living Conditions of Populations Affected by Desertification, Land Degradation, and Drought

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WOCAT
World Overview of Conservation Approaches and Technologies

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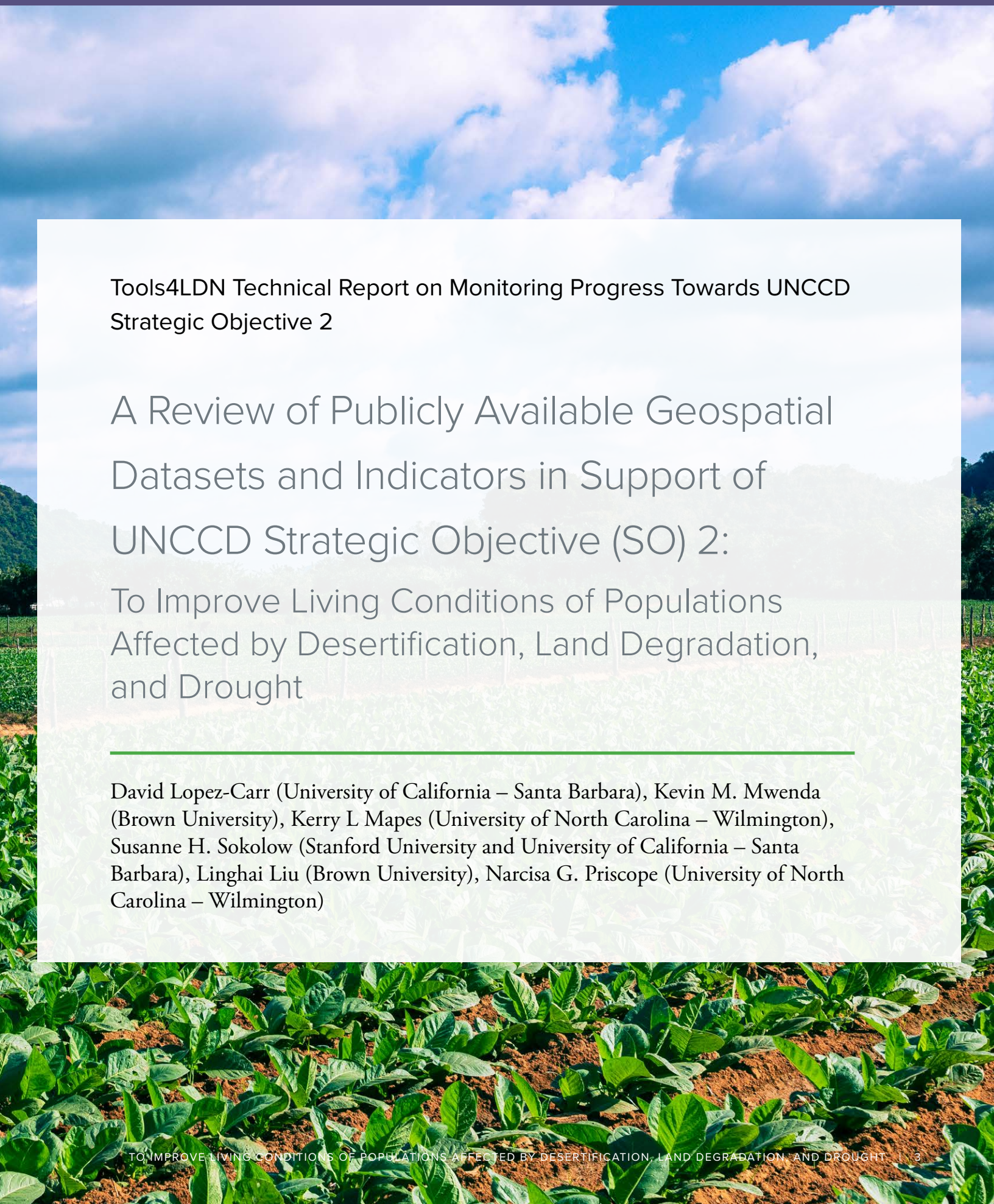

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Acronymns

AVHRR HRPT	Advanced Very High Resolution Radiometer High Resolution Picture Transmission System
BWS	Baseline Water Stress
CEISIN	Center for International Earth Science Information Network
CI	Conservation International
DHS	Demographic and Health Surveys
DLDD	Desertification, Land Degradation, and Drought
ERS	Economic Research Service
ESA	European Space Agency
ESA CCI-LC	European Space Agency Climate Change Initiative-Land Cover
FAO	Food and Agriculture Organization of the United Nations
FEWSNET	Famine and Early Warning Systems Network
FIES	Food Insecurity Experience Scale
GAP	Gender Action Plan
GDI	Gender Development Index
GEF	Global Environment Facility
GEIH	Gran Encuesta Integrada de Hogares
GHI	Global Hunger Index
GHSL-MOD	Global Human Settlement Layer – Settlement Model
GID-DB	Gender, Institutions and Development Database
GII	Gender Inequality Index
GLRD	Gender and Land Rights Database
GM	Global Mechanism of the UNCCD
GMAS	Global Multi-Hazard Alert System
GNI	Gross National Income
GPG	Good Practice Guidance
GPS	Global Positioning System
GPW	Gridded Population of the World
GRACE	Gravity Recovery and Climate Experiment
GRACE-FO	Gravity Recovery and Climate Experiment Follow On
HDI	Human Development Index
HDR	Human Development Report
HEA	Household Economy Analysis
HWISE	Household Water Insecurity Experiences
IFL	Intact Forested Landscapes
ILO	International Labour Organization
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPC	Integrated Phase Classification
IPU	Inter-Parliamentary Union
IPUMS-International	Integrated Public Use Microdata Series, International
IUCN	International Union for the Conservation of Nature
IWI	International Wealth Index
JMP	Joint Monitoring Program
JRC	Joint Research Center of the European Commission
KIHBS	Kenya's Integrated Household Budget Survey
LCCS	Land Cover Classification System
LDN	Land Degradation Neutrality
LMIC	Low- and Middle-Income Countries
LSMS	Living Standards Measurement Survey
LULC	Land Use/Land Cover
MERIS	Medium Resolution Imaging Spectrometer
MICS	Multiple Indicators Cluster Survey
MPI	Multidimensional Poverty Index
MRLC	Multi-Resolution Land Characteristics
NASA	National Aeronautics and Space Administration
NEET	Not in Education, Employment or Training
OECD	Organization for Economic Co-operation and Development
OPHI	Oxford Poverty and Human Development Initiative
ORNL	Oak Ridge National Laboratory
PCA	Principal Component Analysis
PoU	Prevalence of Undernourishment
PPI	Poverty Probability Index
PPP	Purchasing Power Parity
PROBA-V	Project for On-Board Autonomy-Vegetation
SDG	Sustainable Development Goal

Acronymns

SEDAC	Socioeconomic Data and Applications Center
SO	Strategic Objective
SPI	Science-Policy Interface
SPOT	Satellite Pour l'Observation de la Terre
TWS	Terrestrial Water Storage
UN	United Nations
UN IGME	United Nations Interagency Group for Child Mortality Estimation
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
USAID	U.S. Agency for International Development
USDA	United States Department of Agriculture
VCM	Vicious Circle Model
WBL	Women Business and Law
WEAI	Women's Empowerment in Agriculture Index
WHO	World Health Organization
WMO	World Meteorological Organization
WRI	World Resources Institute
WWAP	World Water Assessment Programme
WWF	World Wildlife Fund

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1. SO2 Report Overview

Addressing the global challenges of desertification, land degradation, and drought (DLDD) is a key component of the 2030 Agenda for Sustainable Development.

1.1 Executive Summary & Recommendations for SO2

Addressing the global challenges of desertification, land degradation, and drought (DLDD) and their impacts on coupled human-environmental systems is a key component of the 2030 Agenda for Sustainable Development. In particular, Sustainable Development Goal (SDG) 15.3 aims to, *by 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world*. Addressing this challenge is essential for improving the livelihoods of those most affected by DLDD and for safeguarding against the most extreme effects of climate change.

To meet these challenges and, specifically to achieve SDG 15.3, and Strategic Objective 2 (SO2) of the United Nations Convention to Combat Desertification (UNCCD), we look to Strategic Framework for 2018-2030 (Decision 7/COP.13), which aims *to improve the living conditions of [DLDD] affected populations*. It sets a priority to support country Parties to effectively monitor changes in DLDD, and the human dimensions associated with those changes. Towards this end, this report recommends priority datasets, variables, and indices for monitoring DLDD in the context of SO2 and its expected impacts: food security and adequate access to water for people in affected areas are improved; the livelihoods of people in affected areas are improved and diversified; local people, especially women and youth, are empowered and participate in decision-making processes in combating DLDD; and migration forced by desertification and land degradation is substantially reduced.

To facilitate country-level implementation of UNCCD SO2 and related SDGs through the Trends.Earth monitoring tool, this report aims to assist country Parties in following a standardized framework for assessing human vulnerability to DLDD. The report provides a background on processes and relevant research that underpins monitoring recommendations for SO2 expected outcomes. Secondly, the report develops a conceptual DLDD framework at the individual, household, community, and regional levels. Third, major terms are defined and prior UNCCD and partner work summarized. Fourth, inclusion/exclusion criteria for datasets are outlined. Data that are freely available, have a global (or nearly global) spatial coverage, provide sub-national observations, and permit gender disaggregation are prioritized. Selected SO2 relevant datasets that fail to meet one or more of our inclusion criteria are mentioned

for complementary analysis purposes. Fifth, datasets and their SO2-pertinent indices and variables are identified and summarized. Thematic and spatio-temporal caveats are considered, and alternative and complementary datasets are discussed. For human exposure and livelihoods monitoring, priority datasets include WorldPop's gridded 100m global estimation of population density and Demographic and Health Surveys (DHS) data. DHS data, where available, are a rich source of data on water access, health outcomes, and gender empowerment. The Famine and Early Warning Systems Network (FEWSNET) and the National Aeronautics and Space Administration (NASA) provide additional and potentially useful food security data. WorldPop Migration Flows and Integrated Public Use Microdata Series International (IPUMS-International) provide sources of migration data with several caveats. With respect to land and water resources and sustainable management, Intact Forested Landscapes (IFL), NASA Trends in GRACE (for Gravity Recovery and Climate Experiment) and Copernicus and European Space Agency (ESA) land cover data are useful complementary datasets. Sixth, integrated monitoring best practices for each of the four SO2 expected impacts are presented along with alternative monitoring approaches for member nations lacking priority data. The report concludes with a discussion of limitations, opportunities, and future considerations.

1.2 Introduction

1.2.1 Background and Significance of the UNCCD and SDGs

This report supports SO2 of the United Nations Convention to Combat Desertification (UNCCD) Strategic Framework for 2018-2030 (Decision 7/COP.13) (1). We evaluate approaches for understanding human and ecological vulnerability and resilience to desertification, land degradation, and drought (DLDD) and we identify priority datasets, variables, and indices for monitoring DLDD in the context of SO2 and its four expected impacts:

The COP.13 Strategic Framework acknowledges the global challenges of DLDD, and its contributions to "economic, social, and environmental problems" that "pose serious challenges to sustainable development". It notes that addressing DLDD will involve long-term integrated

Strategic Objective 2: To improve the living conditions of affected populations

Expected impact 2.1 Food security and adequate access to water for people in affected areas is improved.

Expected impact 2.2 The livelihoods of people in affected areas are improved and diversified.

Expected impact 2.3 Local people, especially women and youth, are empowered and participate in decision-making processes in combating DLDD.

Expected impact 2.4 Migration forced by desertification and land degradation is substantially reduced.

strategies that simultaneously focus on the improved productivity of land and the rehabilitation, conservation and sustainable management of land and water resources. The vision of the Strategic Framework is:

"A future that avoids, minimizes, and reverses desertification/land degradation and mitigates the effects of drought in affected areas at all levels and strives to achieve a land degradation-neutral world consistent with the 2030 Agenda for Sustainable Development, within the scope of the Convention (Decision 7/COP.13)."

This report builds on the monitoring principles outlined in the Good Practice Guidance (GPG) for SO1. Similar to the SO1 GPG, here we define the SO2 component parts followed by an assessment of priority datasets and measures. SO1 is the UNCCD Strategic Objective most closely linked to SDG Target 15.3 – Land Degradation Neutrality (LDN). Additionally, SO1 aims to "improve the condition of affected ecosystems, combat desertification/land degradation, promote sustainable land management and contribute to land degradation neutrality (2)."

Globally consistent and publicly available geospatial data enable country Parties of the UNCCD to effectively report on LDN in the absence of suitable national data. While the guidance suggests that national data are the preferred resource for reporting, global default data is provided to assist country Parties when data are absent, or to complement and enhance national data, subject to validation and reporting by national authorities. For successful and timely monitoring and evaluation of country Party progress toward SDG goals and cognate UNCCD Objectives, it is critical to develop methods and tools for assessing DLDD and for understanding the socio-economic conditions of vulnerable communities in affected areas using free and open geospatial platforms. However, more work is needed to better understand the human dimensions of vulnerability in relation to DLDD, especially when attempting to create a globally standardized monitoring approach. Further, there is a need to identify suitable datasets, metrics, and indices for progress assessment. Therefore, this report develops a framework for human population vulnerability to DLDD and identifies suitable datasets, metrics, and indicators to facilitate country-level implementation of UNCCD SO2 and related SDGs through Trends.Earth. The Trends.Earth[1] platform was developed by Conservation International (CI) scientists, with support from the Global Environment Facility (GEF), with the goal of enhancing GEF and UNCCD monitoring and reporting. The tool permits country Parties to access the most suitable data on land status and trends through an innovative cloud and desktop-based tool. The tool interweaves local data with global and national-scale information and remotely sensed imagery. Spatial resolution of the integrated data depends on the data sources used.

In decision 11/COP.14, as a framework to track and monitor populations exposed and vulnerable to drought, the UNCCD adopted a tiered drought indicator and monitoring framework consisting of three complementary levels largely based on the World Meteorological Organization (WMO) Global Multi-Hazard Alert System (GMAS), and the **Risk = Hazard x Exposure x Vulnerability** model (1). This report follows this three-tiered monitoring framework.

1 Trends.Earth. Conservation International. Available online at: http://trends.earth. 2018.

Below we introduce report objectives followed by a review of work to date on pertinent monitoring approaches. We discuss a conceptual approach for human dimensions of DLDD at the individual, household, and community scales. Following this, in Section II we review and discuss appropriate datasets and indices for monitoring SO2 progress and conclude (Section III) with considerations for application and propose potential next steps for developing global DDLD monitoring and development frameworks and tools.

1.2.2 Objectives of the Report

- To develop a synthesis report on global datasets to complement or enhance progress towards SO2, or to facilitate reporting where the use of national-level data for analysis is not possible.
- To examine, identify, and recommend global socioeconomic datasets to complement or enhance progress towards SO2 and to examine spatial patterns of SO2 component parts and how men and women are affected by and respond to drought, land degradation and desertification.

1.2.3 A Famework for Strategic Objective 2: To Improve the Living Conditions of Affected Populations: Vulnerability & Resilience to DLDD

Vulnerability is generally considered a function of human exposure to a stressor, effect (also termed sensitivity or potential impact) and the recovery potential to that stressor (also termed resilience or the capacity to cope with or adapt to slow or fast-onset changes) (3,4). In the context of DLDD, the vulnerability of human beings and their livelihoods is integral in the SO2. Livelihoods are intimately linked to DLDD and can have positive and/or negative consequences on DLDD. This is especially the case with migration where a move may have net positive impacts in one location and potentially net negative outcomes in the other location (or vice versa). As shown in **Figure 1**, livelihoods connect to DLDD most intimately in developing regions where a large percentage of the population depends on local natural resources. In such instances, livelihood decisions have a direct impact on the environment and thus on LDN efforts. Conversely, developed world and urban populations often have a greater impact on DLDD secondarily, vis a vis the impact of their consumption, often in remote locations.

Following **Figure 1**, SO2 sub-objectives are coupled in complementary synergies or in mutually deleterious processes. Households will respond to DLDD in one or multiple ways simultaneously or sequentially. Responses can be to components of demographic, political, socio-economic, and environmental processes at global, national, and local scales, and/or household and individual scales (5–9). Households and individuals facing DLDD-related resource scarcity may respond economically by changing their livelihood strategy and/or they may respond demographically, e.g., by delaying one or more births or by out-migration (domestically or internationally, temporarily or permanently, among select household members or the entire household) as depicted in **Figure 1** (6–10). Changing food consumption patterns, water conservation, land use, labor, capital investments, and fertility are common first-line DLDD adaptation responses that can occur within the context of other stressors sequentially or simultaneously by one (or more) household member. Once *in situ* options have become exhausted (e.g., water and land management and/or off-farm labor, and fertility changes), adaptation strategies may include the decision for a household member or the entire household to out-migrate, often to an urban center. Once a decision, or series of decisions, is made, other responses ensue, and the household once again is faced with external structures and processes that shape subsequent decision making. Wherever they are located, the agency of individuals and households to make multiple sequential and simultaneous decisions in response to DLDD will unfold within political-economic structures and environmental processes at multiple scales (10).

1.3 Human Dimensions of Desertification, Land Degradation, and Drought

1.3.1 Strategic Objectives 1 - 3

In decision 18/COP.13, the UNCCD has endorsed a scientific conceptual framework for LDN which provides a scientifically sound basis to understand LDN, to inform the development of practical guidance for pursuing LDN, and to monitor progress towards the LDN target.

SO2 To Improve Living Conditions of Affected Populations

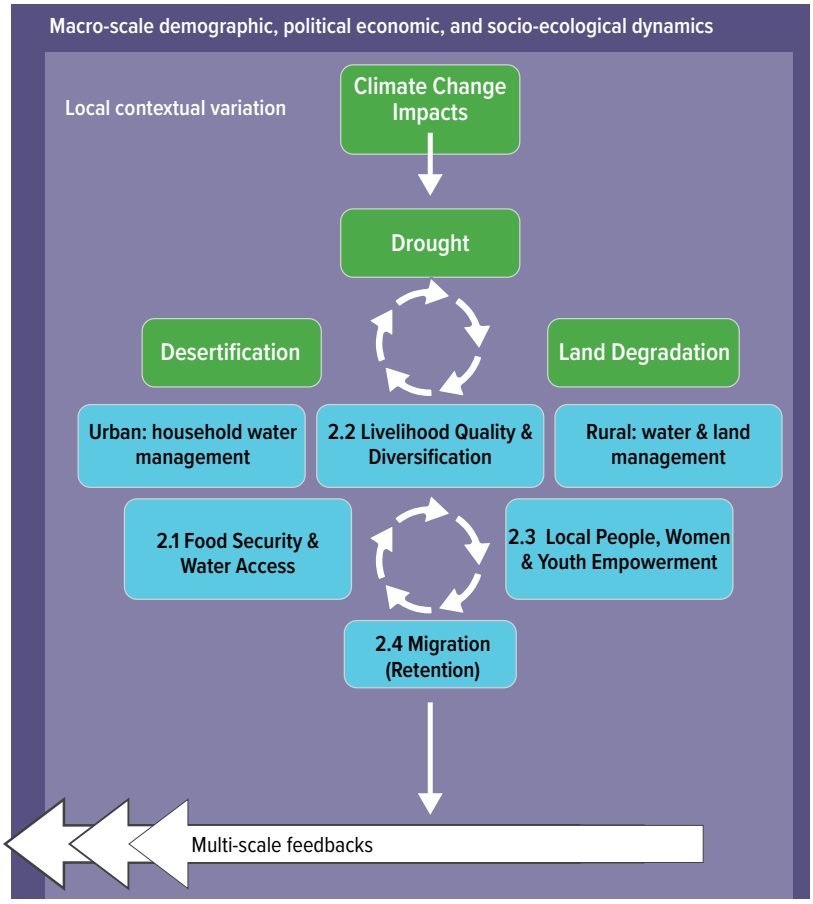

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Figure 1. SO2 Community (blue) and ecosystem (green) vulnerability and resilience to DLDD. The 4 sub objectives are linked in a cycle. Synergistic ''virtuous'' cycles empower local people, women, and youth, improve food security, water access, and livelihood quality and diversity while decreasing migration.

Additionally, the Good Practice Guidance (GPG) for SDG Indicator 15.3.1 provides methodological guidance on how to calculate the extent of land degradation for reporting on SDG Indicator 15.3.1. An updated and revised version of the GPG was being finalized at the time of writing this report. To facilitate the implementation of GPG recommendations, Trends.Earth, a free and open-source platform, provides standardized methods and priority datasets for land degradation assessments. Over 130 countries have been trained in the use of Trends.Earth as a land degradation monitoring tool. Daldegan et al. (2) review publicly available datasets which could improve monitoring for the three SDG 15.3.1 sub-indicators: trends in land cover, land productivity, and carbon stocks. The authors present several spatially-explicit datasets at spatial resolutions with sufficient granularity (i.e., 10 – 30 m) to assess human drivers of land degradation. Pricope et al. (11) review publicly available datasets and indicators to support monitoring of drought hazard, exposure, and vulnerability; with future efforts aimed at incorporating these recommendations into the Trends.Earth platform to support SO3 reporting.

The focus of SO2 on improving the living conditions of affected populations is distinct in theme and in scale from SO1 and SO3. Thematically, the livelihoods of people in affected areas include multiple human and natural characteristics of local environments, including adequate access to food and water, either directly through subsistence livelihoods, through sufficient income to purchase food and water security, or a combination of both. If food and water security are achieved, out-migration from affected areas should no longer be forced but rather voluntary in nature. Whereas SO1 and SO3 focus on DLDD, SO2 delves into the human dimensions of DLDD, including the socio-economic components of vulnerability and resilience to DLDD. When dealing with the human dimensions of DLDD, the appropriate scale

of analysis is no longer the ecosystem, as in SO1 and SO3, but rather the anthropomorphic: individual, household, and community (as shown in **Figure 1**). SO2's 4 sub-objectives are cyclically connected. Synergistic "virtuous" cycles empower local people, women, and youth, improve food security, water access, and livelihood quality and diversity while decreasing migration. Conversely "vicious" cycles unfold when the converse occurs.

1.3.2 Livelihoods

Socially and economically marginalized populations, communities and households tend to be disproportionally vulnerable to climate change and the combined effects of DLDD. The ability to identify and quantify the makeup, distribution, and relative vulnerability of such populations, communities, and households is critical in reinforcing livelihood resilience in order to enhance positive adaptations to DLDD (12). Livelihoods encompass how people, either individually at the household level or collectively at the community level, obtain the necessary resources for survival and their respective capacities and ways of living. Major factors that combine to make up a livelihood include food, income, and assets. Environmentally sustainable livelihoods maintain or enhance the assets on which livelihoods depend at various scales. Livelihoods are socially sustainable when they successfully adapt to stresses and shocks, such that they can continue to provide for future generations.

A livelihoods framework characterizes households as making decisions regarding livelihood activities based on available natural, social, human, physical, and financial capital. The examination of different types of capital allows for a more complete understanding of population, poverty, and environment relationships. Pertinent to assessing DLDD, de Sherbinin et al. (13) have demonstrated that the livelihoods framework can be applied to assess a vicious circle model (VCM) of population, poverty, environment, and climate dynamics. According to the VCM, positive feedbacks at the household level among population growth, poverty, and environmental degradation lead to a downward spiral for poor households. Similarly, the sustainable livelihoods approach improves understanding of the livelihoods of the poor (**Figure 2**). It organizes the factors that constrain or enhance livelihood opportunities and shows relationships among them. This approach helps to plan development activities and to assess the contribution that existing activities have made to sustaining livelihoods.

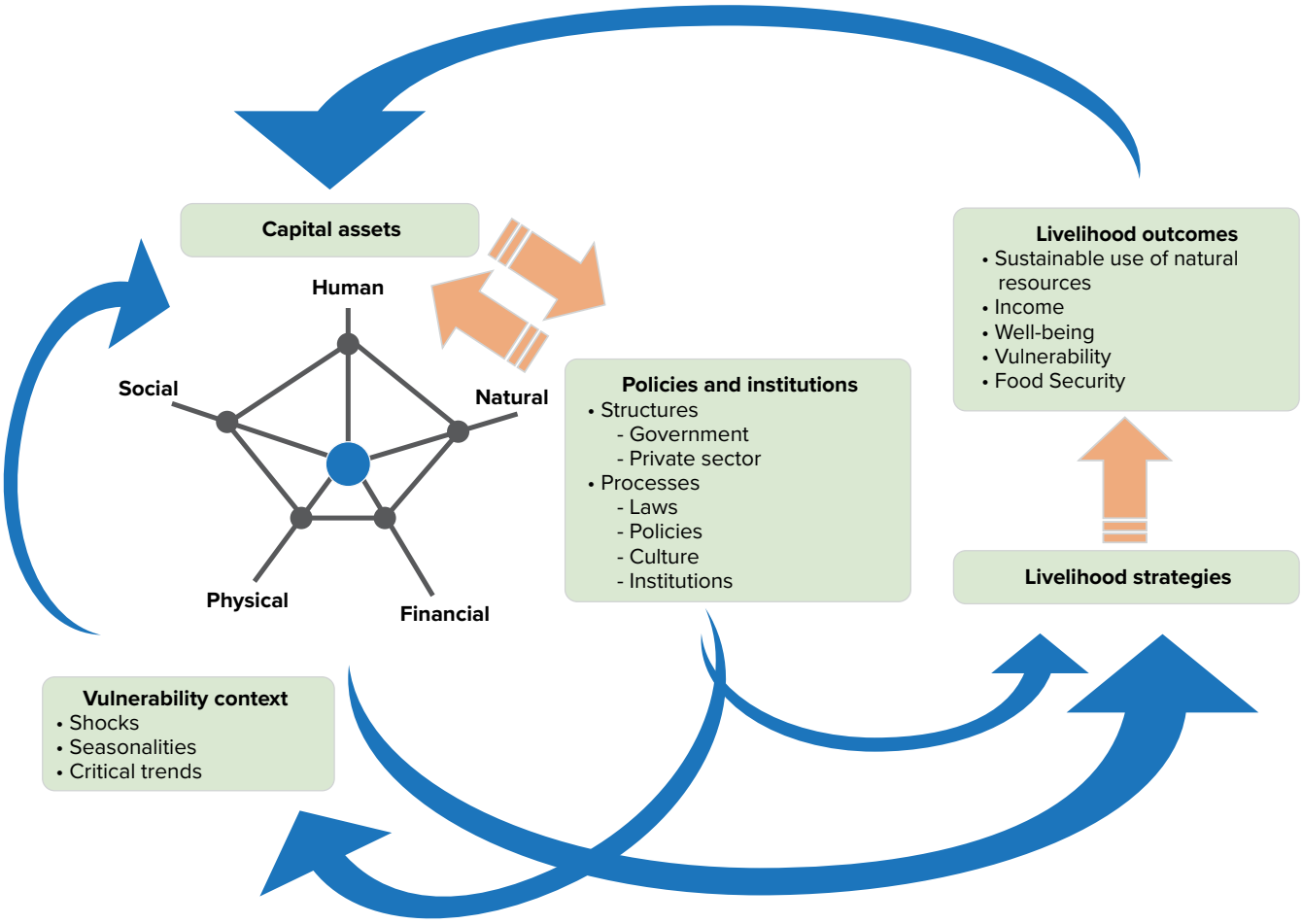

Figure 2. The sustainable livelihoods approach improves understandings of the livelihoods of the poor and relevant outcomes for populations and ecosystems. Adapted from Serrat (14).

As a brief introduction to the general topic, below we share some definitions of key terms and a summary of the broader issue of challenges and opportunities to building resilience to climate change and DLDD.

In a briefing note published by the UNCCD, data gathered from over 800 subnational regions demonstrated that places with the highest proportion of degraded land have the most adverse socio-economic performance, both in terms of high poverty rates and high levels of income inequality (15). Linkages can also be explored in the reverse direction, which is how poverty, income, and wealth can induce land degradation under certain circumstances. The UNCCD concluded that investing in LDN acts to reduce poverty and inequalities. Thus, monitoring approaches should prioritize poverty and/or inequality in areas affected by DLDD. Based on the work done for this publication, UNCCD is currently working on a methodological note for a new SO2 indicator to monitor trends in the proportion of the population exposed to land degradation by sex and potentially age, which would complement the drought exposure indicator included under SO3.

1.3.3 Food and Water Security

Food security is a critical dimension of the health and wellbeing of households and communities. Sustainable Development Goal 2, *to reduce hunger by 2030 to zero*, is unlikely to be achieved in this timeframe given that the number of people who suffer from **food insecurity** (defined as the *disruption of food intake or eating patterns because of lack of money and other resources*) and hunger has begun to slowly increase since 2015 to reach 750 million people in 2019 (United Nations SDGs [2]). Reduced food security, malnutrition, and **hunger** cause diverse negative outcomes, both in children and adults and may pose severe deleterious effects on the long-term health of affected populations, even with short-term exposure. Hunger is commonly measured by the prevalence of **undernourishment** – SDG Indicator 2.1.1; where undernourishment means that a person is not able to acquire enough food to meet the daily minimum dietary energy requirements over a period of one year.

The United Nations (UN) Food and Agricultural Organization (FAO) defines hunger as being synonymous with chronic undernourishment. The FAO conceptualizes food insecurity along a continuum (**Figure 3**) based on the Food Insecurity Experience Scale[3] (FIES; also SDG Indicator 2.1.2). The FIES is a quantitative metric of severity of food insecurity at the household or individual level that relies on people's direct yes/no responses to eight brief questions regarding their access to adequate food[4]. It is a statistical measurement scale like other widely accepted statistical scales designed to measure unobservable traits such as aptitude/intelligence, personality, and a broad range of social, psychological and health-related conditions. Most relevant to national and global monitoring of food insecurity are the moderate and severe food insecurity categories. **Moderate food insecurity** describes people facing uncertainties about their ability to obtain food and having been forced to reduce, at times, the quantity and/or quality of food due to lack of money or other resources. **Severe food insecurity** refers to people who are likely to run out of food, have experienced hunger, and, at the most extreme, have gone for days without eating, putting their health and well-being at grave risk. Since SDG Indicator 2.1.2 refers to the total number of people suffering from food insecurity, even at moderate levels, the number will be higher than those suffering from hunger. In the UNCCD Strategic Framework, an indicator for food insecurity or hunger has not been identified.

2 https://www.un.org/sustainabledevelopment/hunger/

3 http://www.fao.org/in-action/voices-of-the-hungry/fies/en/

4 http://www.fao.org/3/a-i7835e.pdf

Figure 3. Food insecurity severity along a continuous scale. Source: Food and Agricultural Organization.

Water security is defined by UN-Water as "*the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.*"[5] Thus, **water insecurity** occurs when people are faced with inadequate or inequitable access to clean, safe, and affordable water for drinking, cooking, sanitation, and hygiene; with cascading consequences including food insecurity, conflict, and migration. Currently, a variety

5 https://www.unwater.org/publications/water-security-infographic/

of data and indicators captures water availability and quality (for example, SDG Indicator 6.1.1 – Proportion of the population using safely managed drinking water services). However, these metrics fall short of capturing the multi-dimensional nature of water insecurity. Worldwide, 4 billion people experience severe water scarcity for at least 1 month of the year (16), 663 million people lack access to an improved water source (and at high risk for drinking contaminated water). Thus, the development and implementation of a water insecurity indicator that is similar in nature to the FIES is imperative. The robust assessment of global water insecurity is vastly important given that water insecurity can be a driver of food insecurity. Currently, a consortium of scholars funded by the National Science Foundation is developing such an assessment called the Household Water Insecurity Experiences (HWISE) Scale[6], which is being developed as a cross-culturally validated scale of household water insecurity, which will capture the unique experience of water-insecure individuals. This tool will enable scientists, program developers, and community leaders to determine the magnitude of water insecurity, to track its change over time, and to measure the effectiveness of various interventions.

The UN monitors and assesses progress towards water security through SDG 6: *Ensure availability and sustainable management of water and sanitation for all.* The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) surveyed the relevance of addressing land degradation on the SDGs. IPBES found SDG 6: *Clean Water and Sanitation* to have the second highest relevance, following SDG 15: *Life on Land*. The UNCCD released a report in 2020 titled *Land Degradation Neutrality for Water Security and Combatting Drought*[7], in which they applied a water-related LDN assessment approach that integrates five primary categories: 1) integrated land and water management, 2) improved management of water resources, 3) increased water-use efficiency, 4) an enabling environment, and 5) measures related to wetlands and aquatic ecosystems. Due to interdependence of land and water management, multiple benefits can be achieved through reversing land degradation for sustainable development, water security, and resilience to natural hazards such as drought. Achieving LDN contributes towards the achievement of several SDGs, particularly SDG 6 on water. SDG 6 is assessed through nine indicators[8] broadly relating to access to safe drinking water, access to sanitation services, access to wastewater treatment, ambient water quality, water use efficiency, water stress, water resources management, transboundary cooperation, and protection of water-related ecosystems. In the context of SO2, the UNCCD uses a simple indicator, SO2-2: *Trends in access to safe drinking water in affected areas*, which is synonymous with a time trend for SDG Indicator 6.1.1: *Proportion of population using safely managed drinking water services.*

One major challenge when monitoring water security is assessing the disproportionate effect on women and girls. Without safe drinking water, adequate sanitation, and hygiene facilities at home and in places of work and education, it is disproportionately harder for women and girls to lead safe, productive, healthy lives for three main reasons[9]. First, women and girls usually bear the responsibility for collecting water, which is often very time-consuming and arduous. Second, women and girls are more vulnerable to abuse and attack while walking to, and using, a toilet or open defecation site. And third, women have specific hygiene needs during menstruation, pregnancy, and child rearing. Addressing the needs of females in relation to water, sanitation and hygiene is a key driver in achieving global gender equity. Currently, a data gap on water and gender still exists, which forms a major obstacle to the production of scientific evidence of gender inequality. The recently released Water & Gender Toolkit[10] from the World Water Assessment Programme (WWAP) includes four tools that can be used to develop gender-responsive indicators for water assessment, monitoring, and reporting. It describes methodologies for the collection of sex-disaggregated water data and provides guidelines and a sample questionnaire for the collection of gender-disaggregated water data.

6 https://hwise-rcn.org/

7 https://catalogue.unccd.int/1442_LDN_Water_Security_drought_report%20Web.pdf

8 https://www.sdg6monitoring.org/indicators/

9 https://www.unwater.org/water-facts/gender/

10 http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/display-singlenews/news/the_2019_water_gender_toolkit_has_been_launched/

1.3.4 Local People, Women, and Youth Empowerment

Within the UNCCD decision 11/COP.14, Parties requested the secretariat "to align the reporting process for strategic objectives 1– 5 with the gender-responsive indicators and guidelines under development as part of the Gender Action Plan activities to ensure that the gender dimensions of land degradation are fully captured" (1). In addition, the UNCCD obliges Parties to promote awareness and participation by local populations, particularly women and youth, in all efforts to combat DLDD (Article 5), calls for participation by women in policy planning, decision-making, and review of programs (Article 10), and calls for capacity-building for women and girls (Article 19).[11]

The Gender Action Plan (GAP) of the UNCCD[12] was borne out of decision 30/COP.13 to support gender-responsive implementation of the UNCCD 2018–2030 Strategic Framework. Several follow up actions are ongoing to support country Parties and the secretariat to undertake concerted efforts to ensure its gender-responsive implementation and to make resources available to Parties to do so. The GAP built on similar GAPs created by the Convention on Biological Diversity[13] and the UN Framework Convention on Climate Change.[14] Several reports have been released to support specific considerations in the monitoring of Land Degradation Neutrality with respect to a "gender responsive and transformative" approach, such that women (as well as youth and local peoples) participate in and benefit from UNCCD activities.

Despite these stated priorities, a recent evaluation of LDN Target Setting Project (17), published in 2019, reports that gender dimensions remained poorly incorporated into the Target Setting Projects' designs. The evaluation report further explains that although some gender-related work was undertaken, it was unstructured and reactive. Therefore, the evaluation's recommendation #3 was the following: "The UNCCD Secretariat, the GM [Global Mechanism of the UNCCD], and IUCN [International Union for the Conservation of Nature], should undertake research into the integration of gender within LDN strategies and targets, with a view to producing guidance on how countries should mainstream gender within their national LDN efforts. Partners should also consider extending this work to explore the integration of livelihoods and other co-benefits within LDN strategies and targets."

An internal report, "Exploring options for the integration of SDG indicators relevant to the UNCCD Gender Action Plan into the UNCCD reporting process including gender relevant indicators for UNCCD strategic objectives 1–5" and another follow-up task titled "Task 2: Gender indicators for UNCCD strategic objectives 1-5 (gender dimension of desertification, land degradation, and drought)"- provide initial guidance on integration of women and youth empowerment indicators into the overall UNCCD approach to monitoring DLDD. The report's recommendations largely follow those of the 2017 report titled "Scientific conceptual framework for land degradation neutrality" (18) wherein the UNCCD Science-Policy Interface (SPI) lays out some "Gender considerations for the design of preliminary assessments [of Land Degradation Neutrality (LDN)]" (p. 73-74). An additional report providing guidance is the "Manual for Gender-responsive Land Degradation Neutrality Transformative Projects and Programmes" prepared by UNCCD and partners in 2019 (19). Themes that emerge from these reports include the importance of 1) women's property rights and land tenure, 2) women's participation in decision making (at household, government, and LDN policy levels), 3) women, youth, and other vulnerable groups' participation in the economy and their equitable access to resources, 4) sex and age disaggregated population (and other) data, and 5) consulting gender specialists early and often.

1.3.5 Migration

Given the importance of migration as an adaptation and resilience strategy, as described above, especially when other in situ adaptation strategies have been exhausted, migration is an important proxy for human adaptation and resilience in the context of DLDD (20). Migration

11 https://treaties.un.org/doc/Treaties/1996/12/19961226%2001-46%20PM/Ch_XXVII_10p.pdf

12 https://www.unccd.int/sites/default/files/documents/2018-01/GAP%20ENG%20%20low%20res_0.pdf

13 https://www.cbd.int/gender/action-plan/

14 https://unfccc.int/topics/gender/workstreams/the-gender-action-plan

is "[movement] across an international border or within a State away from a person's habitual place of residence, regardless of (1) the person's legal status; (2) whether the movement is voluntary or involuntary; (3) what the causes for the movement are; or (4) what the length of the stay is."[15] Because migration is fluid without one clear event such as a birth or a death, and because individuals and households can migrate numerous times, migration is notoriously difficult to define and to measure. To the extent that there is agreement on broad terms, migration of people from one country into a destination country is known as immigration. The converse, migration from an origin country is called emigration. The same processes internally within a country are known as in-migration and out-migration, respectively. Origin areas are the source of migration, destination areas are locations of migrant arrival.

No one source of migration data exists at the global scale. Because of this, the spatial and temporal resolution of data that may track these flows is limited, and the frequency of data collection is highly variable across world regions and nations. Further complicating cross regional analyses are the varying definitions of migration. This issue is particularly vexing for urban migration, where a definition of 'urban' varies widely across and even within distinct nations. At the household level, number of out-migrants and time of out/in-migration, years at destination/time of arrival, reasons for migration (both "pushes" from origin areas and "pulls" in destination areas), and information on quantity, source, and destination of remittances are priority variables that potentially respond to and impact DLDD in both origin and destination areas.

Pertinent variables at the community level or higher level of community aggregation include number of out-migrants, number of in-migrants (or emigrants and immigrants), and net migration total and rate – the net sum outcome of in and out-migration, providing a negative, static, or positive number or rate per 1000 people. Occasionally, for some select countries, there may be sparse information available about intra-migration, that is, migration within the same area/region. Alternatively, gridded population data may fill the gaps in migration data sources. For example, the UNCCD (21) assessed the role of drought and land degradation as drivers of human migration using gridded population data. Results indicate a significant negative effect of drought and land degradation on population density in a country.

Gender disaggregation, where available, is critical to measure, as gender-distinct patterns occur in different migration streams. For example, both rural and international migrants are often initially men while urban migrants are often female. Origin and destination characteristics are also important. Typically, migration streams occur where certain origin areas are connected to specific destination areas.

1.3.6 SO2 Monitoring Implications

The nested scales conceptual approach has important monitoring implications. Human data is significantly scarcer in space and time than biophysical data. The finer scales of the individual, household, and community further exacerbate the challenge of measuring and monitoring SO2 Progress. Below we discuss a conceptual approach pertinent to human dimensions of DLDD at the individual, household, and community scales. Following this, we move to our central exposition of appropriate datasets and indices for monitoring SO2 progress.

15 UN Migration Agency definition

2. PROPOSED SO2 MONITORING INDICATORS

In this section we describe suggested Level 1 and 2 indicators for monitoring progress towards SO2. We also describe complementary indicators that could be used to assess progress towards the four SO2 sub-objectives (**Figure 1**). Although the main recommendation remains for country Parties to utilize data which they have collected to construct these metrics, we discuss additional sub-national data available globally, quasi-globally, or in some cases, much more limited spatial coverage, that country Parties could use in the absence of nationally collected data (**Table 1**).

These recommended datasets are described in more detail in Section 3, and additional datasets reviewed but not meeting one or more inclusion/exclusion criteria in Appendix A.

Table 1. Potential Biophysical and Socioeconomic Datasets for Monitoring SO2. DHS and WorldPop data are considered multi-purpose due to inclusion of variables relating to water access and women's empowerment in addition to demographic and socio-economic variables (DHS) or due to being gender/age disaggregable (WorldPop). Regional* = Select food insecure nations in Central America and the Caribbean, Central Asia, East Africa, Southern Africa, and West Africa.

Dataset	Source	Spatial Resolution	Temporal Coverage	Temporal Resolution	Spatial Coverage	Gender Disaggregation
Multipurpose Datasets						
Demographic and Health Surveys	The DHS Program	National, sub-national (provincial)	1984 - 2020	Annual	Quasi-global	Yes
WorldPop Population Counts (unconstrained)	WorldPop	30-arc seconds & 3-arc seconds (~ 1 km & 100 m at the Equator)	2000 - 2020	Annual	Global	Yes
WorldPop Population Density (unconstrained)	WorldPop	30-arc seconds (~ 1 km at the Equator	2000 - 2020	Annual	Global	Yes
Food Security & Water Access (SO-2.1)						
Food Insecurity Hotspots Data Set v1	NASA SEDAC/ CIESIN	250 m x 250 m	2009 – 2019	Annual	Regional*	No
Food Security Classifications	FEWS NET	Sub-national (districts)	2009 - present	3-monthly	Regional*	No

Dataset	Source	Spatial Resolution	Temporal Coverage	Temporal Resolution	Spatial Coverage	Gender Disaggregation
Land & Water Management						
Global Land Cover v3.0	Copernicus Global Land Service	100 m x 100 m	2015 to 2019	Annual	Global	No
ESA CCI-LC (MRLC Maps v207)	European Space Agency	300 m x 300 m	1992 to 2018	Annual	Global	No
Intact Forested Landscapes (IFL)	IFL Mapping Team	Sub-national	2000, 2013, 2016	Irregular	Global	No
Trends in Global Freshwater Availability from the Gravity Recovery and Climate Experiment (GRACE)	NASA SEDAC/ CIESIN	0.5° x 0.5° (~ 55 km at the Equator)	2000 - 2016	Annual, Monthly	Global	No
Livelihoods (SO-2.2)						
Multidimensional Poverty Index (MPI)	OPHI (Derived from harmonized DHS and MICS data)	Household, sub-national (provincial), national	2010 - 2020	Annual	Quasi-global. (Since ~2015, subnational MPIs are available annually for >77 countries)	Yes
Local People, Women's, & Youth Empowerment (SO-2.3)						
Modeled Surfaces: Women's literacy ED_ LITR_W_LIT	The DHS Program	5 km x 5 km	2013 – 2018	Irregular	38 countries	NA (women focused indicator)
Landmark	Landmark	National, Sub-national (community)	2018	Monthly to Annual	Global with gaps in coverage	No
Migration (SO-2.4)						
Migration Global Variables (Person)	IPUMS-International	National, Sub-national**	1960 – 2018 (depending on variable and country)	Annual	Select nations	Yes
WorldPop Internal Migration Flows	WorldPop	Sub-national (municipal)	2005 - 2010	N/A	LMIC	No

* Regional = Select food insecure nations in Central America and the Caribbean, Central Asia, East Africa, Southern Africa, and West Africa.

** For IPUMS-international, subnational units employed are categorized into major and minor administrative units and specific unit names depend on the country. Some names will overlap (e.g., for some countries, district is a major unit while for some it is a minor unit)[16].

16 https://international.ipums.org/international-action/variables/MIGRATE5#comparability_section

2.1 SO2 Level I Monitoring

In the UNCCD Strategic Objective Framework, the Level 1 indicators and associated metrics for SO2 monitoring are defined in **Table 2**. We discuss these metrics in subsequent sections, followed by an identification and discussion of factors that should be considered for further review. Finally, we present a modified approach to SO2 Level 1 monitoring that better aligns the metrics with the stated indicators and monitoring objectives.

Table 2. The Level 1 Indicators for SO2 monitoring consist of components for poverty and/or income inequality and safe water access and are aligned with the SO2 Sub-Objectives outlined in COP.13.

Sub-Objective	Indicator	Metrics or Proxies
SO2-1	Trends in population living below the relative poverty line and/or income inequality in affected areas	Poverty Headcount (Percent of Population Below $1.90 per day) or Income inequality (i.e., Gini Index)
SO2-2	Trends in access to safe drinking water in affected areas	Proportion of population using safely managed drinking water services

2.1.1 SO2-1 Sub-Indicators

Because people can successfully adapt to DLDD through a host of economic and demographic responses simultaneously and sequentially, one component of the Level 1 Indicator for progress towards SO2 is a simple bare minimum for assessing and monitoring the ability of people to subsist and survive. The use of a simple indicator such as Poverty Headcount or Gini Index ensures that the underlying data are relatively easy for nations to obtain and interpret compared to more complex poverty indicators. Based on an extensive review of available datasets, we recommend that country Parties obtain the underlying data from internal collection mechanisms such as national censuses to ensure that the data are collected at a subnational level. At this time, there are no global datasets that country Parties could rely on to complement their calculation of the SO2-1 sub-indicator at a subnational level. Both Poverty Headcount (Percent of Population Below $1.90 per day) or Income Inequality (i.e., Gini Index) are available only at the country level via the World Bank Living Standards Measurement Survey (LSMS) dataset (see Appendix A). Country Parties may potentially utilize the World Bank LSMS data to monitor national-level changes in poverty over time, however.

2.1.1.1 Poverty Headcount (Percent of Population Below $1.90 per day)

Poverty Headcount is measured as the percentage of the population living below the international poverty line, which as of 2020 was set at $1.90 in purchasing power parity per day measured at 2011 international prices. Purchasing power parity (PPP) in this context refers to a comparable basket of goods, such as milk, bread, and grains, and services, such as water provision, consumed by most citizens globally and asks what these would cost if the US dollar were used to purchase them. Below $1.90 USD earned daily is considered below poverty and, internationally, it is considered extreme poverty. The poverty headcount is also a SDG Indicator 1.1.1.

The PPP conversion factor, applicable to private consumption, represents the number or the amount of a country's currency required to buy the same amount of goods and services in the domestic market that a U.S. dollar would be able to purchase in the United States.

The formula for describing the proportion of a population living below the poverty line, also known as the headcount index, is as follows:

$$P_0 = \frac{1}{N}\sum_{i=1}^{N} I(y_i \leq z) = \frac{N_p}{N}$$

Where *I(.)* is an indicator function that takes on a value of 1 if the expression in parentheses is true, and 0 if not. If individual consumption or income (y_i) equals a value less than the poverty line (z), then *I(.)* is equal to 1 and the individual is living below the poverty line. N_p is the total number of poor individuals and N is the total population.

Consumption and income data are derived from national household surveys, containing questions about spending habits and income sources. Consumption is preferred to income for poverty measurements, while income is used as an alternative measure. Income is typically difficult to measure accurately, and consumption better represents the notion of the standard of living than does income, which often varies over time. Consumption is calculated for the entire household and divided by the number of household members to derive a per capita estimate.

Households are ranked by consumption or income per capita. Distributions are weighted by household size and sample expansion factors. Therefore, a given fractile (such as the poorest quintile) would have an equal share of the country-specific population across the sample. To estimate the proportion of the population that is poor, the total number of individuals below the poverty line is then divided by the total population t. The resulting number, multiplied by 100, yields a percentage[17]. These data are available annually from the World Bank at the national level (see Appendix A).

2.1.1.2 Income Inequality (i.e., Gini Index)

The Gini Index is based on the Gini coefficient, a statistical dispersion measurement that ranks income distribution on a scale between 0 and 1. The Gini index is often represented graphically through the Lorenz curve, which shows income (or wealth) distribution by plotting the population percentile by income on the horizontal axis and cumulative income on the vertical axis. The Gini coefficient is calculated using the formula:

$$\textit{Gini coefficient} = \frac{A}{A + B}$$

where A is the area above the Lorenz curve line and B is the area below the Lorenz curve. An example is shown in **Figure 3**.

17 http://iresearch.worldbank.org/PovcalNet/methodology.aspx

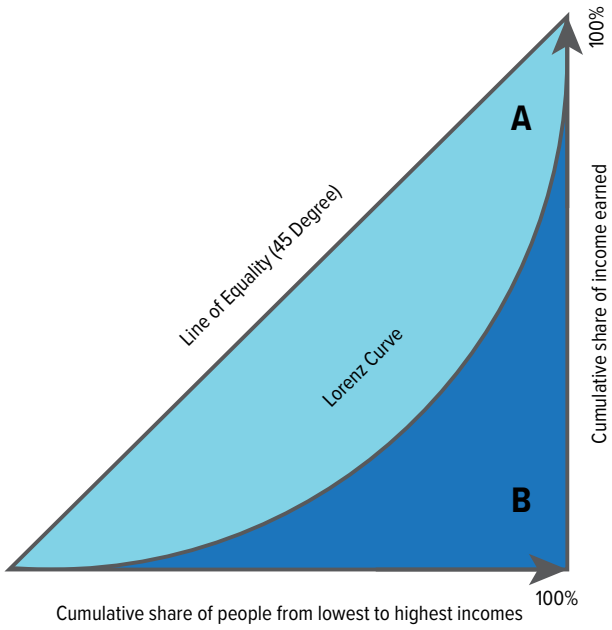

Figure 3. The graph shows that the Gini coefficient is equal to the area marked A divided by the sum of the areas marked A and B, that is, Gini = A/(A + B).

The measure has been in use since its development by Italian statistician Corrado Gini in 1921. It can be used to measure the inequality of any distribution but is commonly associated with wealth. A Gini index of 1 indicates perfect (or total) inequality. If everyone had the same amount of money (i.e., were uniformly poor, uniformly wealthy, or anywhere in between), the index would register a reading of 0; this can be problematic in that very different income distributions can result in identical Gini Index values. The Gini Index measures net income, not net worth, so most of a nation's wealth can still be concentrated in the hands of a small number of people even if income distribution is relatively equal. As well, it does not show demographic variations among subgroups within the distribution, such as incomes across age, race, gender, and social groups.

2.1.2 SO2-2 Sub-Indicator

The second sub-indicator, *Proportion of population using safely managed drinking water services*, is a simple metric for whether or not people have access to safe drinking water. In the absence of this basic need, humans suffer consequences such as disease, hunger, undernourishment (especially in children), and death; this metric therefore represents a critical measure of global human wellbeing.

Access to safely managed drinking water, through improved drinking water sources, includes piped water, boreholes or tubewells, protected dug wells, protected springs, rainwater, and packaged or delivered water. The water should be located on the premises, available when needed, and free of fecal and priority chemical contamination (e.g., endocrine disruptors). If the water comes from an improved source that does not fulfill the above-mentioned criteria, it is categorized as "basic" services, provided the collection time is less than a 30-minute round trip. Where the improved drinking water source is located further away, the service is categorized as "limited".

This metric is also an SDG indicator (SDG indicator 6.1.1[18]). The WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) has produced regular estimates of national, regional, and global progress on this metric since 1990[19] as part of the water, sanitation, and hygiene (WASH) dataset (see Appendix A), with estimates primarily coming from household surveys and censuses.

Sub-national data collected by countries is preferred to compute this metric. A complementary or alternative dataset is DHS sub-national vector data (see Section 3.2.1). In some cases, DHS Modeled Surfaces may be available and country Parties may wish to utilize this gridded dataset which is available only for 2013-2018 in 34 countries and is not updated annually. However, country Parties can take advantage of the WASH dataset if they wish to understand country-level statistics over time.

2.1.3 Proposed Modifications for SO2 Level 1 Monitoring

Within this section we discuss three factors to be considered in terms of the existing indicators shown in **Table 2**. First, we suggest that there should be one universal metric to assess SO2-1 at Level 1 rather than two (Poverty Headcount or Income Inequality). Poverty Headcount (below the national poverty line) is recommended over Income Inequality (Gini Index) since

18 https://www.sdg6monitoring.org/indicator-611/

19 https://unstats.un.org/sdgs/dataContacts/

the former is inherently easier to compute and interpret. Poverty Headcount below the national poverty line (which is consonant with SDG Indicator 1.2.1) would create synergies with the SDGs as outlined in the *Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development* and our recommended Level 2 Indicator (Trends in population living in poverty in all its dimensions according to national definitions in affected areas; consonant with SDG 1.2.2).

Second, we suggest that the language used in the SO2-1 and SO2-2 Indicators is not entirely consistent with the associated metrics. Specifically, the inclusion of the phrase "*in affected areas*" is not accounted for within the chosen metrics, unless they are reported explicitly for areas/population affected by DLDD as compared to areas/populations unaffected. Recognizing the challenges in defining "affected areas" and the evolution of the meaning over time, we suggest that, for UNCCD reporting purposes, the SO2-1 and SO2-2 indicators be calculated according to subnational administrative boundaries but reported over the total land area of the country for simplicity, and additionally or optionally reported based on a division between DLDD affected areas and unaffected areas. This would create better understanding of SO2 reporting metrics as they relate to DLDD. If the reporting within affected areas were to be optional, we suggest the removal of this language from the Level 1 indicator description. In Section 2.2.2 we provide an example of how country Parties could calculate an indicator within affected areas using degraded land areas as an example. Finally, we propose the inclusion of a third indicator that allows for the quantification of trends in population exposed to land degradation (as determined by the SO1 indicator). This indicator could be further broken down in terms of population by gender and/or age if a country Party wished to do so, promoting the ability to assess components of SO2-3, (i.e., women's and youth empowerment). This would also better allow country Parties to determine how many total people are affected by land degradation, whether or not those people lack resources (i.e., do they live in poverty and do they have access to water?) and further promote the equitable distribution of resources or establishment of policies that benefit all people affected.

We present our modified approach to Level 1 monitoring in **Table 3** and **Figure 4** below.

Table 3. The modified Level 1 Indicators for SO2 monitoring consist of components for poverty, safe water access, and trends in population exposed to land degradation and are aligned with the SO2 Sub-Objectives outlined in COP.13.

Sub-Objective	Indicator	Metrics or Proxies
SO2-1	Trends in population living below the national poverty line	Poverty Headcount (Percent of Population Below national poverty line per day)
SO2-2	Trends in access to safe drinking water	Proportion of population using safely managed drinking water services
SO2-3*	Trends in population exposed to land degradation	Proportion of population within degraded areas (by SO1 indicator)

*optional disaggregation by gender and age makes this indicator consonant with Expected Impact 2.3 in terms of women's and youth empowerment.

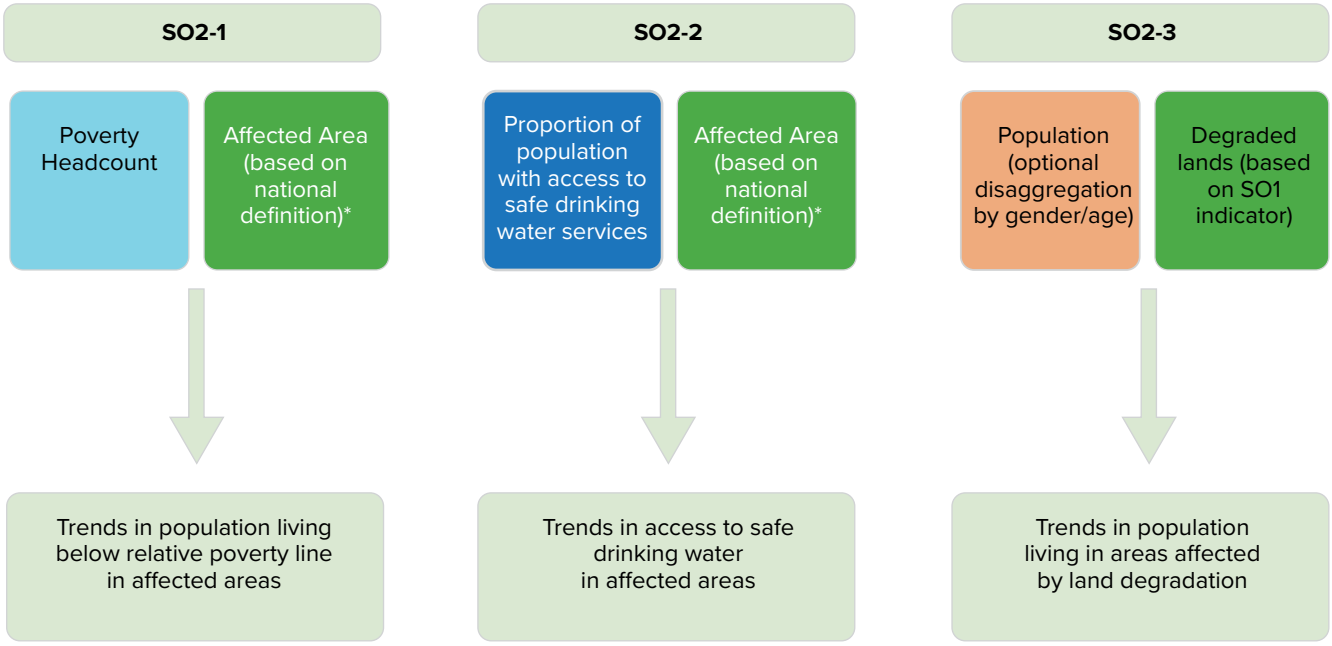

Figure 4. The SO2-1 and SO2-2 indicators for poverty headcount and safe drinking water access can optionally be computed within affected areas according to national definitions (i.e., degraded lands, drought areas, etc.). Trends in population exposed to land degradation require overlaying population with degraded land areas, which can be computed using the SO1/SDG 15.3.1 Indicator.

2.2 Level II Monitoring of SO2

For a more in depth (Level II) Monitoring approach for SO2, we recommend an indictor/metric which goes beyond a simple measure of asset poverty. Instead, we recommend a metric that considers asset and non-asset deprivations that make up multidimensional poverty, such as the Multidimensional Poverty Index (MPI). This index can be computed using subnational data that is collected by country Parties during national censuses or surveys, thus satisfying the national ownership criterion. The MPI is a strong candidate in that it accounts not only for relative poverty (SO2-1), but for access to safe drinking water (SO2-2). Thus it is more integrated and comprehensive than asset poverty or water access indicators alone (**Table 4**). An additional benefit is the ability to further split the poverty class into poverty intensity groups. As for the Level I indicator, we recommend a Level II indicator that also accounts for affected areas. By overlaying poverty intensity and affected areas, country Parties can determine how much of each poverty class is falling within affected vs. non-affected areas and compare those metrics to non-poverty classes within the same areas, thus allowing country Parties to better prioritize resources where they are most needed. This approach, which we describe in more detail in the subsequent sections, supports harmonization between the UNCCD Strategic Objectives.

Table 4. The proposed Level II Monitoring Approach is derived from SDG 1.2.2. *Proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions.* Calculating multidimensional poverty within affected areas makes this index highly consonant with both SO2-1, SO2-2. We also recommend optional disaggregation by gender and/or age.

Sub-Objective	Indicator	Metrics or Proxies
SO2-1 & SO2-2	Trends in population living in poverty in all its dimensions according to national definitions in affected areas	Multidimensional Poverty Index categorized as 'MPI Poor' by poverty intensity class within affected areas

2.2.1 Multidimensional Poverty Index (as a subnational-level index)

The MPI is an international measure of acute multidimensional poverty covering over 100 Low- and Middle-Income Countries (LMIC). The MPI was proposed by Alkire and Foster (22) –and then further described in Alkire and Santos (23,24) - as a result of a joint effort of the Oxford Poverty and Human Development Initiative (OPHI), University of Oxford and the Human Development Report (HDR) from the Office of the United Nations Development Programme (UNDP). It has been published annually by OPHI and has been present in the HDRs since 2010 (25). There are currently two main categories of MPI measures: *Global* MPI and *Regional/National* MPIs. The global MPI is calculated at the country level using globally comparable data while the Regional/National MPIs are calculated at the sub-national level using measures that are locally relevant and feasible.

The rationale for the construction of the MPI builds on the approach to creating the Human Development Index (HDI, see Appendix A), a score composed of three dimensions: Health, Education, and Living Standards (**Table 5**).

Table 5. Dimensions, Indicators, Deprivation Cutoffs, Weights and SDG Areas addressed in the Multi-Dimensional Poverty Index (MPI). Source: OPHI (2018). Global Multidimensional Poverty Index 2018: The Most Detailed Picture to Date of the World's Poorest People. Oxford Poverty and Human Development Initiative, University of Oxford.

3 Dimensions of Poverty (weight)	10 Indicators (weight)	Deprived f Living in A Household Where…	SDG Area
Health (1/3)	Nutrition (1/6)	Any person under 70 years of age for whom there is nutritional information is **undernourished**.	SDG 2: Zero Hunger
	Child mortality (1/6)	A child **under 18** has **died** in the household in the five-year period preceding the survey.	SDG 3: Health & Well-Being
Education (1/3)	Years of schooling (1/6)	No eligible household member has completed **six years of schooling**.	SDG 4: Quality Education
	School attendance (1/6)	Any school-aged child is **not attending** school **up** to the age at which he/she would complete **class/grade 8**.	SDG 4: Quality Education

3 Dimensions of Poverty (weight)	10 Indicators (weight)	Deprived f Living in A Household Where...	SDG Area
Living Standards (1/3)	Cooking fuel (1/18)	A household cooks using **solid fuel**, such as dung, agricultural crop, shrubs, wood, charcoal, or coal.	SDG 7: Affordable and Clean Energy
	Sanitation (1/18)	The household has **unimproved** or no sanitation **facility** or is improved but **shared** with other households.	SDG 6: Clean Water and Sanitation
	Drinking water (1/8)	The household's source of **drinking water** is **not safe** or safe drinking water is a **30-minute** or **longer walk** from home, roundtrip.	SDG 6: Clean Water and Sanitation
	Electricity (1/18)	The household has **no electricity**.	SDG 7: Affordable and Clean Energy
	Housing (1/18)	The household has **inadequate** housing materials in **any** of the three components: **floor, roof,** or **walls**.	SDG 11: Sustainable Cities and Communities
	Assets (1/18)	The household does **not own more than one** of these **assets**: radio, TV, telephone, computer, animal cart, bicycle, motorbike, or refrigerator, and does not own a car or a truck.	SDG 1: No Poverty

The MPI assesses poverty at the individual level based on the achievements of the entire household, measuring deprivation instead of possession and "shows the number of people who are multidimensionally poor (suffering deprivations in 33% of weighted indicators) and the number of deprivations with which poor households typically contend" (25). The MPI uses the household as a unit of analysis, in which the MPI and informing indicators apply to all members of each household.

The MPI combines two key pieces of information: (1) *Headcount ratio (H)* – the proportion or incidence of people (within a given population) who experience multiple deprivations and are thus identified as poor; (2) *Average deprivation share (A)* – the intensity of their deprivation, meaning the average proportion of (weighted) deprivations they experience – in other words, how poor people are, on average. The MPI is the product of both: MPI = H x A (26). The MPI ranges between 0 and 1, where 0 is multidimensionally not deprived and 1 is multidimensionally deprived.

The Global MPI relies on three main internationally comparable and publicly available datasets available for most low- and middle-income countries (LMICs): The DHS[20], The Multiple Indicators Cluster Survey (MICS)[21] and the World Health Survey[22]. The DHS questionnaires for example typically report all the necessary information needed to create the MPI, with some exceptions for older surveys. For countries in which none of the aforementioned internationally comparable surveys is available, country-specific surveys that contain information on the MPI indicators are employed (26). The MPI can be constructed for different population subgroups at household or cluster level as well as at higher levels (e.g., region, country). It can also be decomposed by dimension to show how the structure of poverty varies between different groups. Detailed methodology of assembling the MPI can be found in Alkire and Santos (23).

One key feature of the MPI is that it can be decomposed by population subgroups relevant to a given country, for example: urban vs. rural, or by ethnicity and various geographic sub-regions (e.g., districts, provinces, states).

20 http://www.measuredhs.com/aboutsurveys/dhs/start.cfm

21 http://www.childinfo.org/mics.html

22 http://www.who.int/healthinfo/survey/en/

Overall, keeping in mind that the global MPI unit of analysis is the household, MPI can be decomposed by any relevant characteristic that may vary across households (e.g., gender and age-groups). Further decompositions (e.g., by gender and age) may be possible beyond the characteristics of the household if a national MPI has been designed at the individual level, assuming the survey data is representative of those groups and relevant for policy.

For national MPIs designed at the individual level, one can decompose household MPI by gender by computing the MPI for men and women, respectively. The formula for this is below

$$MPI_{household} = \frac{n_M}{N} MPI_M + \frac{n_W}{N} MPI_W$$

where M denotes men and W denotes women, $\frac{n_M}{N}$ is the number of men in the household divided by the total household members, $\frac{n_W}{N}$ is the number of women in the household divided by the total household members.

Given the above expression, one can easily compute the contribution of gender to household poverty by using the formulae below:

$$\textit{Contribution of Men to household MPI} = \frac{\frac{n_M}{N}}{MPI_{household}} \text{ x100}$$

$$\textit{Contribution of Women to household MPI} = \frac{\frac{n_W}{N}}{MPI_{household}} \text{ x100}$$

Whenever the contribution to household MPI of a specific group widely exceeds the household share, this suggests that there is a significantly unequal intra-household poverty, with a specific gender bearing a disproportionate share of poverty.

There are open-source resources available to country Parties for calculating regional/national MPI, including the methodological notes (27) and the statistical package R[23]. STATA do-files[24] are also available but the STATA software itself requires a paid subscription of more than USD$750.00/year (in 2021) for a single user Government/nonprofit license[25]. The R code is recommended as it can be run on an open-source platform, is easy to implement, and has additional benefits, such as the ability to assign and assess the contribution of each dimension and indicator towards the MPI, allowing country Parties to assess which factors are more influential on poverty at subnational scales. This can allow country Parties to not only prioritize *where* resources are needed, but determine *what* resources are needed to improve the living conditions of affected populations.

2.2.2 Calculating MPI in "affected areas"

One way for a country Party to decompose national MPI by DLDD indicators is to compute the MPI for the populations living in the proportion of land that is affected, then do the same for the populations living in the proportion of land that is not affected. Here we use degraded land areas according to the SO1/SDG 15.3.1 Land Degradation Indicator as an example, while recognizing that country Parties have different definitions of "affected areas" and may choose their own definition for computation of this metric. Given the MPI for populations in degraded and non-degraded areas, one can obtain the overall national MPI as verified by the weighted sum of the MPI for the populations in degraded and non-degraded areas, using the population shares as weights. The formula for this is below:

$$MPI_{national} = \frac{n_{LD}}{N} MPI_{LD} + \frac{n_{ND}}{N} MPI_{ND}$$

where LD denotes "affected areas" and ND denotes "non-affected areas", $\frac{n_{LD}}{N}$ is the population of affected areas divided by the total population, $\frac{n_{ND}}{N}$ is the population of non-affected areas divided by the total population.

Given the above expression, country Parties can easily compute the contribution of populations in degraded land areas to overall poverty by using the formula below:

23 https://rpubs.com/Sternonyos/545576

24 https://ophi.org.uk/multidimensional-poverty-index/data-tables-do-files/

25 https://www.stata.com/order/new/gov/single-user-licenses/dl/

$$\textit{Contribution of LD areas to MPI} = \frac{\frac{n_{LD}}{N}}{MPI_{national}} \times 100$$

Whenever the contribution to MPI of populations in degraded areas widely exceeds its population share, this suggests that there is a significantly unequal distribution of poverty in the country, with people in degraded areas bearing a disproportionate share of poverty.

This method can be applied to any indicator and use any definition for affected areas, thus allowing it to be applied to optional reporting of trends in the Level 1 indicators as described in Section 2.1.3. In **Figure 5**, we show a generalized depiction of the components and calculation of the proposed SO2 Level 2 indicator.

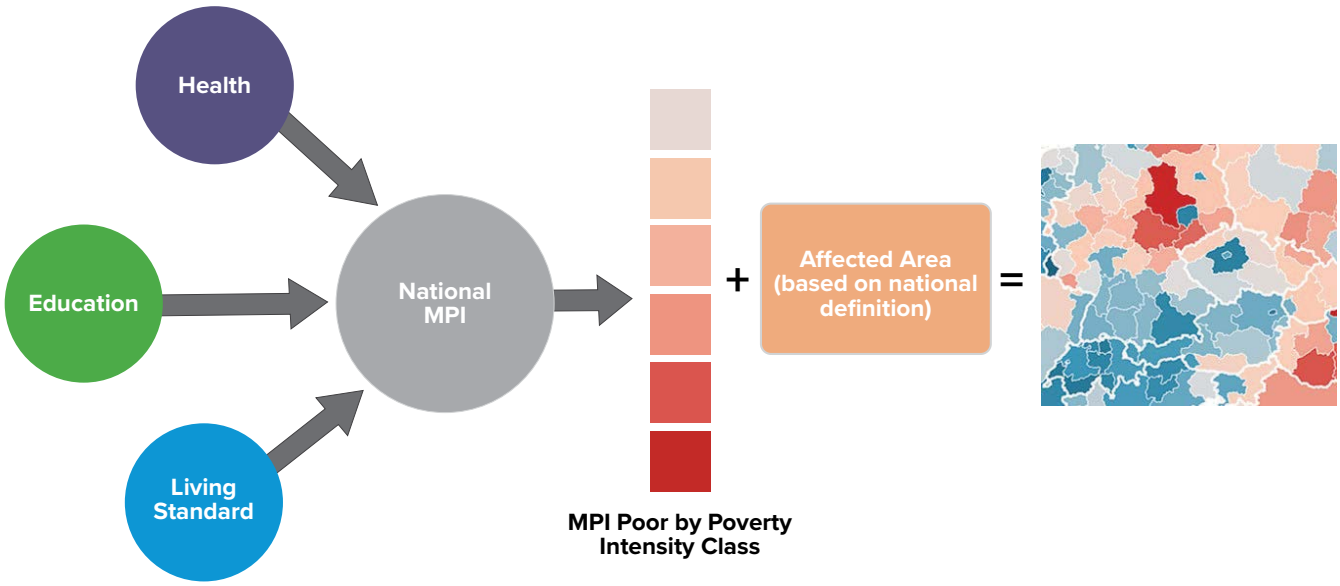

Figure 5. Trends in population living in poverty in all its dimensions according to national definitions in affected areas

2.2.3 Women's and youth empowerment in relation to MPI (i.e., gender/age disaggregation)

The methods described in section 2.2.2 can also be used to derive statistics for different groups of people living in affected areas, such as women versus men or youth versus adults, so long as the underlying survey data required for the calculations are available at an individual level (for example DHS data). One caveat is that many of the core DHS modules are collected at the household rather than the individual level, making disaggregation by age and gender more difficult. However, the OPHI group that publishes the Global MPI statistics have made templates widely available that country Parties could use to run surveys specific to calculating MPI in a gender and age disaggregable manner. This would be useful for harmonizing reporting to UNCCD and reporting on progress towards SDG 1 (Ending poverty), specifically for Indicator 1.2.2 *"Proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions."*

2.3 Additional Complementary Indicators for Monitoring Progress Towards SO2

Additional complementary indicators used in monitoring progress towards SO2 will ideally allow country Parties to assess progress towards the SO2 specific outcomes (**Figure 1**) by incorporating aspects of livelihoods; food and water security; empowerment of local people, women, and youth; and migration. We describe here simple monitoring indicators which could be collected by country Parties as part of census or other surveys, or through openly available sources, and would enhance the ability of Parties to understand progress towards SO2. We do not specifically

recommend these as formal indicators at this point in time as they would need more assessment in terms of ease of implementation and suitability for the specific purpose.

2.3.1 Food Security (Expected Impact 2.1)

2.3.1.1 Prevalence of Undernourishment (PoU)

The prevalence of undernourishment (PoU) is an estimate of the proportion of the population whose habitual food consumption is insufficient to provide the dietary energy levels that are required to maintain a normal active and healthy life over a period of one year. It is expressed as a percentage. PoU is also SDG Indicator 2.1.1. The PoU provides countries a metric to track progress towards eliminating hunger; when combined with SDG Indicator 2.1.2 (Section 2.1.4.2 below), this is ideal for evidence-based policymaking to reduce the global hunger figure to zero. At the national level, PoU historical data and estimates can be obtained from the FAO[26]. Due to the lack of publicly available subnational data sources, country Parties will need to collect this information as part of national censuses.

2.3.1.2 Prevalence of Severe Food Insecurity based on Food Insecurity Experience Scale (FIES)

The FIES is a quantitative metric of severity of food insecurity at the household or individual level that relies on people's direct yes/no responses to eight brief questions regarding their access to adequate food (**Figure 6**). It is a statistical measurement scale like other widely accepted statistical scales designed to measure unobservable traits such as aptitude/intelligence, personality, and a broad range of social, psychological and health-related conditions. FIES is also SDG Indicator 2.1.2. Due to the lack of publicly available subnational data sources, country Parties will need to collect this information as part of national censuses.

During the last 12 months, was there a time when, because of lack of money or other resources:
1. You were worried you would not have enough food to eat?
2. You were unable to eat healthy and nutritious food?
3. You ate only a few kinds of foods?
4. You had to skip a meal?
5. You ate less than you thought you should?
6. Your household ran out of food?
7. You were hungry but did not eat?
8. You went without eating for a whole day?

Figure 6. The Food Insecurity Experience Scale (FIES) questionnaire.

2.3.1.3 Integrated Phase Classification

The Integrated Phase Classification (IPC)[27] is a food insecurity index devised in a global partnership of governmental and nongovernmental agencies, including FEWS NET. IPC is used to describe the severity of food emergencies and is widely accepted by the international community. IPC supports a harmonized approach to spatio-temporal comparisons because it allows for various methods of data collection and analysis to be described using the same language and standards, allowing governments and humanitarian organizations to quickly understand a crisis or potential crisis. IPC 3.0 was launched in 2019 and can be used to describe the anticipated severity of acute food insecurity. In the calculation of IPC, households or areas are classified according to a five-phase scale (**Table 6**) based on a convergence of indicators relating to food consumption, livelihoods, malnutrition, and mortality. Then, the current status of the projected food security situation is classified using the IPC reference tables. A unique aspect of this classification includes accounting for the level of humanitarian assistance being provided in an area, shown in **Table 6** with wheat bag symbols. If country Parties are unable to collect this type of data or want to rely on complimentary sources, they can access subnational vector data through the IPC Mapping Tool,FEWS NET or a gridded data product produced by NASA (see Section 3.3). Limitations of these data sources include the lack of global availability; however, they are routinely updated for

26 http://www.fao.org/publications/sofi/en/

27 http://www.ipcinfo.org/

countries where food insecurity is a common issue and are thus available for many places where the information is most useful.

Table 6. Integrated Phase Classification (IPC) Acute Food Insecurity Phase Descriptions.

Phase 1 Minimal	Households are able to meet essential food and non-food needs without engaging in atypical and unsustainable strategies to access food and income.
Phase 2 Stressed	Households have minimally adequate food consumption but are unable to afford some essential non-food expenditures without engaging in stress-coping strategies.
Phase 3 Crisis	Households either: Have food consumption gaps that are reflected by high or above-usual acute malnutrition; OR Are marginally able to meet minimum food needs but only by depleting essential livelihood assets or through crisis-coping strategies.
Phase 4 Emergency	Have large food consumption gaps which are reflected in very high acute malnutrition and excess mortality; OR Are able to mitigate large food consumption gaps but only by employing emergency livelihood strategies and asset liquidation.
Phase 5 Famine	Households have an extreme lack of food and/or basic needs even after full employment of coping strategies. Starvation, death, destitution, and extremely critical acute malnutrition levels are evident. (For Famine Classification, area needs to have extreme critical levels of acute malnutrition and mortality.
	At least 25 percent households met at least 25 percent of their caloric requirements through humanitarian food assistance.
	At least 25 percent of households met at least 50 percent of their caloric requirements through humanitarian food assistance.

2.3.2 Women, Local People, and Youth Empowerment (Expected Impact 2.3)

2.3.2.1 Women

Women's empowerment within UNCCD monitoring and reporting can be addressed in a two-pronged approach: first, by ensuring that all aspects of LDN monitoring and activities are gender responsive, with gender disaggregation allowing measurement of impacts to men and women separately, wherever possible; and second, by measuring and monitoring indices and metrics focused specifically on gender equality, women's empowerment, women's land rights/tenure, and women's participation in decision making at household, government, and LDN project levels.

To ensure gender responsive metrics are employed throughout all aspects of LDN monitoring, we have noted wherever possible throughout this report which datasets are disaggregable by gender and prioritized those that are. In some cases, where datasets are not gender disaggregable, we note suitable alternatives or methods to infer separate impacts on men versus women. As an example, we suggested the addition of a new indicator within the Level I reporting scheme that focuses on "Trends in population exposed to land degradation" and that a gender (and age) disaggregable population dataset be used to do so, such that impacted men and women (or adults and youth) can be quantified separately. However, it is insufficient to know the simple number of men, women and/or youth affected without also understanding the differential impacts that land degradation, drought, and desertification have on the living conditions, health, and wellbeing of these groups. Therefore, we recommend, as a Level II indicator, the Multidimensional Poverty Index which, in theory, can be easily gender (and age) disaggregated if the underlying survey data to do so are available (See Section 2.2.2 and 2.2.3 on MPI).

For measuring and monitoring indices focused specifically on gender equality, women's empowerment, women's land rights/tenure, and women's participation in decision-making, we conclude there are no publicly available

datasets that meet our criteria for inclusion in this report. Most datasets failed the criterion that the data are available sub-nationally and/or the criterion that data are updated frequently. Within the Appendix, we have summarized all the women's empowerment relevant datasets and metrics that we considered, in hopes that some of these datasets may prove useful to country Parties in the future, or that some may be helpful now to assess the broader *context* of women's empowerment within monitoring and reporting. Metrics at the country level on the general state of women's equality and legal status—for example the Gender Inequality Index (GII), the Gender Development Index (GDI), or the World Bank's Women, Economy and Law database on laws that are gender discriminatory—can be very useful in providing contextual information that can frame monitoring and reporting in a way that is gender responsive. In addition, there are emerging metrics, such as the one devised by OPHI (Women's Empowerment in Agriculture Index[28], see Appendix A) that may soon provide data that is widely available, or that may be undertaken by country Parties within their own national surveys in the future, and thus should be reconsidered for gender responsive monitoring once data are available.

2.3.2.2 Local People - Indigenous and Local Community Land Tenure

Indigenous people are "people with distinct social, cultural, or economic characteristics practicing in part or in full their own customs or traditions. Whether a group or person is considered to be indigenous is based on self-identification (ILO Convention 169)" (28). Local communities are "groupings of individuals and families that share common interests in a definable local land area. They may be formally recognized as a community and structured via state institutions or exist informally" (28). Local communities depend directly on their ecosystems for their livelihoods. While there are commonalities between the two groups, there are also distinctions including how their rights are recognized in national and international policies. Important metrics relating to the empowerment of these groups include first knowing the physical location and areal extent of the groups, and secondarily understanding how secure that land is for their current and future use and rights that may affect the ability to respond to situations such as land degradation. Land tenure is the relationship that individuals and groups hold with respect to land and land-based resources, such as trees, minerals, pastures, and water. Land tenure rules define the ways in which property rights to land are allocated, transferred, used, or managed in a particular society. We recommend that country Parties collect or use existing sub-national geospatial data on land areas owned or occupied by Indigenous or Local communities as well as national policy data relating to formal acknowledgement of those lands by the government. There are multiple publicly available spatial datasets (not necessarily endorsed by the UN) that could be utilized in the absence of nationally-collected data, such as Landmark (see Section 3.4.1) and Conservation International's Global Atlas of Indigenous and Community Governance of Lands, Territories, and Resources dataset. The Landmark dataset contains lands that are both formally and not formally acknowledged and a measure of their ability to make decisions (which thus may affect their ability to respond to events such as land degradation). The Conservation International dataset is similar but does not contain land boundaries that have not been formally acknowledged by governments. However, it does contain some boundaries for water bodies (including fresh and saltwater areas) which Indigenous people and communities may own, use, or otherwise have formal claim or tenure over. Specific characteristics of these datasets are described in Section 3.4. Both datasets could be advantageous in quantifying impacts on Indigenous people and communities, with use largely depending on a country Party's willingness to utilize data containing boundaries that have not been formally recognized by the government.

2.3.2.3 Youth

When not employed, in school, or in training, youth face difficulties accessing the labor market and can become a vulnerable group with respect to DLDD. In the 2030 Agenda for Sustainable Development, the international community committed to substantially reduce the proportion of youth not in education, employment, or training (SDG 8.6)[29]. In this context, the ILO provides detailed, harmonized, national level labor statistics on

28 https://ophi.org.uk/the-womens-empowerment-in-agriculture-index-2/

29 https://ilostat.ilo.org/topics/sdg/

youth which could provide a robust way to monitor impacts of DLDD policies that might promote better youth employment and empowerment outcomes. The metric of interest that we recommend is SDG indicator 8.6.1 - Proportion of youth (aged 15-24 years) not in education, employment or training (%) (youth NEET rate). This data is provided at country-level by ILO for 153 countries in various years between 2010 and 2019 (see Appendix A), but ultimately should be collected by country Parties as part of sub-national censuses and surveys if the data will be used to assess impacts of land degradation.

Similarly, the MPI can also be used in an age disaggregated manner, such that poverty is assessed within various age groups separately (see Section 2.2.2 and 2.2.3). The MPI global dataset, curated by OPHI (**Table 1**), already provides age disaggregated estimates of populations living in multidimensional poverty. The data are summarized at a national level only, but additional data could be calculated at subnational scales by country Parties wishing to assess youth living specifically in areas affected by land degradation, using their own survey data (see Sections 2.2.2 and 2.2.3).

2.3.3 Migration - Movement across administrative or national boundaries (Expected Impact 2.4)

We recommend that to the extent possible, country Parties design and employ subnational and national surveys to capture migration changes across space and time. If country Parties do not already have their own sub-national migration data collected by local surveys, we recommend considering WorldPop Internal Migration Flows, if available[30]. WorldPop Internal Migration Flows represent the modelled number of people migrating between subnational administrative units for malaria endemic countries in Africa, Asia, Latin America and the Caribbean between 2005 and 2010[31].

30 https://www.worldpop.org/project/categories?id=11

31 https://www.who.int/malaria/publications/country-profiles/en/

For country Parties interested in determining subnational migration flows that are not covered by the WorldPop Internal Migration Flows, we recommend the following migration variables from the IPUMS-International dataset to quantify number of people who moved across administrative boundaries: MIGRATE1, MIGRATE5 and MIGRATE0, indicating a person's place of residence 1 year, 5 years and 10 years ago, respectively. We also recommend MIGRATEP, an indicator for whether a person's most recent move (if any) was between minor administrative units, major units, or countries. From a spatial perspective, we recommend GEOMIGI_P, GEOMIGI_5, GEOMIGI_10 that indicate the major administrative unit in which a person previously resided immediately before, 1 year, and 5 years prior to the respective survey.

For migration between national boundaries, we recommend the following migration variables from the IPUMS-International dataset: MIGCTRY1, MIGCTRY5 and MIGCTRY0, indicating the country of residence 1 year, 5 years, and 10 years ago, respectively, for international migrants.

Overall, capturing migration variables can be complex when not designed in national surveys. However, country Parties may want to consider national-level gridded population density changes as a valid proxy for intra-national migration. In that case, we recommend the WorldPop gridded population density variable (number of people in each 100 m2 pixel) from 2000-2020 available for all countries in the world[32]. The WorldPop population density data is only produced using the unconstrained method. Annual population density changes from 2000-2020 would be a valid proxy for intra-national migration. Some pros of the WorldPop datasets include: 1) the finest gridded resolution (~100 m) currently available for national-level population estimates for the entire globe; 2) the efficacy of the multivariate population estimation ensures that the dataset is tailored to match data conditions and the geographical nature of each individual country and region; 3) availability of gender-structured global population count datasets (unconstrained) for all countries in the world, for each year from 2000 to 2020. Some limitations of these datasets include their "highly-modelled" nature and the relatively higher spatial resolution that might affect the overall computational processing times.

2.3.4 Land & Water Management

2.3.4.1 Freshwater Availability

The supply of freshwater on Earth is finite in quantity and all people rely on it for their survival. Where it is plentiful, humans and societies thrive. In areas where it is constrained, humans face deleterious consequences to health, livelihood, and societal stability. With current population growth trends predicted to add billions more people to the planet in the coming decades, the consumption of freshwater will increase while the availability of freshwater becomes a major determining factor for human health and prosperity both at the levels of the individual and society. Therefore, quantifying changes in the availability of freshwater over time presents country Parties with a metric to assess the sustainability of current quantities and make predictions for the future. With the launch of NASA's GRACE and GRACE-FO (for Follow-On) satellites, the ability to quantify freshwater across the entirety of the globe has been realized. The NASA Socioeconomic Data and Applications Center (SEDAC) produced a dataset that quantifies long term and annual changes in freshwater availability based on GRACE data that can be used to better understand impacts on regional food supplies, human and ecosystem health, energy generation, and social unrest. This Trends in GRACE dataset is described in Section 3.5.2.1.

2.3.4.1.1 Landscape Conversion/ Alteration

Land cover information is helpful in identifying the conversions and alterations in a specific place that may occur as the result of land management decisions. We make a distinction between land cover change (a shift from one land cover type to another over a period of time, such as from forest to built) and land cover conversions (more subtle shifts in land cover that do not result into differentiation into a distinct new category, such as conversions from woodlands to shrublands that can be difficult to quantify from remote sensing without in situ reference data). Under the assumption that vegetated

32 https://www.worldpop.org/project/categories?id=18

lands with low population densities are less vulnerable to DLDD than other land cover types, the land cover classes can be ranked with a different vulnerability rating such as that used in Mainali and Pricope (29), with forest being the least vulnerable and barren land as the most vulnerable to DLDD in addition to land cover changes/conversions (**Table 7**). Land within the Built-Up area class receives the highest ranking.

Table 7. Land cover vulnerability ranks from Mainali and Pricope, 2017 (29).

Land Cover Type	Vulnerability Rank
Forest	1
Shrubland	2
Grassland	3
Agriculture	4
River/Lake/Snow/Glacier	5
Barren Land/Bare Areas	6
Built-Up Area	7

Time series analysis can help determine the degree of conversion over time, where a higher percentage of conversion to higher vulnerability land covers has a negative influence on living condition, and a higher percentage of conversion to lower vulnerability land covers has a positive influence on living condition.

2.3.4.1.2 Landscape Fragmentation, Deforestation, and Modification

Fragmentation of natural landscapes during urbanization processes has been well-linked to biodiversity loss and changes in ecological and ecosystem function. Fragmentation can also have profound effects on provision of ecosystem services and on human social dynamics and well-being within cities. Deforestation is one of the major drivers of increased greenhouse gas emission and has deleterious effects on water cycles, soil erosion, and livelihoods. 1.25 billion people around the world rely on forests for shelter, livelihoods, water, fuel, and food security, and 750 million people (approximately one-fifth of the total rural population) live in forests. This includes 60 million Indigenous people[33]. With forests constituting over 30% of the land cover on Earth, understanding the degree to which these areas have been fragmented and what percentage has been left intact serves as a valuable measure of human living conditions. An Intact Forest Landscape (IFL) is a seamless mosaic of forest and naturally treeless ecosystems within the zone of current forest extent, which exhibit no remotely detected signs of human activity or habitat fragmentation and is large enough to maintain all native biological diversity, including viable populations of wide-ranging species. IFLs have high conservation value and are critical for stabilizing terrestrial carbon storage, harboring biodiversity, regulating hydrological regimes, and providing other ecosystem functions[34]. IFLs have been mapped at a global scale and used to inform policy, however, using a binary measure such as IFL does not account for modification within remaining forests. A recent analysis constructed a Forest Landscape Integrity Index based on observed pressures (infrastructure, agriculture, tree cover loss), inferred pressure based on proximity to the observed pressures, and changes in forest connectivity; the findings indicate that in the year 2019 only 40.5% of forests have high ecosystem integrity, with only 27% of that area within nationally designated protected areas (30). If country Parties desired to do so, they could utilize self-generated or publicly available datasets to quantify IFL or Forest Landscape Integrity Index to provide transparent and defensible methodological frameworks to inform policy and decision-making throughout subnational areas.

2.4 Recommendations for Matching Datasets and Metrics to SO2 Indicators

There is a great need to translate indicators into component data parts. In doing so, there is a trade-off between benefits and drawbacks in selecting and applying data for monitoring indicators. The intent should be to match datasets and metrics with the UNCCD SO2 sub-objectives and additional indicators that align with SO2's four expected outcomes (**Figure 1**). In Section III, we describe the potential complementary datasets (**Table 8**) that form the basis of our recommendation for SO2 monitoring and inclusion in Trends.Earth.

33 https://www.worldwildlife.org/threats/deforestation-and-forest-degradation#causes

34 http://www.intactforests.org/

3. SO2 RELEVANT DATASETS FOR TRENDS.EARTH

3.1 Inclusion/Exclusion Criteria for Datasets Relevant to SO2

Using document ICCD/COP(14).CST/7 as a guide, and following Pricope et al. (11), we present our ideal inclusion/exclusion criteria for complementary datasets relevant to SO2 in **Table 8** below. While we largely maintain consistency with the recommendations outlined in Pricope et al. (11), we note that human survey-derived data rarely match all our inclusion criteria. In these cases, we examined the databases that most closely approximated our criteria. The priority complementary datasets that we recommend may be provided to country Parties through Trends.Earth when nationally collected data is unavailable or insufficient. These datasets are described starting with Section 3.2 below.

Table 8. Inclusion/Exclusion Criteria Employed in the Recommendation of Datasets for Trends.Earth Implementation.

Fidelity to SO2 and SDG indicator 15.3: in ICCD/COP(14) referred to as *Sensitivity* of the indicator to the SO.
Comparability of candidate metrics/indices with consideration for development and implementation of international standards in underlying data, methodologies, and guidance (modified from criteria in ICCD/COP(14)).
Data Validity and Reliability: Datasets have been assessed for accuracy/uncertainty and have proven to be valid in mapping spatio-temporal patterns of food security, water access, livelihood, women and youth empowerment, and /or migration.
Readiness/Adaptability: Datasets do not require special permission to access and can be freely downloaded from the internet (could be considered a component of Readiness per ICCD/COP 14).
Global Coverage: Datasets should have quasi-global to global coverage, including most inhabited land areas (component of *Readiness* per ICCD/COP(14)).
Spatial Resolutions: The data should be sub-national vector or gridded data, such that subnational differences within a country can be quantified.
Temporal Range: Covers periods since 2000 for food security, water access, livelihood, women and youth empowerment, and /or migration. Recommended ideal benchmark for contemporary indicators and datasets would be 2018 – 2020.
Temporal Resolution: The dataset should be available at a temporal resolution that makes it easy to assess both short term (e.g. up to 1 year) and long term (e.g. 5 – 10 year) changes in the living conditions of affected populations (could be considered component of *Readiness/Adaptability* per ICCD/COP 14).
Feasibility of Trends.Earth Integration (user-friendly): Datasets that are easier to work with are preferable (component of Readiness per ICCD/COP 14).

Update Frequency: The dataset should be routinely updated on a regular basis, meaning datasets that are no longer operational or do not have an easily identified timeframe for subsequent releases are excluded. For both biophysical and socioeconomic datasets, those that are updated at least yearly are preferred (could be considered a component of *Readiness/Adaptability* per ICCD/COP 14).

Gender Disaggregation: Socio-economic data and indicators with gender disaggregation will be preferred (component of Readiness/Adaptability per ICCD/COP 14).

Capacity to Create Ownership at the National Level (component of *Readiness/Adaptability* per ICCD/COP(14)): where we provide guidance for countries to replace with their own data, thereby allowing them to validate, accept, or reject the recommended data.

3.2 Multi-Purpose Datasets

3.2.1 Demographic and Health Surveys (Expected impacts 2.1-2.3)

The DHS Program collects, analyzes and disseminates population, health, socioeconomic, and nutrition data through more than 400 surveys in over 90 countries, primarily in LMIC since 1984 (31). The DHS Program focuses on fertility, family planning, maternal and child health, gender, HIV/AIDS, malaria, and nutrition, among other demographic and health related topics. It is funded by the U.S. Agency for International Development (USAID) with contributions from other donors and individual countries and is implemented by ICF (formerly the Inner City Fund, now legally recognized as the ICF).

The DHS collects and provides cluster-randomized survey data by first-order sub-national regions (for example at province or state level) and urban/rural strata. More recent surveys now provide geocoded data for individual household clusters. Global positioning system (GPS) coordinates for DHS household clusters provide highly resolved locational information that can be linked with other geospatial variables for further analysis. DHS data provide some of the highest quality, standardized, subnational data available for examining social, economic, and health-related variables specific to SO2. For example, some countries' DHS data contain specific modules assessing women's empowerment by collecting quantitative data on various social and economic dimensions of women's participation in household decision making, women's land tenure, violence, education, and other dimensions which could prove useful for assessing SO2 expected impacts.

The Women's Questionnaire[35] is one module within the DHS Program applied only sporadically by countries depending on their own monitoring needs and priorities (not as a core DHS activity, some forms of the Women's Questionnaire are currently available in 69 countries, see Appendix A). Within the questionnaire, Section 9 – Husband's background and Woman's work – asks specific household level questions about women's participation in household level decisions and provides a quantitative proxy for women's empowerment through the percentage of currently married women with final say in all household decisions (or a similar proxy of the percentage with final say in no household decisions)[36]. DHS also provides one metric within its Modeled Surface Data that is relevant to women's empowerment: "ED_LITR_W_LIT" Percentage of women aged 15-49 who are literate[37] (available for 38 countries, see Appendix A).

Modeled Map Surfaces (32) in the Spatial Data Repository of the DHS program contains information covering countries participating in the DHS program with surveys collected approximately every five years. Modeled spaces consist of gridded data, with unsampled value in space inferred from nearby grids using spatial interpolation methods such as Bayesian geostatistics. The indicators included in this dataset are mostly spatially heterogeneous, varying along geographical space, and not temporally or micro-seasonally restricted, so the scope of this dataset is limited compared with the complete DHS surveys. Model uncertainty surface visualization is also provided.

35 https://dhsprogram.com/Methodology/Survey-Types/DHS-Questionnaires.cfm#CP_JUMP_16179

36 https://dhsprogram.com/topics/gender/index.cfm

37 https://spatialdata.dhsprogram.com/modeled-surfaces/

3.2.2 WorldPop

The WorldPop collection is a global gridded high-resolution geospatial dataset on population distributions, demographics, and dynamics. WorldPop's spatially disaggregated layers are gridded with an output resolution of 3 arc-seconds and 30 arc-seconds (approximately 100 m & 1 km, respectively at the equator). These layers incorporate inputs such as population census tables & national geographic boundaries, roads, land cover, built structures, urban areas, night-time lights, infrastructure, environmental data, protected areas and water bodies. The input data are modelled to produce annual population estimates for the years 2000-2020 and some select country-specific years. A set of estimates adjusted to national level population predictions from the UNPD is also produced for the same set of years.

The strengths of WorldPop are that the population estimation method of dasymetric mapping is multivariate, i.e., 'highly modelled', therefore tailored to match data conditions and geographical nature of each individual country and region. Gender information is also available. The weakness of WorldPop is that the utilization of such complex interpolation models with sparse census data may lead to highly uncertain and imprecise population estimates in some sub-national and rural regions. Despite this limitation, WorldPop remains the most ideal gridded population dataset as it satisfies all our inclusion criteria, including spatial resolution, global coverage, frequency of data updates and inclusion of a gender-disaggregated component.

WorldPop data is downloadable as population counts[38] and population density[39]. For population counts, unconstrained data is available for individual countries at 1 km and 100 m spatial resolution for 2000 - 2020. "Unconstrained" means that every grid cell is treated with the same potential to host human population resulting in uninhabited areas containing human population erroneously. Users can also access data that has been adjusted to UN national population estimates for the same years. Constrained population estimates for individual countries and constrained population estimates for individual countries adjusted to UN population projections are available for 2020 only. The "constrained " version uses building footprints to more accurately allocate the population to where there are human structures. This is a better dataset when desiring to accurately identify rural areas and uninhabited places. Constrained data for individual countries adjusted to UN population estimates are also available in 2020. Population density is available as unconstrained estimates only, for individual countries or for individual countries adjusted to UN estimates at 1 km resolution.

3.3 Food Security & Water Access Datasets (Expected Impact 2.1)

3.3.1 FEWS NET Food Security Classifications

FEWS NET food security classification data date to June 2009 and are available for download as regional GIS shapefiles and images[40]. These data are published every three months after Outlook reports are published in February, June, and October (though data prior to 2011 were published every four months). Updates to the Outlook data are also published if changes are made to the data in non-Outlook months. Since February 2019, FEWS NET has used the IPC Version 3.0 scale. Between March 2011 and February 2019, an earlier version of the IPC scale (version 2.0) was used. Prior to March 2011, FEWS NET utilized the FEWS NET Food Insecurity Severity Scale, a scale like the IPC, but with differing classification criteria. The data allow for analysis of historical, current, and future projections of food security and are primarily available for countries routinely at risk from food insecurity.

3.3.2 Food Insecurity Hotspots Data Set v1

The Food Insecurity Hotspots Data Set[41] is produced by NASA SEDAC and hosted at the Center for International Earth Science Information Network (CIESIN) (33). This

38 https://www.worldpop.org/project/categories?id=3

39 https://www.worldpop.org/project/categories?id=18

40 https://fews.net/fews-data/333

41 https://sedac.ciesin.columbia.edu/data/set/food-food-insecurity-hotspots/data-download#close

dataset contains the level of intensity and frequency of food insecurity over the 10 years between 2009 and 2019, as well as hotspot areas that have experienced consecutive food insecurity events, based on FEWS NET Food Security Data. The gridded data (250 x 250 m) are based on subnational food security analysis provided by FEWS NET for selected countries in five regions including Central America and the Caribbean, Central Asia, East Africa, Southern Africa, and West Africa. The classification is based on the IPC, where food insecurity is defined as Minimal, Stressed, Crisis, Emergency, and Famine. This dataset is updated as needed, making it difficult to rely on planned releases. The biggest advantage of this dataset is that it is gridded, and though it does not cover the entire globe, it is focused on regions likely to experience food insecurity.

3.4 Local People, Women's, and Youth Empowerment Datasets (Expected Impact 2.2 and 2.3)

3.4.1 Global Atlas of Indigenous and Community Governance of Lands, Territories, and Resources

This dataset, currently under production by Conservation International, aggregates existing spatial and land rights datasets through collaboration with experts on indigenous and local governance issues and through desk research which includes government and non-profit organization reports and websites, legal documents, and peer-reviewed journals. Following the Rights and Resource Initiative's report, recognized lands, territories, and resources (LTR) are defined as "owned" or "designated" for use, management, or occupation by Indigenous People and local communities (IPLC). Land tenure rights are documented according to the bundle of rights framework. The spatial data consists of the national/subnational and local-community level polygons and points data of the IPLCs territories. In the absence of spatial data, non-spatial statistical, other relevant contextual, and qualitative data and attributes may be collected. The advantages of this dataset are that it contains government-recognized lands and territories, as well as marine data. However, it is not a comprehensive database and lacks information on unrecognized lands and territories (as does the Landmark dataset described next). While this data is not yet public, the data are sharable on request and are anticipated to be publicly available and downloadable by the end of 2021. This summary is adapted from a forthcoming paper by Shrestha et al (2021) on heterogeneity in tenure rights.

3.4.2 Landmark: Global Platform of Indigenous and Community Lands

The Landmark dataset[42] displays geo-referenced information on collectively held and used lands worldwide to consolidate the multiple ongoing local, national, and regional efforts to map and document Indigenous and community lands within a single global platform. The platform distinguishes Indigenous lands from other community lands partially because various international human rights instruments specifically grant Indigenous Peoples a range of rights, including rights to their land and

42 http://www.landmarkmap.org/data/

natural resources that may not otherwise be afforded to communities who do not self-identify as Indigenous. In addition to identity information, the platform also distinguishes the recognition and documentation status of those land areas (**Figure 6**).

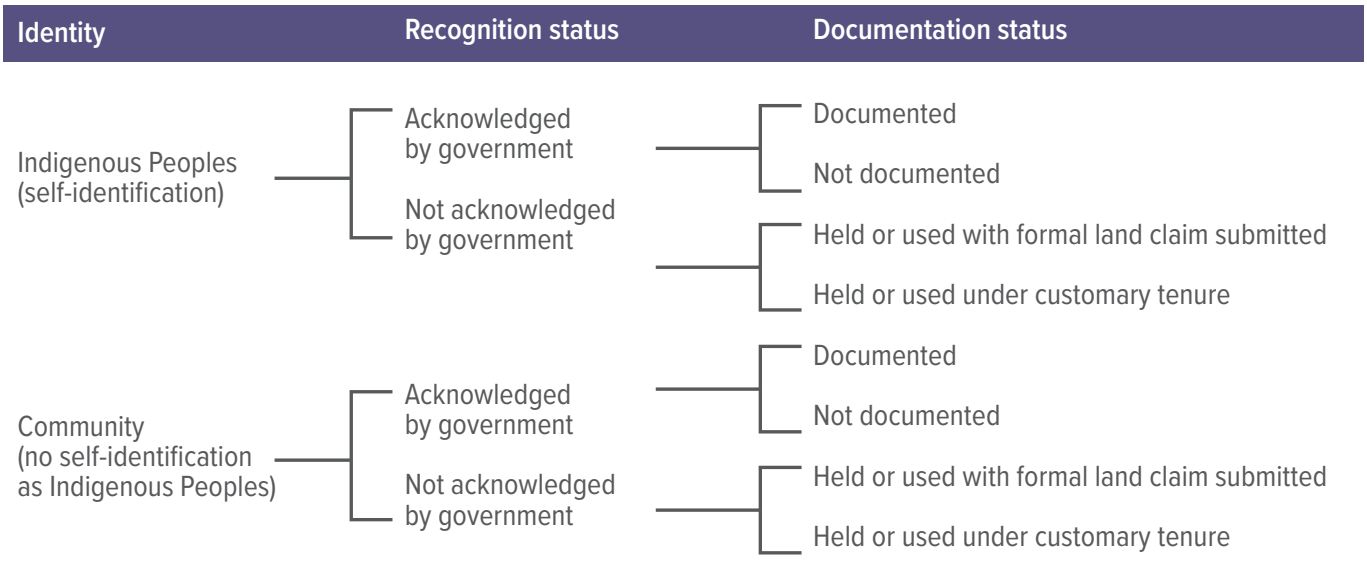

Figure 6. Landmark's Global Platform of Indigenous and Community Lands identity, recognition status, and documentation status categorization scheme.

The data on LandMark is offered at both National level and Community level. The National level data include two datasets that are based on research (e.g., legal reviews, literature reviews, interviews) and include: 1) the percent of land in that country held or used by Indigenous Peoples and Communities (available to download as an Excel Spreadsheet[43]); and 2) the tenure security of Indigenous and Community land based on the evaluation of ten indicators (**Table 9**). The indicators are averaged to produce a national-level estimate[44]. At the Community level, LandMark provides a common platform for hosting data on the locations of Indigenous and Community lands as provided by individuals and organizations around the world with expertise in land rights, including, often, in mapping and documenting rights.

Table 9. Indicators of legal security for Indigenous and Community lands included in Landmark.

Indicators of the Legal Security of Indigenous and Community Lands	
Category	**Indicator**
1. LEGAL STATUS	Does the law recognize all rights that Indigenous Peoples or communities exercise over their lands as lawful forms of ownership?
2. LAND RIGHTS AND COMMON PROPERTY	Does the law give indigenous or community land rights the same level of protection as the rights under other tenure systems?
3. FORMAL DOCUMENTATION	Does the law require the government to provide Indigenous Peoples or communities with a formal title and map to their land?
4. LEGAL PERSON	Does the law recognize the Indigenous Peoples or community as a legal person for the purposes of land ownership?
5. LEGAL AUTHORITY	Does the law recognize the Indigenous Peoples or community as the legal authority over the land?
6. PERPETUITY	Do the law and formal title recognize that indigenous or community land rights may be held in perpetuity?

43 http://communityland.s3.amazonaws.com/LandMark_public/Pct_IP_CommunityLands.zip

44 http://communityland.s3.amazonaws.com/LandMark_public/LegalSecurityIndicators.zip

7. RIGHT TO CONSENT BEFORE LAND ACQUISITIONS	Does the law require the consent of Indigenous Peoples or communities before government or an outsider may acquire their land?
8. RIGHTS TO TREES	Does the law explicitly recognize that indigenous or community land rights include the rights to all trees on the land?
9. RIGHTS TO WATER	Does the law explicitly recognize that indigenous or community land rights include the rights to local water sources on the land?
10. LAND RIGHTS IN PROTECTED AREAS	Does the law uphold indigenous or community land rights in the ownership and governance of national parks and other protected areas?

Landmark integrates data from multiple reputable sources but does not verify the accuracy of the data, therefore users should consider viewing the Data Provider[45] and Data Quality[46] information associated with the geographic area of study.

3.4.3 Women and Youth Empowerment - No Suitable Datasets

No women's or youth empowerment datasets met our criteria for inclusion. However, the data on women's and youth empowerment that we reviewed are explained in Appendix A.

3.5 Migration Datasets (Expected Impact 2.4)

3.5.1 IPUMS-International Migration Global Variables

IPUMS-International[47] collects and distributes census micro-data from around the world, with the overall goal of preserving data and documenting, harmonizing, and disseminating data free of charge. These data are accumulated from 98 countries and account for 443 censuses and surveys with over 1 billion individual records. Pertinent to migration are 19 variables that account for migration status, country of residence, first subnational geographic level of residence, years residing in current locality, and reason for migration. Variables include anywhere from 2 to 53 countries with temporal coverage varying between 1960 and 2018 (**Table 10**) [48]. This dataset is unique in that it is the only one of its kind to collate and harmonize disparate person-level data that allow researchers and institutions to study change, conduct comparative research, merge information across data types, and analyze individuals within family and community contexts.

Table 10. Spatio-temporal coverage of IPUMS-International Migration Global Variables.

Variable	Variable Label	# Countries	Temporal Coverage
MIGRATE1	Migration status, 1 year	25	1979 – 2018
MIGRATE5	Migration status, 5 years	43	1960 – 2011
MIGRATE0	Migration status, 10 years	9	1990 – 2012
MIGRATEC	Migration status, last census	2	1962 – 1999

45 http://www.landmarkmap.org/data/#data-6

46 http://www.landmarkmap.org/data/#data-2

47 https://international.ipums.org/international/index.shtml

48 https://international.ipums.org/international-action/variables/live_search

Variable	Variable Label	# Countries	Temporal Coverage
MIGRATEP	Migration status, previous residence	41	1960 – 2013
MIGCTRY1	Country of residence 1 year ago	17	1979 – 2018
MIGCTRY5	Country of residence 5 years ago	28	1970 – 2011
MIGCTRY0	Country of residence 10 years ago	5	1981 – 2011
MIGCTRYC	Country of residence last census	2	1975 – 1999
MIGCTRYP	Country of previous residence	38	1960 - 2013
GEOMIGI_P	1st subnational geographic level of previous residence, world [consistent boundaries over time]	43	1960 - 2013
GEOMIGI_1	1st subnational geographic level of residence 1 year prior to survey, world [consistent boundaries over time]	19	1979 - 2018
GEOMIGI_5	1st subnational geographic level of residence 5 years prior to survey, world [consistent boundaries over time]	35	1970 - 2015
GEOMIGI_10	1st subnational geographic level of residence 10 years prior to survey, world [consistent boundaries over time]	7	1981 - 2012
MIGYRS1	Years residing in current locality	53	1960 - 2013
MIGYRS2	Years residing in current dwelling	7	1960 - 2011
MIGHOUSE	Same house 5 years ago	4	1971 - 2007
MIGCAUSE	Reason for migration	16	1976 - 2013
MIGFORCE	Forced migration	1	2001

Users should be aware that some samples are weighted such that sample subjects do not uniformly represent the same number of persons in the population. The use of the weight variables when performing analyses is crucial. Also, not all samples contain the full universe (where universe is defined as the population at risk of having a response for the variable in question) of persons in the national population. Small subpopulations such as the institutionalized population, transients, migrants, and indigenous peoples may be excluded or under-represented, therefore it is important to examine the source data. Users should also be aware that the data is rectangularized, where household information is input to the person record and the separate household record is dropped. This means that analyses at the household level can be distorted. Finally, to assure confidentiality, geographic information is usually limited, sometimes severely, with places with a population smaller than 20,000 not being identified, though this can be higher in some places, and for some areas only state or region can be determined.

3.5.2 Demographic and Health Surveys (DHS) Migration

As mentioned earlier, since 1984 the DHS Program has collected, analyzed and disseminated population, health and nutrition data through more than 400 surveys in over 90 countries, primarily in LMIC. While migration is not one of the main topics covered in the DHS surveys[49], for a few (~8) select countries, the DHS questionnaires include questions about migration such as whether any member of the household in the past 12 months or later

49 https://dhsprogram.com/publications/Journal-Articles-Search.cfm

resides outside the country or in a different region within the same country. Where such information is collected, the responses are disaggregated by gender, among other indicators such as age and wealth quintile, though specifics vary by country. Data can be downloaded online[50].

3.5.3 WorldPop Internal Migration Flows

The WorldPop Internal Migration Flows are modelled datasets that represent internal (subnational) migration flows within each malaria-endemic LMIC in Africa, Asia, Latin America, and the Caribbean[51]. They represent mobility within each country. A gravity-type spatial interaction modeling approach was employed to estimate the total number of people migrating from one administrative unit to any other administrative unit, between 2005 and 2010 (34,35). The migration flows can be mapped from centroids of one administrative unit to another (**Figure 8**). Datasets are freely available for download.

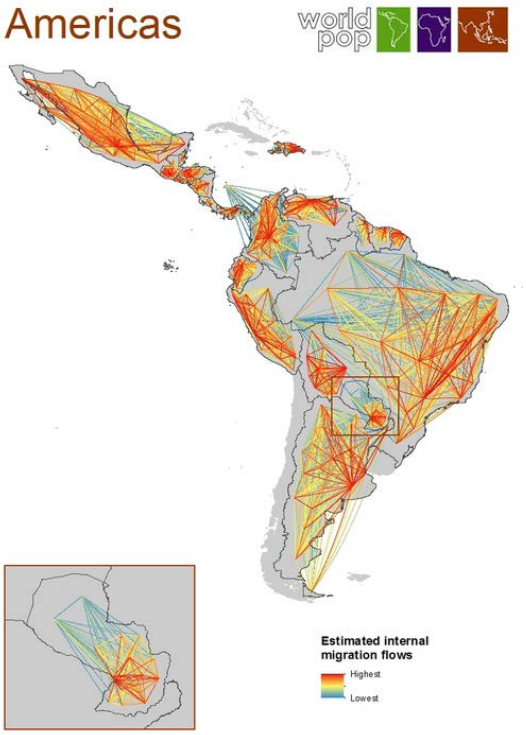

Figure 8. WorldPop Internal Migration Flows data represent internal migration flows within each malaria-endemic Low- and Middle-Income Country (LMIC) in Africa, Asia, Latin America, and the Caribbean. Figure modified from https://www.worldpop.org/geodata/summary?id=1283.

3.6 Land and Water Management Datasets (Expected impacts 2.1-2.4)

3.6.1.1 Copernicus Global Land Cover

The Copernicus Global Land Cover product is derived from the Project for On-Board Autonomy-Vegetation (PROBA-V) sensor and is a medium-resolution land cover product that primarily targets land cover detection and change. The land cover data is provided from 2015 – 2019 in conjunction with vegetation continuous field layers that provide proportional estimates of vegetation cover for several land cover types. The version 3.0 annual 100 m spatial resolution land cover classes were mapped with high temporal stability across years and an overall mapping accuracy just over 80%[52].

This product is widely utilized for a variety of applications including deforestation, desertification, urbanization, land degradation, loss of biodiversity and ecosystem functions, water resource management, agriculture and food security, urban and regional development, and climate change. The Copernicus Global Land Cover data can be used as a proxy for land management in monitoring SO2 expected outcomes.

3.6.1.2 ESA CCI-LC (MRLC maps v207)

The European Space Agency Climate Change Initiative-Land Cover (ESA CCI-LC[53]; Multi-Resolution Land Characteristics - MRLC maps v207) is produced by the ESA Climate Office and includes annual global land cover maps at 300 m spatial resolution from 1992 to 2018. This dataset utilizes the UN Land Cover Classification System (LCCS), which supports the conversion of the 22 land cover classification values into Plant Functional Types distribution required by Earth System Models.

These maps are derived from a unique baseline MRLC

50 https://migrationdataportal.org/data?i=stock_abs_&t=2020
51 https://www.worldpop.org/geodata/listing?id=26
52 https://land.copernicus.eu/global/products/lc
53 http://www.esa-landcover-cci.org/

map that is created using a classification chain applied to the entire MEdium Resolution Imaging Spectrometer (MERIS) Full Resolution (FR) and Reduced Resolution (RR) archive from 2003 to 2012. Independently from this baseline, MRLC changes are detected at 1 km based on a time series of annual global classifications generated from the Advanced Very High Resolution Radiometer High Resolution Picture Transmission System (AVHRR HRPT; 1992 - 1999), Satellite Pour l'Observation de la Terre Vegetation (SPOT-Vegetation; 1999 - 2012) and PROBA-V (2013 - 2015). The temporal trajectory of each pixel is systematically analyzed to depict major changes using a simplified classification consisting of cropland, forest, grassland, wetlands, settlements, and other lands; the category 'other' is further divided into shrubland, sparse vegetation, bare area, and water. Changes detected at 1 km are re-mapped at 300 m where MERIS FR or PROBA-V data are available.

The ESA CCI-LC dataset has been used to analyze built settlement expansion (36), map the SDG 6 water scarcity indicator (37), and is the default land cover dataset provided by the UNCCD to countries for reporting on SDG indicator 15.3.1 during the 2018 reporting cycle (38). For the upcoming reporting cycle, UNCCD is considering whether to continue using the ESA-CCI or if it is possible to use the Copernicus Global Land Cover previously described. The ESA-CCI high-resolution dataset can also be used to map land use conversions across the globe.

3.6.1.3 Intact Forested Landscapes

The IFL concept and its technical definition were introduced by a diverse team (including Greenpeace, The University of Maryland, and Transparent World, with support from the World Resources Institute (WRI) and World Wildlife Fund (WWF) Russia) to help create, implement, and monitor policies concerning the landscapes alteration and fragmentation at the regional-to-global levels. The essence of the IFL method is to use freely available medium spatial resolution satellite imagery to establish the boundaries of large undeveloped forest areas, so called IFLs, and to use these boundaries as a baseline for forest degradation monitoring (39).

The most recent update of this dataset, dating from 2017, employed the latest available cloud-free Landsat composite data from 2016 and annual forest cover change products produced by the Global Land Analysis and Discover lab[54]. Therefore the 2017 dataset represents conditions as close as possible to the end of the year 2016 and beginning of the year 2017. As this dataset continues to be updated, additional time steps could be incorporated into Trends. Earth for reporting purposes.

3.6.1.4 Trends in Global Freshwater Availability from the Gravity Recovery and Climate Experiment (GRACE)

NASA's GRACE was launched in 2002 and ended in 2017,; the GRACE-FO mission launched in mid-2018. These satellites are unique in their ability to measure variations in terrestrial water storage by assessing small changes in Earth's gravity field, including all water stored above and within the land surface. The isolation of groundwater and other components of terrestrial water storage is achieved by integrating GRACE data with other ground- and space-based observational data including meteorology (precipitation, solar radiation, temperature, wind, humidity, and pressure) and biophysical data (vegetation, soils, topography). This is achieved within the Catchment Land Surface Model using the Ensemble Kalman smoother type data assimilation. GRACE data has been used in the quantification of terrestrial water availability and changes for both surface and groundwater, as well as in the development of groundwater- and soil moisture-based drought indicators. The GRACE satellite measures Terrestrial Water Storage (TWS) in equivalent height of water in cm/year and is released as a monthly product quantifying water storage anomalies per month. This dataset offers many options to quantify water access and availability, though it requires more advanced knowledge of remote sensing and hydrology and is more computationally intensive, making it less user-friendly.

The Trends in Global Freshwater Availability from GRACE v1 is a global gridded data set at 0.5 degrees spatial resolution that presents trends in freshwater availability based on data derived from 2002 to 2016 NASA GRACE data[55] (40,41). The Trends in Global

54 http://www.intactforests.org/data.ifl.html

55 https://sedac.ciesin.columbia.edu/data/set/sdei-trends-freshwater-availability-grace/data-download#openModal

Freshwater Availability dataset provides an observation-based assessment of how the global water cycle is responding to human impacts (such as consumption, irrigation, etc.) and climate variations, and thus serves as an important tool to evaluate and predict emerging threats to water and food security. The data values are expressed as a rate of change in centimeters per year. This dataset is a user-friendly alternative to GRACE data because it has been processed and presented in a format that is easy to comprehend and was specifically created for the purpose of assessing food and water security. However, this dataset is limited in terms of making annual comparisons, with the last release in 2019 (for data up to 2016).

4. RECOMMENDATIONS ON INTEGRATED MONITORING PROGRESS TOWARDS SO2 FOR UNCCD AND TRENDS.EARTH

This report provided a summary review of the publicly available global geospatial datasets and pertinent metrics and indicators that enable the assessment of SO2 of the UNCCD 2018-2030 Strategic Framework, and its four expected impacts. In the following sections, we outline recommended approaches for integrating data towards monitoring each of the four SO2 expected impacts. We conclude with a discussion of limitations, attribution, and future considerations.

4.1 Expected impact 2.1: Food security and adequate access to water for people in affected areas is improved.

For food security monitoring, we recommend the use of a simple indicator of food security such as PoU or FIES as the minimum reporting requirement. Due to the absence of complementary subnational data sources, country Parties will need to collect this data internally. We also suggest the suitability of a more robust indicator such as IPC, for which country Parties could collect their own data or rely on publicly available subnational datasets such as FEWS NET Food Security Classifications or NASA's Food Insecurity Hotspots Data Set v1. The FEWS NET data is provided as subnational vector data in food insecure regions and updated every 3 months, making its use in annual reporting highly feasible. NASA's dataset has the advantage of being gridded, therefore allowing fine-scale analyses of food insecurity in the world's most food insecure regions, but is not released on a regular basis, with the most recent release including data only to 2017.

Monitoring water security is currently more complicated than food security as there has yet to be a dataset available that quantifies water security in the way that FIES or IPC does for food security. Currently, a robust water security indicator called the HWISE Scale is being developed, but in the meantime water security/insecurity are commonly measured using a simple access metric such as proportion of the population with access to safe drinking water. Additional access metrics such as access to sanitation services or handwashing facilities can be considered (see Appendix A). At the most basic level, the reporting metric should consider proportion of the population with access to safe drinking water, which is available via the DHS dataset. **We recommend that Trends.Earth provide DHS data to facilitate the reporting of trends in access to safe drinking water where country Parties cannot rely on internally collected data.** If DHS gridded data are available, this would be preferrable to DHS subnational vector data, but given the limited availability of the DHS gridded products, the DHS vector data is a more feasible option. The WWAP Water & Gender Toolkit[56] should be further utilized to develop gender-responsive indicators for water assessment, monitoring, and reporting by applying

56 http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/display-singlenews/news/the_2019_water_gender_toolkit_has_been_launched/

its methodologies or questionnaire for the collection of gender-disaggregated water data.

4.2 Expected impact 2.2: The livelihoods of people in affected areas are improved and diversified

For Level 1 livelihood monitoring, we recommend that country Parties utilize Poverty Headcount estimates obtained from national censuses, as there are no suitable complimentary datasets that could provide subnational data for this indicator. It is also possible to overlay Poverty Headcount data with population density (i.e., WorldPop) to yield the number of people per unit area within the poverty threshold.

For measuring human population exposure, vulnerability, and resilience to DLDD in the absence of nationally collected data, we recommend Trends.Earth provide WorldPop's global gridded high-resolution geospatial dataset on population distributions, demographics, and dynamics. WorldPop provides two spatially disaggregated layers for each country for population count gridded datasets; one at 100m and another at 1km resolutions (at the equator).

Built into the database are population census data, national political boundaries, roads, land cover, built structures, urban areas, night-time lights, infrastructure, environmental data, protected areas, and water bodies. The data are modelled estimates of annual population for the years 2000-2020 and optionally match UN national population estimates. A notable strength of WorldPop is its incorporation of variables modeled to fit individual countries and regions and the ability to gender disaggregate the data. While interpolation in areas with sparse census data lead to variation in spatial uncertainty, WorldPop satisfies all our inclusion criteria.

For Level 2 livelihood monitoring, we recommend that country Parties construct an index in line with the Multidimensional Poverty Index (MPI). We also recommend that Trends.Earth provide global MPI data for use in the absence of nationally collected data. The MPI includes data from the individual level to the global scale, allows urban, regional and gender disaggregation, and is updated annually or biannually. A challenge is that only the global MPI measures allow comparisons among countries and regions (since it is standardized). The MPI includes the proportion of people who are relatively less well-off according to multiple deprivations, but to produce a spatial estimate of the number of people facing acute poverty, gridded population density must overlay the MPI data.

We propose MPI should be overlayed with WorldPop gridded population density variable (number of people in each 100m pixel). Given MPI data available at the household level, and WorldPop's 100m gridded resolution, this overlay would permit an estimate of livelihood conditions for the estimated population for each grid (or pixel). MPI data is available annually from 2010-2020 and WorldPop is available as a gender-structured global population count dataset for all countries in the world, for each year from 2000 to 2020.

4.3 Expected impact 2.3: Local people, especially women and youth, are empowered and participate in decision-making processes in combating DLDD

Ideally, women, youth, and local people's empowerment would be monitored via several dimensions related to SO2.3, including land tenure and land rights, education, employment, and participation in decision-making at the household, government, and LDN planning/project levels. No dataset on these aspects met all our criteria for inclusion. Most available data are not global, not harmonized, not gridded (or not subnational), and/or are irregularly and infrequently updated. Given these caveats, however, there are several datasets that could be used, wherever available, to monitor women, youth, and local people's empowerment.

For women's empowerment, at a bare minimum, we recommend that country Parties monitor trends in populations affected by land degradation, with data disaggregated by gender to assess the number of men versus the number of women affected. Because of potential inequalities, however, it is not sufficient to simply know the numbers of men and women affected but also the differential effects land degradation may have on their respective health, livelihoods, and wellbeing. For those reasons, we also recommend using the MPI,

calculated separately for the two genders. The global MPI dataset does not currently provide gender disaggregated estimates (but they do offer an age disaggregated poverty dataset at the national scale, see Table 1). To report gender disaggregated data and in order to understand impacts sub-nationally, country Parties would have to calculate their own subnational-level MPI statistics. Templates and free statistical packages are readily available to help them do so, as long as relevant survey data are available.

Monitoring female land tenure and land rights is extremely relevant to UNCCD goals. However, among previous UNCCD reports and work to date, there were disagreements about the appropriateness of the FAO Global Land Rights Database for monitoring this aspect of women's empowerment, with a 2017 SPI report favoring the dataset, but the gender consultant Strohmeier dismissing it as too data sparse (see Appendix A). In addition, OPHI's Women's Empowerment in Agriculture Index (see Appendix A) is a new index for which there are no existing global datasets but for which datasets may become available in the future. Therefore, there may be an opportunity for the UNCCD or its partners to support a future data compilation and harmonization effort pertinent to female agricultural land tenure and land rights at the subnational level, but no implementable, subnational dataset yet exists for inclusion in Trends.Earth.

Youth empowerment is best addressed by identifying and monitoring the most vulnerable groups, represented by those living in poverty (such as those identified as multidimensionally poor in the global MPI dataset or the youth NEET rate). Data on the youth NEET rate are provided by the ILO as part of their reporting on Sustainable Development Goal 8 'Decent Work for All,' and particularly for Target 8.6 'By 2020, substantially reduce the proportion of youth not in employment, education, or training.' This indicator is available for 153 countries from at least one or more time points over the past decade, and is likely to be updated in the future, as one subcomponent of the SDGs.

Local people's empowerment can be monitored using an indicator of land tenure, as this is a critical determinant for local people (i.e., Indigenous and local communities) to make decisions which affect their land and, in turn, their food supplies and livelihoods. One dataset that we find suitable in this context is the LandMark dataset since it is in a spatial format and ultimately provides an ordinal score for land security of the indigenous and community populations in most countries. Additionally, the future availability of the similar dataset produced by Conservation International will facilitate assessment of impacts of DLDD on Indigenous and local community lands and waters.

4.4 Expected impact 2.4: Migration forced by desertification land degradation is substantially reduced

The role of DLDD as factors influencing human migration can be measured by quantifying the change of population density per pixel and across time using spatially explicit gridded population datasets such as WorldPop and overlaying environmental layers representing food and water security. Suitable temporal lags may be applied between DLDD patterns and migration measures to approximate some level of credible attribution between the former and the latter. While multiple sources of migration data exist, the spatial and temporal resolution limitations necessitate the use of datasets such as WorldPop that are highly modelled but reliable at the subnational to national scales and are gender disaggregable. The use of WorldPop population density datasets would highlight locations in which drought and land degradation potentially serve as environmental factors that tend to "push" migration. In so doing, characteristics lowering the detrimental impact of these environmental changes on livelihoods can be explicated before mitigating their impacts on migration.

There is a need to develop future (richer) databases on migration which fully map the origin and the destination of migrants per cell over time, account for destination specific variables, and include a design for a richer set of mixed effects (i.e., controlling explicitly for variables specific to the main destination of migrants, such as livelihood differences between origin and destination cells). We acknowledge that any quantitative assessment of the drivers of migration is necessarily limited in scope: it leads to a focus on environmental, economic, and demographic variables at the expense of all the other unobservable factors that trigger migration. In order to deepen their understanding of the link between

environmental changes and migration, country Parties will want to conduct local qualitative studies specific to each subnational region.

We recommend that Trends.Earth make WorldPop Internal Migration Flows data available for country Parties to use in the absence of, or as a complement to, internally collected migration data. The data is modeled to match data from each country and region and covers all countries for each year between 2000-2020. One notable challenge is the absence of a survey with multiple questions, such as the DHS or LSMS, that could assist in elucidating attribution between migration and DLDD patterns. Another challenge is the lack of gender disaggregation. For including gender disaggregation, the IPUMS-International migration dataset may be preferable. And for select countries where data is available, DHS migration data may be useful.

4.5 Sustainable Land and Water Management: The Pathway to Land Degradation Neutrality

Though not explicitly identified as an expected impact, sustainable land and water management practices and the monitoring of landscape and ecosystem health, water quality and quantity, and other related factors can allow country Parties to assess progress towards LDN or possibly elucidate links between land and water management and the SO2 sub-objectives and expected impacts. Additionally, by providing datasets that enable country Parties to determine areas that have been affected by DLDD, Trends.Earth can aid in the determination of "affected areas." For drought, suitable indicators and datasets are reviewed and discussed in Pricope et al. (11). These datasets and indicators support country Parties reporting for SO3 and allow them to quantify physical areas, ecosystems, and people affected by drought and the vulnerability of those people and ecosystems affected. Datasets, indicators, and methodologies for computing land degradation are reviewed and discussed in Daldegan et al. (2), with multiple datasets and resources for these computations currently provided on the Trends.Earth platform. For country Parties who wish to assess any of the SO2 sub-objectives or expected impacts within areas affected by land degradation, these resources are beneficial. This report describes a methodology that can be used to disentangle the SO2 indicators within affected areas. **Recognizing that country Parties may have different definitions of "affected areas," we recommend that Trends.Earth provide guidance on quantifying differences in SO2 indicators within affected and non-affected areas that supports country Parties' varying definitions.**

Additionally, we suggest that Trends.Earth make use of the following datasets to support data dissemination and analysis for land and water management in the absence of internally collected data: ESA CCI-LC and/or Copernicus, IFL, and NASA Trends in Global Freshwater Availability from GRACE. None of these datasets is gender disaggragable; additionally, the differences in spatial resolution for gridded data will need consideration when analyzing data to produce statistically meaningful results.

4.6 Limitations, Attribution, and Future Considerations

Indicators, indices, and databases presented here are intended to serve as best practices for monitoring SO2 with the Trends.Earth monitoring tool. To prioritize uniformity and standardization for all UN country Parties and end users, the selection criteria are purposefully narrow: global coverage, sufficient temporal resolution to measure change meaningfully, sufficient spatial scale to measure sub-national patterns, and the capacity for gender disaggregation, among others. However, few available data, especially human data, meet these criteria. We therefore highlight the importance of country Parties and end users to review this report in the context of the variability in data availability and ability to process data from one nation to another. This report focuses on what is possible globally but does not elaborate on what may be possible in places where richer data relating to SO2 targets are available. While we discuss some of these cases in the report, a case-by-case assessment should be made for each end user's context and needs. Future guidance at the national level would be a fruitful effort for subsequent reports, especially for indicators that require country Parties to collect their own data for annual reporting.

Given that data are an imperfect reflection of reality, context is important to understand potential attribution

of DLDD and the relative effects on ecosystems and people. Take the case of SO2-4, migration relative to DLDD. If population change data suggest net out-migration from a region in which vegetation index-derived landscape greenness had decreased in immediate prior or parallel years, it could be inferred that DLDD may have played a role in pressuring livelihood sustainability for local populations, ultimately pushing people off the land to migrate elsewhere. However, that signal alone may not be enough to determine attribution. Other factors would provide more information suggestive of causation, including trends derived from drought indices and an on-the-ground understanding of socio-political dynamics, livelihoods, and land and water management. For example, if a war had broken out during the same period of the above hypothetical analysis, fleeing violence could be the main driver of out-migration. Conversely, if the primary livelihoods of residents in the region of interest are white collar, service, or industrial, then political-economic factors might be more important drivers of out-migration than DLDD. If, on the other hand, the primary livelihoods are agro-pastoral, with few wage labor opportunities, DLDD would be a more likely driver. However, even in this case, more information would be useful to convincingly suggest attribution. What adaptations, if any, were possible or observed in the region? Did large landholders consolidate area land and intensify production? If so, to what extent were agro-pastoralists absorbed (if at all) into the changing land regimes as agricultural laborers? If intensification was technologically and capital intensive, we may infer a higher level of out-migration from the region than if DLDD adaptations were labor intensive. No measure currently exists that provides a perfect, direct, relationship among all the complex components that comprise human and ecosystem vulnerability and resilience. Context is critical and the critical contextual questions posed above are of the sort that must be pursued when assessing the relative attribution of human responses to change (or stasis) in ecosystem variability and vulnerability.

Potential exists for enhancing monitoring to advance the UNCCD's Strategic Objectives among country Parties. This report focuses on how monitoring can be improved based on freely available data globally germane to SO2. There is potential for new data sources and for the improvement of existing ones. As technology advances, today's expensive cutting-edge products will be tomorrow's publicly available data. But there is also opportunity to innovate, leveraging extant publicly available datasets, such as those presented here. Various spatial statistical methods enable the conversion of data of relatively low spatial resolution to data of higher resolution, with associated location-specific data value probability ranges. Despite ongoing challenges of data scarcity in some remote rural areas within nations, future efforts could expand on what already works. For example, many of our recommended indicators are derived from DHS surveys. Yet approximately half the world's nations have yet to conduct a DHS survey and those that have could usefully increase the frequency of years in which the data are collected. Similarly, DHS questionnaires are not perfectly uniform. Not all countries include the full suite of questions needed to assess women's empowerment in the household. It would be of great benefit to SO2 monitoring if these important variables were standardized across all DHS surveys.

Of great value also would be the inclusion of several key migration variables in the DHS survey, such as those present in the LSMS surveys. We note in this report the lack of direct household and individual data on migration. Relying on estimates derived from gridded population data is unreliable and limited. The DHS surveys would be a priority vehicle for global migration monitoring given their wide adoption and the rich potential for analyzing migration relative to other DHS variables. We also see great promise in enhancing the spatial coverage of some of the data presented here. Again, the DHS offers some spatially available data for certain countries. Subsequent efforts could usefully prioritize building on and improving these efforts both in spatial coverage and in the fidelity and reliability of the spatial modeling techniques. With these and other investments and improvements in data richness, collection and availability, attributions between DLDD and human dynamics promise to be enhanced. These and related efforts will be necessary priorities if country Parties' SO2 monitoring capacity development is to match the urgency of the challenges being monitored.

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6. APPENDIX A. DESCRIPTIONS OF ADDITIONAL INDICATORS AND DATASETS REVIEWED

1. Livelihoods Indicators and Datasets

1. Human Development Index

The HDI was created by the UNDP to emphasize that expanding human choices should be the ultimate criteria for assessing development results as it goes beyond just assessing the process of economic growth. The HDI can be used to assess national policy choices that produce different results even when the countries have the same Gross National Income (GNI) per capita. The HDI incorporates standardized data from 189 countries as of 2019. The primary dimensions of the HDI include long and healthy life, knowledge, and a decent standard of living, which are used to compute the indices for each dimension including the Life Expectancy Index, Education Index, and Gini Index (**Figure A1**). Multiple data sources are used for the annual HDI, including DHS, FAO, ILO, International Monetary Fund, several UN sources, and several additional sources[57]. The HDI simplifies and captures only part of what human development entails. It does not reflect on other aspects of inequality, poverty, human security, empowerment, etc. While the HDI is a robust index in that it encompasses multiple aspects of human development, it is available only as national-level data for a limited number of countries[58].

57 http://hdr.undp.org/en/statistics/understanding/sources

58 http://hdr.undp.org/en/indicators/137506

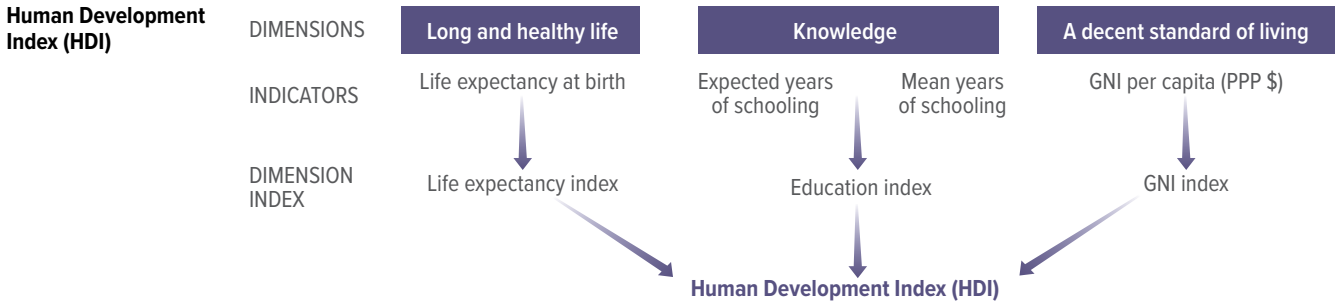

Figure A1. The dimensions, indicators, and indices of the Human Development Index.

2. Gender Inequality Index (GII)

The GII measures gender inequalities in three important aspects of human development—reproductive health, measured by maternal mortality ratio and adolescent birth rates; empowerment, measured by proportion of parliamentary seats occupied by females and proportion of adult females and males aged 25 years and older with at least some secondary education; and economic status, expressed as labor market participation and measured by labor force participation rate of female and male populations aged 15 years and older[59] (**Figure A2**). The

59 http://hdr.undp.org/en/content/gender-inequality-index-gii

higher the GII value the more disparities between females and males, with a range from 0 (perfect equality) to 1 (one gender scores as low as possible across all dimensions). In other words, for a GII value between 0 and 1, the closer the value to 0, the lower that country's development potential due to obstacles caused by gender inequality. Technically, the GII is a mean of means, with the first mean being the geometric mean of scores across all dimensions, calculated for men and women separately. The final GII takes the harmonic mean of the (mean) scores across the two genders. The GII is a complex, but comprehensive measure of the loss development due to inequality across male and female achievement in the measured dimensions. Although available only at the country level, the data are based on well-accepted frameworks developed for the HDI, are frequently updated, and are available for about 160 countries[60]. The lack of subnational data is made up for by the care in which the index appropriately disaggregates country level data by gender using multiple data sources. The GII calculation method is unconnected with absolute development achievement but assesses only a country's current gender achievement and distance from the baseline of equality.

60 http://hdr.undp.org/en/indicators/68606

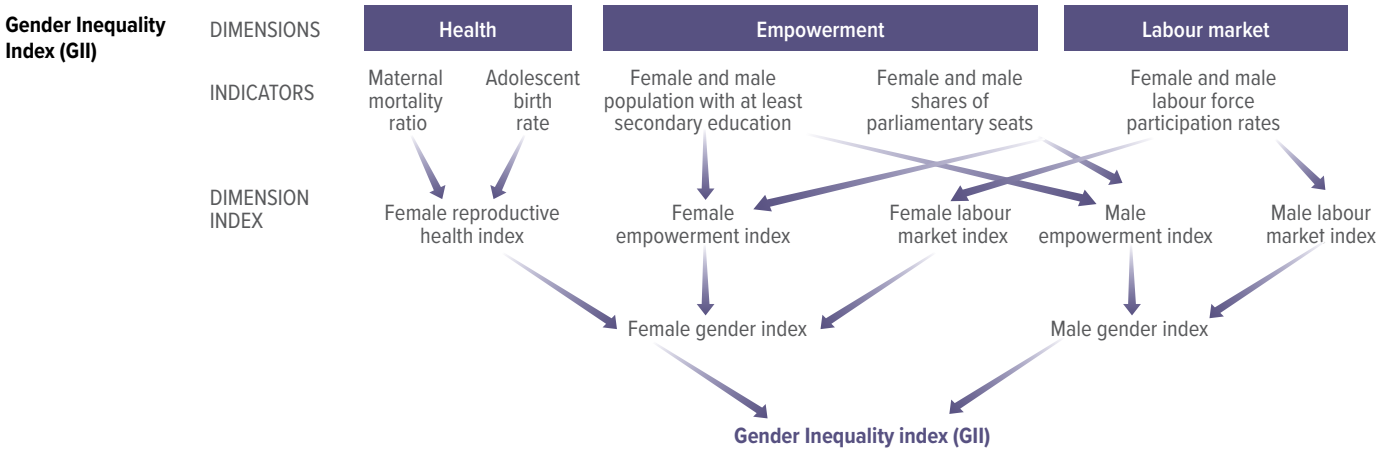

Figure A2. The components of the Gender Inequality Index (GII).

3. Gender Development Index (GDI)

The GDI is the ratio of female HDI to male HDI[61] (**Figure 8**). To calculate it, the HDI is first calculated separately for females and for males. The same goalposts as in the HDI are used for transforming the indicators into a single scaled indicator ranging from zero to one. The only exception is life expectancy at birth where the goalposts are adjusted, to reflect the empirical finding that on average, women have a biological advantage over men, living about 5 years longer.

Just like HDI, the GDI measures achievements in three basic dimensions of human development: health, education, and command over economic resources.

However, for GDI, gender disaggregated data is used in each dimension. That is, wherever HDI would be used, it is possible to analyze female HDI and male HDI separately (available in the GDI dataset), essentially offering a gender disaggregable version of HDI, which would otherwise not be gender disaggregable. This means specific impacts on men and on women could be separately examined.

61 http://hdr.undp.org/en/content/gender-development-index-gdi

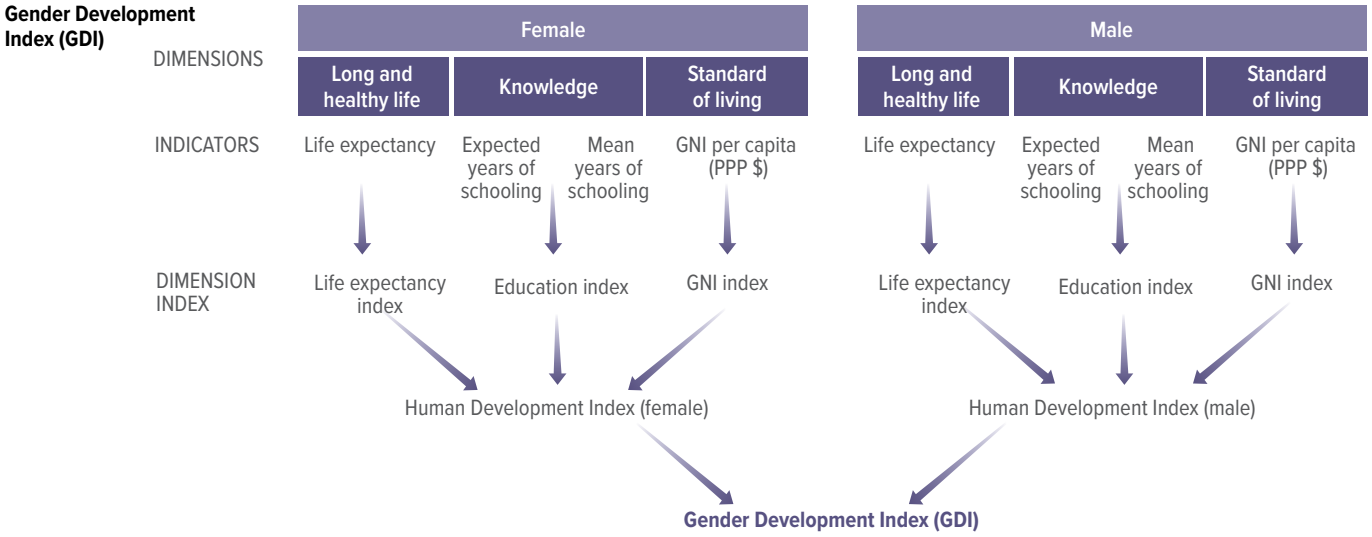

Figure 8. The Gender Development Index (GDI) is a gender-disaggregated version of the Human Development Index (HDI).

The female and male HDI suffer the same limitations as overall HDI, namely that they are not available sub-nationally or as gridded data[62]. In addition, estimating the female and male HDIs for all countries relies on many approximations, such as assuming wage ratios of 0.8 (women's wages: men's wages, the global average) for many countries with missing data. Because of these limitations, the estimated HDIs need to be interpreted with caution. Though intercountry ordinal rankings might be inaccurate and can change over time within a country, it may still be useful to monitor with these metrics.

4. International Wealth Index – IWI

The International Wealth Index (IWI) is an asset-based measure constructed by applying principal component analysis (PCA) on data for over 2.1 million households, derived from 165 household surveys held between 1996 and 2011 in 97 LMIC[63,64] (42). Examples of the household surveys include DHS and United Nations Children's Fund (UNICEF) MICS surveys. A household's position on IWI indicates to what extent the household or its members own a basic set of assets that is valued highly by people across the globe. These assets include consumer durables, housing characteristics, and access to public utilities. The IWI scale runs from 0 to 100, with 0 indicating that the household owns none of the consumer durables, has lowest quality housing and no connection to public utilities, and 100 indicating that the household owns all included consumer durables, has highest quality housing and good access to public utilities.

5. Poverty Probability Index – PPI

The Poverty Probability Index (PPI) is a country-specific poverty rapid measuring instrument available for 47 countries (mostly LMIC)[65,66]. This measurement is derived at the household level following responses to 10 questions that are scored to estimate the probability that a household is poor. The PPI uses a construction methodology that processes country-specific data that has already been collected by large, nationally representative household surveys to determine both the set of questions that are most informative and the points attached to each response (43).

A household is defined as poor, with reference to a particular poverty line, if its consumption expenditure,

62 http://hdr.undp.org/en/indicators/137906
63 https://globaldatalab.org/iwi/
64 https://globaldatalab.org/iwi/downloads/
65 https://www.povertyindex.org/
66 https://www.povertyindex.org/ppi-country

adjusted for household size, is below that poverty line. A poverty line is determined based on the cost of consuming a basket of goods and services consistent with a given standard of living. Users may choose a poverty line that suits their goals. For example, for a lower-middle income country like Kenya, users focused on serving the poor may choose the lower-middle income international poverty line ($3.20/person/day 2011 PPP), while other organizations serving a broader market may prefer a higher poverty line (e.g., $5.50/person/day 2011 PPP).

To estimate the probability that a given household is poor, or alternatively, to estimate the proportion of poor households within a group of households, the PPI consists of two essential components – a scorecard and a look-up table. Temporal updates to PPI depend on each country and the nature of the corresponding survey. For instance, the latest PPI for Colombia released in February 2018 was based on data from Colombia's 2016 Gran Encuesta Integrada de Hogares (GEIH) Survey, while the latest PPI for Kenya released in October 2018 was based on data from Kenya's 2015 Integrated Household Budget Survey (KIHBS).

6. Demographic Health Surveys Wealth Index

The DHS Wealth Index is a composite measure of a household's cumulative living standard, based on data collected in the DHS Household Questionnaire[67]. This questionnaire includes questions concerning the household's ownership of several consumer items such as a television, bicycle, car; dwelling characteristics such as flooring material; type of drinking water source; toilet facilities; and other characteristics that are related to wealth status. The DHS Wealth Index is generated using PCA where individual households are placed on a continuous scale of relative wealth. The resulting asset scores are standardized in relation to a standard normal distribution with a mean of zero and a standard deviation of one. These standardized scores are then used to create the break points that define wealth quintiles as: lowest, second, middle, fourth, and highest. Each quintile value can be reproduced as a weighted average of urban/rural rates (weighted by proportions urban/rural) or the male/female rates (weighted by the proportion male/female). The Wealth Index is presented in the DHS Final Reports and survey datasets as a background characteristic. While the DHS Wealth Index is calculated using household characteristics, it is available at the individual level for men, women, and children up to 5 years old within each respective household. Further the Wealth Index can be summarized at the household-cluster level (point format), first subnational level and national level (polygon format). Specific information on the calculation of the wealth index for each DHS, including the syntax used and the factor loadings can be found in the Wealth Index Construction Page[68] (31,44).

7. FEWS NET Livelihood Zones

FEWS NET's Livelihoods analysis focuses on geographic areas where people and households have similar livelihood patterns (or means by which they access food and earn income to meet basic needs) and access to markets. FEWS NET's use of livelihoods information is based on the Household Economy Analysis (HEA). For early warning of food insecurity, livelihoods analysis provides invaluable insight into a household group's vulnerability to a shock (such as natural disasters or economic changes) and the coping mechanisms that are available to them when a shock occurs. Currently, this sub-national data is available for select countries in Central America and the Caribbean, Central Asia, East Africa, Southern Africa, and West Africa that are priority areas for food security monitoring[69]. FEWS NET's knowledge base on livelihoods includes livelihood zone maps, descriptions, profiles, baselines, and seasonal monitoring calendars.

While this dataset is extremely useful for areas where it is available, it has limited utility at the global scale because the analyses are not performed for every nation, and because it was developed specifically in the context of food security. The data are released on an irregular schedule that is inconsistent among countries, largely due to the time-intensive data collection methods that are undertaken to map and document the livelihood zones and associated attributes. Thus, when considering livelihoods at the global level, it is not able to represent all individuals or

67 https://dhsprogram.com/topics/wealth-index/Wealth-Index-Construction.cfm

68 https://dhsprogram.com/programming/wealth%20index/Steps_to_constructing_the_new_DHS_Wealth_Index.pdf

69 https://fews.net/fews-data/335

geographic units in a comparable manner with a simple standard indicator such as percent of population below the poverty line.

8. World Bank Living Standards Measurement Study (LSMS)

The LSMS is a household survey program administered by the World Bank since 1980 in liaison with Countries' Bureaus of Statistics. LSMS generally reports poverty measures based on a consumption metric as an indicator for the estimation of wellbeing among other money metric indicators (e.g., income-based measures such as proportion of people below the $1.25 a day poverty line). Therefore, all their estimates on poverty are mostly constructed on family expenditures, functioning as base indicators for applying different poverty lines.

Together with the DHS program, the LSMS collects and provides cluster-randomized survey data on core development indicators. In addition to their standard open-source data files in which survey results are tabulated by first-order sub-national regions (for example at province or state level) and urban/rural strata, more recent surveys now provide geocoded data for individual clusters. The availability of GPS coordinates for LSMS clusters provides highly resolved locational information that can be linked with survey outputs for quantifying demographic, health and economic status heterogeneities and inequities.

9. Multiple Indicator Cluster Surveys (MICS)

UNICEF has strategically invested in data collection and helped transform the data landscape for more than 20 years. The global MICS program is the centerpiece of this strategy[70]. UNICEF supports governments in carrying out these household surveys through a global program of methodological research and technical assistance in diverse geographic settings. MICS findings have been used extensively as a basis for policy decisions and program interventions, and for the purpose of influencing public opinion about children and women around the world.

UNICEF works closely with others, such as the DHS program, to harmonize methodologies and indicators used in MICS. MICS data can be disaggregated by various geographic, social, and demographic characteristics[71]. DHS and MICS have similar sample frames, which allow their integration into the MPI for over 100 countries (27). UNICEF has been assisting countries at more frequent intervals since 2009 - every three years instead of every five years.

10. Gridded Population of the World v4 (GPWv4)

The Gridded Population of the World (GPW) collection is a gridded global population dataset developed by CIESIN at Columbia University. Now in its fourth version (GPWv4), this spatially disaggregated layer is gridded with an output resolution of 30 arc-seconds (approximately 1 km at the equator) and incorporates inputs such as population census tables & national geographic boundaries, protected areas, and water bodies[72,73]. The input data are weighted and extrapolated to produce population estimates (counts and densities) for the years 2000, 2005, 2010, 2015, and 2020. A set of estimates adjusted to national level population predictions from the United Nation's World Population Prospects report is also produced for the same set of years. Raster data are also available for basic demographic characteristics (age and sex), data quality indicators, and land and water areas.

The strengths of GPWv4 data are that the population estimation method of areal-weighting is straight-forward, i.e., 'lightly modelled', therefore providing higher fidelity to the input census data. Therefore, this dataset can be analyzed in conjunction with other datasets such as land cover and elevation without concern for endogeneity. However, the disadvantage of using areal-weighting as the spatial disaggregation method leads to a high variability of grid-level estimates. Consequently, for counties where the input (e.g., administrative) units are relatively large, the precision of population estimates for individual grids within that unit can be compromised.

70 https://mics.unicef.org/

71 https://mics.unicef.org/surveys

72 https://sedac.ciesin.columbia.edu/data/collection/gpw-v4

73 https://sedac.ciesin.columbia.edu/data/collection/gpw-v4/documentation

11. LandScan

The LandScan Global dataset is a gridded global population dataset developed by the Oak Ridge National Laboratory (ORNL)[74]. This spatially disaggregated layer is gridded with an output resolution of 30 arc-seconds (approximately 1 km at the equator) and incorporates inputs such as population census tables and national geographic boundaries, roads, land cover, built structures, urban areas, infrastructure, and environmental data. The input data are modelled to produce annual population estimates for the years 1998, 2000 - 2018.

The strength of LandScan is that the population estimation method of dasymetric mapping is multivariate, i.e., 'highly modelled', therefore tailored to match data conditions and geographical nature of each individual country and region. The main disadvantage is that LandScan lacks gender disaggregation.

2. Land and Water Management Indicators and Datasets

1. Water Stress – Baseline Water Stress

The Baseline Water Stress (BWS) layer, developed as part of the WRI Aqueduct Water Risk Atlas[75], is an indicator that measures the ratio of total water withdrawals relative to the annual available renewable surface water supplies. To obtain the BWS values, water withdrawals (year 2010) are divided by mean available blue water (1950–2008). A higher percentage means more water users are competing for limited water supplies; the percentages are typically ranked according to **Table A1**. Areas with available blue water and water withdrawal less than 0.03 and 0.012 m/m2 respectively are coded as "arid and low water use". This dataset is available globally at the national and subnational levels (except for Greenland and Antarctica)[76]. One significant disadvantage of this dataset is that it is at this time over 10 years outdated, with no indication of future releases by which the United Nations or member nations could rely on it for monitoring and reporting of UNCCD SOs. This dataset does not allow gender disaggregation.

Table A1. Baseline Water Stress (withdraws / available flow).

Low	< 10%
Low to medium	10 – 20 %
Medium to high	20 – 40 %
High	40 – 80 %
Extremely high	> 80 %
Arid & low water use	available blue water and water withdrawal less than 0.03 and 0.012 m/m2 respectively

2. Global Map of Irrigated Areas

Irrigation represents up to 95 percent of all water uses globally and plays a major role in food production and food security. Future agricultural development strategies of most countries depend on the ability to maintain, improve, and expand irrigated agriculture. On the other hand, the increasing pressure on water resources by agriculture competes with other water use sectors and threatens the environment in many regions. In terms of global studies on water and agriculture, including for food and water security, understanding the spatial distribution and coverage of irrigated areas is imperative. The FAO Global Map of Irrigated Areas allows for the spatially explicit quantification of *"Percent of arable land equipped for irrigation,"* which represents one component of food security.

The Global Map of Irrigation Areas was produced by the FAO and shows the amount of area equipped for irrigation around the year 2005 in percentage of the total area on a raster grid with a resolution of 5 arc-minutes (~10km at the equator)[77]. Additional map layers show the percentage of the area equipped for irrigation that was used for irrigation and the percentage of the area equipped for irrigation that was irrigated with groundwater, surface water or non-conventional sources of water. Country-level

74 https://landscan.ornl.gov/landscan-datasets

75 https://www.wri.org/resources/data-sets/aqueduct-global-maps-30-data

76 https://indicators.ucdavis.edu/water/resources/world-resoures-institute-wri-geospatial-data-download

77 http://www.fao.org/aquastat/en/geospatial-information/global-maps-irrigated-areas

time series on area equipped for irrigation, starting in 1961, can be found on the FAOSTAT website by choosing the item "Total area equipped for irrigation"[78].

3. Aquastat

The FAO's Aquastat provides a global information system on water resources especially focused on agricultural water management[79]. The Aquastat core database contains country-level information on:

- land use: total area, arable land, and permanent crops
- population: total, urban, and rural (updated annually)
- conventional water resources: surface water and groundwater (long-term avg last updated 2014)
- non-conventional sources of water: wastewater, desalinated water, and fossil water (updated annually if country provides updated information)
- water withdrawal by sector: agricultural, domestic, and industrial (updated annually if country provides updated information)
- water withdrawal by source: surface water, groundwater, and non-conventional water (updated annually if country provides updated information)
- irrigation potential (updated annually if country provides updated information)
- area under irrigation or agricultural water management (updated annually if country provides updated information)
- irrigation techniques: surface, sprinkler, and localized drained areas (updated annually if country provides updated information)
- irrigated crops: area and yield (updated annually if country provides updated information)

Several variables available in Aquastat address both land and water management. Users can choose to focus on respective indicators depending on the reporting thematic focus and geographic scale. This data is available only at a national level, so it is not preferred for sub-national analysis, but still represents a useful source of information in a global context.

4. GHSL-SMOD

The Global Human Settlement Layer – Settlement Model (GHSL-SMOD) is a gridded global settlement dataset developed by the European Commission Joint Research Center (JRC) and gridded at a resolution of 1 km. This dataset incorporates GHS-BUILT built-up density and GHS-POP population grid as inputs to create classes (urban center, urban cluster, and rural) derived from combinations of population density, size, and density of built-up, normalized to the years 1975, 1990, 2000 and 2015[80]. This dataset is open access[81]. The GHS-SMOD dataset can be used to differentiate between urban and rural areas, thus facilitating the ability to analyze rural land management in addition to both rural and urban water management. This dataset is extremely useful when used in conjunction with land use/land cover (LULC) data due to the difficulties in mapping built areas and built area conversion with LULC data alone. GHS-BUILT can be used to mask built areas from the LULC raster time-series and produce a more accurate analysis in the remaining area (45).

3. Food and Water Security Indicators and Datasets

1. FAOSTAT Production indices

The FAO indices of agricultural production are generated by the FAO. The indices depict the relative level of the aggregate volume of agricultural production for each year compared with the base period 2004-2006. They are based on the sum of price-weighted quantities of 173 different agricultural commodities (crop and livestock) produced after deductions of quantities used as seed and feed weighted in a similar manner. The aggregate represents disposable production for any use except as seed and feed. All the indices at the country, regional, and world levels

78 http://www.fao.org/faostat/en/#data/RL

79 http://www.fao.org/aquastat/en/

80 https://ghsl.jrc.ec.europa.eu/data.php?sl=4

81 https://ghsl.jrc.ec.europa.eu/ghs_smod2019.php

are calculated by the Laspeyres formula:

$$\textit{Laspeyres Price Index} = \frac{\sum(Pi,t) \times (Qi,0)}{\sum(Pi,0) \times (Qi,0)} \times 100$$

Where P*i*, 0 is the price of the individual item at the base period and P*i*, t is the price of the individual item at the observation period and Q*i*, 0 is the quantity of the individual item at the base period.

Production quantities of each commodity are weighted by 2004-2006 average international commodity prices and summed annually. To obtain the index, the aggregate for a given year is divided by the average aggregate for the base period 2004-2006. The most pertinent variable for SO2 monitoring is total agricultural production per country per year, which is provided in addition to production of each of the 173 commodities.

Global data are produced at the national level from 1961 – 2018 and are released annually[82]. No quality reports or studies are carried out by FAO to assess the quality of national-level data, and no national quality reports are collected at present. It is not possible to assess the overall accuracy of the dataset, as the source data is largely collected by member countries; nor is information provided regarding sampling and non-sampling error.

A potential disadvantage of this dataset is that there is little geographical comparability due to differences between countries in methods and coverage (except for regions where countries are bound by regulations mandating harmonized methods such as the European Union). For shorter time periods, data for a particular country are reasonably comparable over time because there is stability in the product definition and classification; however, over long periods of time full comparability cannot be expected. Gender disaggregation is not possible.

2. FAOSTAT Food Security Indicators

The FAOSTAT Food Security Indicators provide data relating to food availability, access, stability, and utilization at the national level from 2000 - 2020[83]. The indicators are revised annually based on the new information received from nations and international organizations. Statistics are subject to the general quality assurance framework of FAO with accuracy varying by indicator depending on the sampling design and size and accuracy of the basic variables that make up the indicator. The data are reasonably comparable over time by country if methodology and classification have not changed, but there is limited geographic comparability between countries. The complete list of indicators and their associated measurements included in this dataset are shown in **Table A2**.

One potential application of this suite of indicators is the quantification of stunting, wasting, and undernourishment at the national level as metrics are specifically provided for these indicators.

82 http://www.fao.org/faostat/en/#data/QI

83 http://www.fao.org/faostat/en/#data/FS

Table A2. Metrics included in the FAOSTAT Food Security Indicators database.

Availability	
Average dietary energy supply adequacy	Percent (3-year average)
Average value of food production	Constant 2004-2006 i$/cap (3-year average)
Dietary energy supply used in the estimation of prevalence of undernourishment	Kcal/cap/day (3-year average)
Share of dietary energy supply derived from cereals, roots, tubers	Kcal/cap/day (3-year average)
Average protein supply	g/cap/day (3-year average)
Average supply of protein of animal origin	g/cap/day (3-year average)
Access	
Rail line densities	Total route in km per 100 km2 of land
Gross domestic product per capita, PPP, dissemination	Constant 2011 international $
Prevalence of undernourishment	Percent
Number of people undernourished	Million
Prevalence of severe food insecurity in the total population	Percent
Prevalence of moderate or severe food insecurity in the total population	Percent
Number of severely food insecure people	Million
Number of moderately or severely food insecure people	Million
Stability	
Cereal import dependency ratio	Percent (3-year average)
Percent of arable land equipped for irrigation	Percent (3-year average)
Value of food imports in total merchandise exports	Percent (3-year average)
Political stability and absence of violence/terrorism	Index
Per capita food production variability	Constant 2004-2006 thousand international $ per capita
Per capita food supply variability	Kcal/cap/day
Number of severely food insecure people	Million
Number of moderately or severely food insecure people	Million
Utilization	
Percentage of population using safely managed drinking water services	Percentage
Percentage of population using a least basic drinking water services	Percentage
Percentage of population using safely managed sanitation services	Percentage
Percentages of population using at least basic sanitation services	Percentage
Percentage of children under 5 years of age affected by wasting	Percentage
Percentage of children under 5 years of age who are stunted	Percentage

Percentage of children under 5 years of age who are overweight	Percentage
Prevalence of obesity in the adult population (18 years and older)	Percentage
Prevalence of anemia among women of reproductive age (15 – 49 years)	Percentage
Prevalence of exclusive breastfeeding among infant 0-5 months of age	Percentage
Prevalence of low birthweight	Percentage

3. WASH Data

Established in 1990, the WHO/UNICEF Joint Monitoring Program (JMP) global database includes estimates of progress in household drinking water, sanitation, and hygiene since 2000 that have been calculated from data produced by national authorities[84]. The JMP monitors WASH at the household level in addition to schools and health care facilities, with reporting focused on inequalities in service levels between rural and urban, sub-national regions, and rich and poor and other population sub-groups where data permit. The JMP database includes over 5,000 national data sources with information on WASH in households including nationally representative household surveys, censuses, and administrative reports.

JMP uses a standardized classification and estimation method to facilitate comparisons between countries, regions, and the world (**Table A3**). Estimations start with the identification of nationally representative data pertaining to water use and sanitation and the prevalence of handwashing facilities in the home. Administrative data and household surveys are used to incorporate service level data. Data harmonization is supported using a set of core questions for water, sanitation, and hygiene. Then, simple linear regression is used to estimate the populations using different levels of services using the JMP ladders.

Table A3. WHO/UNICEF Joint Monitoring Program indicators used for global monitoring of WASH service levels in households. This table and the associated core questions are accessible at online[85].

Service Type	JMP Service Ladders	
Drinking Water 1. Improved or unimproved; surface water 2. Basic & limited services 3. Safely managed services 3a – accessibility 3b – availability 3c – quality	Safely Managed	Drinking water from an improved water source that is located on premises, available when needed and free from fecal and priority chemical contamination
	Basic	Drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including queuing
	Limited	Drinking water from an improved source for which collection time exceeds 30 minutes for a round trip, including queuing
	Unimproved	Drinking water from an unprotected dug well or unprotected spring
	Surface Water	Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal

84 https://washdata.org/

85 https://washdata.org/report/jmp-2018-core-questions-household-surveys

Service Type	JMP Service Ladders	
Sanitation 1. Improved or unimproved; open defecation 2. Basic & limited services 3. Safely managed Services 3a – emptying of on-site facilities 3b – treatment and disposal of excreta from onsite facilities 3c – treatment of wastewater	Safely Managed	Use of improved facilities that are not shared with other households and where excreta are safely disposed of in situ or transported and treated offsite
	Basic	Use of improved facilities that are not shared with other households
	Limited	Use of improved facilities shared between two or more households
	Unimproved	Use of pit latrines without a slab or platform, hanging latrines or bucket latrines
	Open Defecation	Disposal of human feces in fields, forests, bushes, open bodies of water, beaches or other open spaces, or with solid waste
Hygiene 1. Facility or no Facility 2. Basic & limited handwashing facility	Basic	Use of improved facilities that are not shared with other households and where excreta are safely disposed of in situ or transported and treated offsite
	Limited	Use of improved facilities that are not shared with other households
	No Facility	Use of improved facilities shared between two or more households
Menstrual Hygiene 1. Special attention to the needs of women and girls 1a – private place to wash and change 1b – use of menstrual hygiene products 1c – exclusion due to menstruation		

Another unique aspect of WASH data is that part of the questionnaire assesses the unique hygienic needs of women as they relate to menstruation, although this metric is not ranked in the same way as the other three making it difficult to assess how well countries are addressing the special attention that is needed to this matter for women and girls.

4. Global Hunger Index

Global Hunger Index (GHI) scores are calculated using a three-step process that draws on available data from various sources to capture the multidimensional nature of hunger[86,87]. First, for each country, values are determined for four indicators: **undernourishment** (the share of the population that is undernourished), **child wasting** (the share of children under the age of five who are wasted, i.e., who have low weight for their height, reflecting acute undernutrition), **child stunting** (the share of children under the age of five who are stunted, i.e., who have low height for their age, reflecting chronic undernutrition), and **child mortality** (the mortality rate of children under the age of five that is, in part, a reflection of the fatal mix of inadequate nutrition and unhealthy environments). Together, child stunting and child wasting are combined equally to create the dimension for **child undernutrition**).

86 https://www.globalhungerindex.org/

87 https://www.globalhungerindex.org/download/all.html

Second, each of the four component indicators is given a standardized score on a 100-point scale based on the highest observed level for the indicator on a global scale in recent decades. Third, standardized scores are aggregated to calculate the GHI score for each country, with each of the three dimensions (inadequate food supply; child mortality; and child undernutrition) given equal weight.

This three-step process results in GHI scores on a 100-point GHI Severity Scale, where 0 is the best score (no hunger) and 100 is the worst. In practice, neither of these extremes is reached. A value of 0 would mean that a country had no undernourished people in the population, no children younger than five who were wasted or stunted, and no children who died before their fifth birthday. A value of 100 would signify that a country's undernourishment, child wasting, child stunting, and child mortality levels were each at approximately the highest levels observed worldwide in recent decades. By combining multiple indicators, the index reduces the effects of random measurement errors.

Undernourishment data are provided by the FAO. Child mortality data are sourced from the United Nations Interagency Group for Child Mortality Estimation (UN IGME). Child wasting and child stunting data are obtained from the joint database of UNICEF, the World Health Organization (WHO), and the World Bank, as well as from WHO's continuously updated Global Database on Child Growth and Malnutrition, the most recent reports of the DHS and MICS, and statistical tables from UNICEF. Thus, this index presents more robust information than can be drawn from any of those data sources in singularity.

Thus, the GHI is an index that represents not only undernourishment in the total population but includes child-specific indicators that reflect the nutrition status within a vulnerable subset of the population for whom a lack of dietary energy, protein, and/or micronutrients (essential vitamins and minerals) leads to a high risk of illness, poor physical and cognitive development, and death. The inclusion of both child wasting and child stunting allows documentation of both acute and chronic undernutrition. As an example, if a country experienced a severe drought recently, the percent of children suffering from wasting may be increased even if chronic stunting is low. Conversely, for a nation that suffers chronic malnutrition over multiple years, changes in percent of children suffering stunting would be a preferred proxy for long-term changes in food security.

5. USDA International Food Security Assessment

The United States Department of Agriculture (USDA) Economic Research Service (ERS) conducts a quantitative and qualitative research and analysis on food security issues in 76 LMIC countries, focusing on food security measurement and the key factors affecting food production and household access to derive its food security indicators. The dataset includes annual country-level data on area, yield, production, nonfood use, trade, and consumption for grains and root and tuber crops (combined as R&T in the documentation tables), food aid, total value of imports and exports, gross domestic product, and population compiled from a variety of sources. As this dataset is produced at a national level for only 76 countries, its implementation in SO2 monitoring is limited, where use of the FAO Food Security Indicators would be recommended if national level data is recommended.

4. Local People, Women, and Youth Empowerment Indicators and Datasets

1. Women's empowerment-relevant datasets

Some initial datasets and proxy indicators we investigated were: FAO Gender and Land Rights Database (GLRD)[88], International Labour Organization (ILO) labor force participation rate by sex, age and rural / urban areas (%), United Nations Development Programme (UNDP) Gender Inequality Index (GII) and Gender Development Index (GDI), the Social Institution and Gender Index Country Profiles produced by the Organization for Economic Co-operation and Development (OECD),[89] particularly indices on laws on women's access to land

88 http:/www.fao.org/gender-landrights-database/ background/en/

89 https://stats.oecd.org/Index.aspx?DataSetCode=GIDDB2019

assets, World Bank's Women, Economy and Law database on laws that are gender discriminatory, and Inter-Parliamentary Union (IPU) data on percentage of parliamentary seats held by women. We also looked at Demographic and Health Survey (DHS) Women's Questionnaire which is implemented in a few countries and contains very relevant metrics such as the percent of women with final say in all (or no) household decisions, and percentage of women who are literate, the latter of which is also freely available as a gridded "Modeled surface" dataset from DHS for a subset (38) country (Table A4).

There were some discrepancies in opinions expressed in past reports about some of these datasets. For example, whereas the 2017 SPI report recommends countries "make use of FAO's GLRD which highlights the major political, legal and cultural factors that influence the realization of women's land rights throughout the world," Strohmeier's gender report on Task 1 states: "Although the indicator [Proportion of total agricultural population with ownership or secure rights over agricultural land, by sex] is of utmost importance for the purposes of UNCCD, the available data is limited to such an extent that this indicator is currently not producing meaningful results." The reasons Strohmeier cites to make this statement include underlying agricultural censuses not harmonized across regions, not available regularly across time (i.e., the censuses are reported across irregular years within a 20+ year timeframe) and not global or quasi-global in coverage (i.e., many countries lack data).

Table A4. Details on Indicators and Datasets for Monitoring Women's Empowerment.

Indicator	Data source	Spatial Resolution	Temporal Coverage	Temporal Resolution	Spatial Coverage
Percentage of currently married women with final say in all household decisions	DHS	subnational	1999-2018	Irregular	69 countries
Percentage of currently married women with final say in no household decisions	DHS	subnational	1999-2018	Irregular	69 countries
Percentage of women in national parliaments	Inter-Parliamentary Union	national	1997-2018	Annual	193 countries
WBL index	World Bank: Women, Business and Law Database	national	1970-2019	Annual	190 countries
Legal access to land assets: a 5-level ordinal measure for whether women and men have the same legal rights to land	OECD's GID-DB	national	2014, 2019	5-year interval	160 countries
Female agricultural holders (% of total agricultural holders)	FAO Gender and Land Rights Database	national	1999-2018	Irregular	104 countries
Labor force participation rate by sex, age and rural / urban areas (%)	ILO	national	2005-2024	Annual	189 countries
Gender Inequality Index	UNDP GII	national	1990-2018	Annual	162 countries
Gender Development Index	UNDP GDI	national	1995-2018	Annual	166 countries

Women with account at financial institution or with mobile money-service provider (% of female population ages 15 and older)	World Bank	national	2011, 2014, 2017	5-year interval	180 countries
ED_LITR_W_LIT: Percentage of women aged 15-49 who are literate	DHS	gridded, 5×5km	2013-2018	Irregular/	38 countries

2. Specific metrics for monitoring women's empowerment and participation in decision making

We here discuss utility of various datasets for directly monitoring aspects of women's empowerment from the household to national and international policy levels. At the household level, women's empowerment can manifest as an ability to make major household decisions. Few data at this level of women's empowerment are available, but one potential source is the Demographic and Health Survey (DHS) Women's Questionnaire.

At the national government and policy level, women's empowerment can be proxied by IPU data on percentage of parliamentary seats held by women, (SDG 5.5). The United Nations Development Program (UNDP) Gender Inequality Index (GII) incorporates this indicator as well as a number of other indicators, including women's participation in the labor force, and a number of indicators related to women's health and education. Thus, the UNDP GII offers a rich and multi-dimensional look at women's empowerment that could be used as a focus of specific monitoring efforts towards the goal of overall women's responsiveness and gender inequality in a nation. The major drawback of the GII (as well as other similar indicators reviewed here and mentioned previously but not recommended in this report) is the lack of subnational or gridded data. For this reason, we recommend wherever possible (currently only available for 38 countries, most for only a single timepoint), the use of DHS gridded data on women's literacy (ED_LITR_W_LIT which is Percentage of women aged 15-49 who are literate) as the one and only subnational, gridded, and sufficiently spatialized dataset pertinent to women's empowerment that we could identify.

An alternative to GII is the World Bank Women Business and Law (WBL) Database. Whereas the GII provides an index of women's empowerment and inequality in the context of development, the World Bank WBL Index provides an overall index about gender discriminatory laws pertinent to the various stages of women's working lives, from the decision to work and access to equal pay all the way through inheritance and pensions. This database is updated annually and is available for the vast majority of countries, but it suffers some of the same drawbacks as GII in that it is not subnational or sufficiently spatialized to be very useful beyond an overall national level metric.

3. Female land tenure and land rights

Women's access to land, land rights, and agricultural assets are core issues of women's empowerment pertinent to LDN and DLDD monitoring for SO2. Thus, despite the fact that there were some disagreements about the appropriateness of the FAO GLRD for monitoring this aspect of women's empowerment – with a 2017 SPI report favoring the dataset, with gender consultant Strohmeier dismissing it as too data sparse – here we review this as the most quantitative and primary data on women's land holder status (based on censuses not modeled data). The most relevant metric with enough data to be useful is the 'percentage of female agricultural holders out of total agricultural holders,' which was calculated for at least one time-point between 1998 and 2018 for 104 countries. Because these data are based on different compiled underlying agricultural censuses whose questions and data have not necessarily been harmonized across censuses, it would be most appropriate to monitor this metric for changes over time within a country. To date, change over time is not possible due to only a single time point per country, but so long as updated data points become available in the future, and are confirmed to use harmonized and comparable methods, this metric would be extremely relevant to SO2 monitoring.

A promising alternative to the FAO dataset to evaluate women's empowerment with regard to land tenure and agricultural decision-making is OPHI's Women's Empowerment in Agriculture Index (WEAI). Unfortunately, no global or even quasi-global datasets yet exist based on this index. The WEAI is a new survey-based index designed to measure the empowerment, agency, and inclusion of women in the agricultural sector (46). It was originally commissioned as a tool for the United States government's Feed the Future Initiative, but it may also be used more generally. The WEAI is an aggregate index, based on individual-level data collected by interviewing men and women within the same households. The WEAI comprises two sub-indices: first, the "5DE" evaluates five domains 1) decisions about agricultural production, 2) access to and decision-making power about productive resources, 3) control of use of income, 4) leadership in the community, and 5) time allocation; second, "the Gender Parity Index (GPI)" measures the percentage of women whose achievements are at least as high as the men in their households.

Strohmeier recommended that the OECD's Gender, Institutions and Development Database (GID-DB) indicator assessing laws on access to land be used as an alternative proxy to determine women's land rights and land tenure. This GID-DB indicator, which measures whether women and men have the same legal rights and secure access to land assets, currently follows a 5-level ordinal metric that is qualitative and ranges from 0, meaning women have the same legal rights and secure access to land assets as men, to 1, meaning women do not have the same legal rights and secure access to land assets as men (see Section 3). While this metric is recorded annually, its methods and qualitative levels have changed slightly over the years, precluding some inter-annual comparisons. Also, we deemed this metric too qualitative and too coarse (with only 3-5 qualitative levels) to serve as a good quantitative monitoring tool for SO2 at this time. Another alternative suggested by Strohmeier is the World Bank Indicator "Women with account at financial institution or with mobile money-service provider (% of female population ages 15 and older)." Although not available sub-nationally, this metric has good coverage and is available annually from World Bank and is therefore a reliable source of data on women's empowerment with respect to access to resources (although it is not specific to land access).

4. FAO Gender Land Rights Database

The data compiled in the FAO GLRD is collected through agricultural censuses, including Eurostat and the FAO World Programme for the Census of Agriculture, among others[90]. The indicator within this database that is relevant to SO2 monitoring, and pertinent to women's empowerment is its "Indicator 1," defined as: the percentage of female (or male) agricultural holders out of total agricultural holders, based on the simple equation:

$$\left(\frac{\textit{Female Agricultural Holders}}{\textit{Total Agricultural Holders}} \right) * 100$$

An **agricultural holder** is defined as the civil or juridical person who makes the major decisions regarding resource use and exercises management control over the agricultural holding, with a "holding" defined as an economic unit of agricultural production under single management comprising all livestock kept and all land used wholly or partly for agricultural production purposes, without regard to title, legal form, or size. The holder may also be the owner of the holding but is not necessarily the owner. While agricultural holdings typically are land holdings, they may also comprise other agricultural production resources, and in some cases only non-land resources.

The proportion of female agricultural holders had 104 countries represented at some time-point (few with multiple time-points) between 1999 and 2018. Furthermore, while the FAO Gender and Land Rights Database itself presents only national level data, the agricultural censuses underlying the database likely contain some subnational data that might be accessible (although not online and not confirmed by the authors of this report).

90 http://www.fao.org/gender-landrights-database/en/

5. Inter-Parliamentary Union: Percentage of Women in National Parliaments

The percentage of women in national parliaments is currently measured as the number of seats held by women members in single or lower chambers of national parliaments, expressed as a percentage of all occupied seats[91]. The indicator measures the degree to which women have equal access to parliamentary decision-making, a key aspect of women's opportunities in political and public life. The inclusion of the perspectives and interests of women is a prerequisite for democracy and gender equality and contributes to good governance. Although this metric is, by its nature, available only nationally, it is important to monitor as a contextual indicator of women's empowerment at the highest levels of government. National parliaments report directly to this data platform on a regular basis. This metric could be used as a stand-alone metric of women's empowerment, but it is also included as one dimension of the Gender Inequality Index, which is more comprehensive (and described previously).

6. World Bank: Women, Business, and Law Database (WBL Index)

WBL is a World Bank Group project collecting data on the laws and regulations that restrict women's economic opportunities[92]. The WBL Index is composed of eight indicators about laws pertinent to the various stages of women's working lives, including laws restricting various aspects about women's freedom of movement, decision to work, pay, marriage, work after children, starting a business, property and inheritance, and size of pensions. In the past 10 years, the database has expanded to cover about 190 countries and is updated annually. Although the data are available only at the national level, this index is a rich and multidimensional way to capture women's empowerment in general, and is therefore, pertinent to the Gender Action Plan of UNCCD.

7. The Organization for Economic Co-operation and Development (OECD) Gender, Institutions and Development Database (GID-DB)

The GID -DB provides data on gender biased access to productive and financial resources, including an indicator assessing laws on access to land, which measures whether women and men have the same legal rights and secure access to land assets[93]. The following categorizations are used (a 5-level ordinal metric):

0: Women and men have the same legal rights and secure access to land assets, without legal exceptions regarding some groups of women. Customary, religious, and traditional laws or practices do not discriminate against women's legal rights.

0.25: Women and men have the same legal rights and secure access to land assets, without legal exceptions regarding some groups of women. However, some customary, religious, or traditional practices or laws discriminate against women's legal right.

0.5: Women and men have the same legal rights and secure access to land assets. However, this does not apply to all groups of women.

0.75: Women and men have the same legal rights to own land assets; but not to use, make decisions and/or use land assets as collateral.

1: Women do not have the same legal rights as men to own land assets.

This metric was recommended by the gender consultant Hannah Strohmeier, and indeed data are available for 160 countries at a five-year interval starting in 2014. Yet, the data are available only at the national level (no subnational data), and the 5-level ordinal/qualitative metric may be too coarse and too qualitative to be meaningful as a quantitative measure of SO2 impacts.

91 http://archive.ipu.org/wmn-e/classif.htm

92 https://wbl.worldbank.org/en/wbl-data

93 https://stats.oecd.org/Index.aspx?DataSetCode=GIDDB2019

8. ILO Labor force participation Rate by Sex, Age, and Rural / Urban Areas (%)

Given the link between poverty eradication and secure income generation, it is important to monitor women's participation in the paid labor force, and in economies in general. The ILO tracks statistics on the working-age population engaged in the labor force. In particular, "the Labor force participation by sex, age, and rural/urban areas (%)" is harmonized to account for differences in national data and scope of coverage, collection, and tabulation methodologies as well as for other country-specific factors[94,95]. The limitation with this indicator (and other indicators in this series) is that it is modeled data, and imputed observations that are not based on national data are subject to high uncertainty and should thus not be used for country comparisons or rankings. However, this indicator is useful for providing information on country progress towards UNCCD strategic objectives related to women's empowerment. It could be used alone as an indicator specific to women's participation in the labor force, but it is also used as one aspect involved in the calculation of the UNDP Gender Inequality Index, which is more comprehensive.

9. World Bank Indicator: Women with account at financial institution or with mobile money-service provider (% of female population ages 15+)

Access to financial resources is an important component of empowerment. The World Bank Indicator Women with account at financial institution or with mobile money-service provider (% of female population ages 15+) (represented by the code FX.OWN.TOTL.FE.ZS) denotes the percentage of respondents who report having an account (by themselves or together with someone else) at a bank or another type of financial institution or report personally using a mobile money service in the past 12 months (female, % age 15+)[96]. While this is not specifically an indicator of women's access to land or involvement in decision making, it is an acceptable proxy and may be a useful indicator of women's empowerment in general. The drawbacks of this data are that they are available only at a national (not subnational or gridded) spatial resolution and they are updated only every 5 years[97].

10. Youth NEET Rate: Share of youth (aged 15-24 years) not in education, employment, or training (%)

The Youth NEET Rate is currently monitored as part of Sustainable Development Target 8.6.1 to "substantially reduce the proportion of youth not in employment, education or training" (towards SDG 8 "Decent work for all"). Therefore, data are regularly produced and readily available for most countries. ILOSTAT contains harmonized statistics from national sources on youth NEET rates by sex, with youth defined as age 15-24 (inclusive)[98], calculated by the following equation:

$$NEET\ Rate\ (\%) = \frac{(U+OLF)-(UET+OLFET)}{Youth} * 100$$

where *U* is Unemployed youth, *OLF* is Youth outside the labor force, *UET* is Unemployed youth in education or training, and *OLFET* is Youth outside the labor force in education or training.

The Youth NEET group is neither improving their future employability through investment in skills nor gaining experience through employment. Therefore, this group is particularly at risk of both labor market and social exclusion. In addition, the NEET group is already in a disadvantaged position due to lower levels of education and lower household incomes. It is important to bear in mind that the Youth NEET group is composed of two different sub-groups (unemployed youth not in education or training and youth outside the labor force not in education or training). Major reasons youth end up in the

94 https://ilostat.ilo.org/resources/concepts-and-definitions/description-labour-force-participation-rate/

95 https://ilostat.ilo.org/data/

96 https://datacatalog.worldbank.org/account-ownership-financial-institution-or-mobile-money-service-provider-female-population-ages-15-0

97 https://databank.worldbank.org/reports.aspx?source=2&series=FX.OWN.TOTL.FE.ZS

98 https://ilostat.ilo.org/resources/concepts-and-definitions/description-youth-neet/

NEET group: they are discouraged from working or are outside the labor force due to disability or engagement in household chores, among other reasons.

The ILO provides data on the Youth NEET rate in variable years between 2000 and 2019, for 168 countries (with most countries having statistics in multiple years) and the data are disaggregated by gender. A main limitation of this dataset is that it is available only at the national level, and subnational statistics are not provided. The Youth NEET rate is contained within the "SDG labour market indicators (ISLSGD)" database and is represented with the code SDG_0861_SEX_RT_A. It can be downloaded as an Excel summary or CSVs[99].

99 https://ilostat.ilo.org/data/#