Global Metabolism Initiative

Method Documentation

GMI MATERIALITY ASSESSMENT

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INTRODUCTION

This document summarizes the data and methods used as part of the materiality assessment for the GMI project. The goal of the materiality assessment is to allow the comparison of commodity production between different countries across a variety of environmental themes.

The guiding principle of this assessment has been to rely on spatial data as much as possible in order to capture localized materiality issues. We intersect maps of where commodities are produced with maps of environmental indicators in order to correlate production with the impacts and dependencies on the ground.

You can explore the GMI data in our online dashboard, or download the data to explore it yourself. Please contact us for any questions.

COMMODITY

The focus of this edition of the GMI is on biobased commodities divided into the following categories: crops, livestock, and forestry. The scope of these categories is described below and is dependent on the data that is available:

- **Crop:** The assessment covers 40 crop types. The data is available through the Spatial Production Allocation Model project (MapSPAM).
- **Livestock:** The assessment covers 8 livestock types. The data is available through the Gridded Livestock of the World project (GLW).
- **Forestry:** The assessment covers one forestry type for both coniferous and non-coniferous forests. The data is available through the paper "Classifying drivers of global forest loss".

All of the commodity production datasets are available at a resolution of 5-min arc (or 10km at the equator).

It should be noted that while the broader GMI assessment covers the topic of marine biomass production, it is not included in the impact assessment. This is because spatial data of marine biomass production is not readily available at the moment.

MATERIALITY

"Materiality" means whether a theme is a relevant area of concern for a certain human activity. This includes potential dependencies and/or potential impacts on natural systems. For example, meat production has a high **impact** in terms of the CO_2-eq emissions from meat production. On the other hand, meat production might have a high **dependency** on water risk. Therefore, we say that both the themes of Climate Change and Water are central to meat production.

PRODUCTION

While there are various national level sources for commodity production, sub-national data about commodity production is difficult to find. We rely on the latest datasets to understand the spatial distribution of biobased commodities. The following table summarizes the production data used for the GMI materiality assessment.

Category	Source	Spatial Resolution	Reference Year	Type of Data
Crops	Spatial Production Allocation Model (MapSPAM)	5-min arc (10km at the equator)	2010 (average of 2009-2011)	Production tonnage, land use, water use
Livestock	Gridded Livestock of the World	5-min arc (10km at the equator)	2010	Head count
Forestry	Classifying drivers of global forest loss	5-min arc (10km at the equator)	2010	Land use

CROPS

MapSPAM provides spatial crop production, harvest area, yield, and value data for 42 crops. It also breaks down production areas by the crop watering method. Crops are either irrigated (sprinklers, drip pipe, etc) or rainfed (natural precipitation). The irrigated water can come from anywhere (groundwater, rivers, canals, etc). For GMI, the **production** and **harvest area** data of both **irrigated** and **rainfed** crops was used. A full description of the MapSPAM methodology can be found on their website.

While MapSPAM has data for 42 crops, this was reduced to 40 in order to match FAOStat data of country production that is also being used in the GMI. In particular, the following adjustments were made:

- Arabica coffee and robusta **coffee** were combined into the coffee classification
- Pearl millet and small millet were combined into the **millet** classification

The full crop list used in the GMI materiality assessment is as follows:

- wheat
- rice
- maize
- barley
- millet
- sorghum
- other cereals
- potato
- sweet potato
- yams
- cassava
- other roots
- bean
- chickpea
- cowpea
- pigeonpea
- lentil
- other pulses
- soybean
- groundnut
- coconut
- oil palm
- sunflower
- rapeseed
- sesame seed
- other oil crops
- sugarcane
- sugarbeet
- cotton
- other fibre crops
- coffee
- cocoa
- tea
- tobacco
- banana
- plantain
- tropical fruit
- temperate fruit
- vegetables
- rest of crops

Water Use

Water use for crop production is estimated using the WaterStat from the Water Footprint Network. This dataset describes water use intensity (m^3/tonnes) by crop, country and water type (rainwater, irrigated). The water use figures are averages of data from 1996 to 2005.

Limitations

While country specific data is available, only the global average water use intensity by crop and water type was used. These figures are multiplied with the MapSPAM production maps to create maps of water use.

Opportunity: *use the country specific water use intensity figures instead of the global average.*

Also, while MapSPAM covers global crop production, there are certain sub-national regions where there is no data. For example the potato production map shows no production in the state of Iowa in the USA while there is potato production in all the neighboring states. Unfortunately, MapSPAM does not differentiate between no data and zero values so we cannot account for that in the analysis.

LIVESTOCK

Gridded Livestock of the World (GLW) provides spatial livestock headcount data for 8 livestock types. A full description of the GLW methodology can be found on their website.

The full livestock list used in the GMI materiality assessment is as follows:

- cattle
- buffalo
- sheep
- goat
- horse
- pig
- chicken
- duck

Water Use

Water use for keeping livestock is estimated using the WaterStat from the Water Footprint Network. This dataset describes water use intensity (m3/head) by animal type. The water use figures are averages of data from 1996 to 2005. These figures are multiplied with the head count maps to create maps of water use.

Limitations

It should be noted that the GLW data does not distinguish between beef and dairy cattle or between broiler and layer chickens. These are combined in the cattle and chicken categories, respectively.

In addition, while the GLW data shows where livestock animals are kept, it doesn't explicitly show pastureland. It is assumed that in most cases, animals are kept close to where they are grazed or fed.

While WaterStat distinguishes between beef and dairy cattle, the GLW does not. Therefore, we took the average of the lifetime water use between beef and dairy cattle in order to calculate the water use of cattle. The same method is applied for broiler and layer chickens.

Finally, the water use for livestock includes indirect water used to grow the feed consumed by the animal as well as the direct requirement for drinking water, service water and feed-mixing water. The indirect water footprint associated with livestock accounts for 98% of the total footprint. However, feed is typically brought in from different regions.

***Opportunity:** Consider excluding water use for manufactured feed and only accounting for the direct water footprint of livestock animals as well as water use associated with pasturelands.*

FORESTRY

Curtis et al, 2019 provides spatial data for forest loss due to the following drivers:

- commodity driven deforestation
- shifting agriculture
- wildfire
- urbanization
- forestry

For the GMI, we are interested in the forestry driver which we take as an indication of where there is forestry activity. A full description of the methodology can be found in Curtis et al, 2019.

Given that forests are not watered and we don't know the production volumes, we didn't calculate the water use of the forestry commodity.

Limitations

Because Curtis et al, 2019 only describes land use for forestry, all cells within a country with forestry production are treated equally irrespective of whether some areas are producing more forestry products than others.

THEMES AND INDICATORS

We selected the following environmental themes and associated indicators for the materiality assessment. These were selected based on their importance for natural systems and the availability of data for a spatial assessment.

Theme	Indicator	Source	Reference Year
Water	Water risk	Aqueduct 3.0	2015
Biodiversity	Need for biodiversity protection	Global Safety Net	varies
Land	Land degradation	Trends.Earth	varies
Climate Change	GHG emissions	EDGAR v6.0	2010
Air Pollution	Air pollutant emissions	EDGAR v5.0	2010

Not all themes were used for all commodity types, as illustrated in the following table.

Theme	Commodity Type		
	Crops	Livestock	Forestry
Water	Yes	Yes	Yes
Biodiversity	Yes	Yes	Yes
Land	Yes	Yes	Yes
Climate Change	Yes	Yes	No. GHG emissions from forestry activities were not found.
Air Pollution	Yes	Yes	No. GHG emissions from forestry activities were not found.

INDICATOR PERSPECTIVES

The GMI takes two perspectives when it comes to impact indicators. The first is the '**total' impact** perspective which tries to capture the total impact/dependencies associated with the production of a commodity. The second is the '**normalized' impact** that tries to capture the impact/dependencies associated with the production of a commodity relative to the amount produced or the amount of resources (land, water) required for production. Countries are assigned a percentile rank for each theme based on the impact of their production.

The reason for these perspectives is to capture not just the production impacts/dependencies of countries with high commodity production such as the USA, China and India, but also those of smaller countries which don't have as much production, but are still important to talk about due to the vulnerability or importance of their natural systems.

The formulation of each indicator into these perspectives is described in the subsequent sections.

WATER

WRI's Aqueduct 3.0 compiles advances in hydrological modeling, remotely sensed data, and published data sets into a freely accessible online platform. Water risk measures all water-related risks, by aggregating selected indicators from the Physical Quantity, Quality and Regulatory & Reputational Risk categories. Higher values indicate higher water risk. The following indicators are used in the model.

Final Score	Sub-Score	Indicators
Overall Water Risk	Physical risk quantity	Baseline water stress
		Baseline water depletion
		Interannual variability
		Seasonal variability
		Groundwater table decline
		Riverline flood risk
		Coastal flood
		Drought risk
	Physical risk quality	Untreated connected wastewater
		Coastal eutrophication potential
	Regulatory and reputational risk	Unimproved/no drinking water
		Unimproved/no sanitation
		Peak RepRisk country ESG risk index

The Aqueduct model assigns weights to the indicators based on their importance. Alongside the default weights, it also provides weights for different sectoral activities. For example, according to the Aqueduct model, interannual variability is more important for the agricultural sector as opposed to the construction sector therefore it's weighted more heavily. For the GMI, the indicator weights for the agricultural sector were used.

While the Aqueduct model uses data from various years, in general the reference year is 2015.

Materiality

Water is considered both an impact and a dependency. Commodity production requires water which can **impact** water depletion and stress and ultimately increased water risk. However commodity production is **dependent** on water risk - production is more challenging in areas of high water risk.

Indicators

The following perspectives were used for the water theme:

- **Absolute indicator:** m^3 of water used for crop production that is high or extreme water risk regions
- **Relative indicator:** % of a country's water use for crop production that is in high or extreme water risk regions.

Limitations

There were no notable limitations for this indicator calculation.

BIODIVERSITY

There are various sources of spatial data regarding global biodiversity ranging from maps of butterfly populations to the IUCN Red List of Threatened Species which shows which areas are most important for biodiversity. While these datasets are valuable, most don't specify how much protection is required. For the GMI, we were looking for a dataset that shows which areas needed further protection. For this reason, we decided to use the Global Safety Net (GSN) dataset.

The GSN highlights the importance of protecting and restoring the natural world to address three converging crises -- climate change, the loss of biodiversity, and the emergence of novel viruses such as COVID-19. The research effort builds upon an array of global-scale data sets to identify areas that require conservation beyond the 15.1% of land area currently protected. The following layers were selected for use in the GMI:

- **Species Rarity Sites:** Areas containing the habitats of species that are naturally rare - that is, they have narrow ranger, occur at low densities, or exhibit both conditions
- **High Biodiversity Areas:** Intended to capture areas with high alpha-diversity (a local measure of the average species diversity in a habitat)
- **Large Mammal Landscapes:** Unprotected landscapes containing the last intact large mammal assemblages of the terrestrial realm.
- **Intact Wilderness:** Unprotected parts of the Last of the Wild in each ecoregion and other wilderness areas that provide potential macrorefugia for wildlife and representation of fauna. Last of the Wild is an initiative created in 2002 to identify the last remaining "wild" areas of the earth's land surface measured by human influence.

If an area was identified by the GSN as important for any of the above reasons, it was flagged in the GMI as requiring protection to preserve biodiversity.

Because the GSN uses data from various different sources, there is no single reference year.

Materiality

Biodiversity, specifically areas of biodiversity protection, is considered an impact. If commodity production is occurring in areas requiring biodiversity protection, then that biodiversity is likely not being protected and the production is having a negative **impact**.

Indicators

The following perspectives were used for the biodiversity theme:

- **Absolute indicator:** ha of crop production requiring biodiversity protection
- **Relative indicator:** % of a country's crop production requiring biodiversity protection

Limitations

The GSN (along with most biodiversity datasets) is a good indicator of macro biodiversity and the health of ecosystems. However what is generally lacking, not just in the GSN but other global biodiversity datasets, is indicators for soil microbial biodiversity which is very important for agriculture.

LAND

Land degradation is the process in which the value of the biophysical environment is negatively affected by a combination of human-induced processes acting upon the land leading to desertification, drought and floods. It is informed by factors such as productivity, land cover, soil erosion and soil organic carbon.

Trends.Earth is an online platform that monitors land degradation. Using satellite imagery and global data, Trends.Earth can identify degraded areas and help decision-makers improve them. It is informed by factors such as vegetation productivity, land cover, soil erosion and soil organic carbon. Trends.Earth was developed in part to support the monitoring of SDG 15.3: 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.

Trends.Earth classifies parcels of land as either degrading, stable, or improving. This is based on the following indicators.

Final Score	Indicator	Sub-Indicator
Land degradation indicator	**Productivity:** Land productivity is the biological productive capacity of the land, the source of all the food, fiber and fuel that sustains humans as measured by Net Primary Productivity (NPP)	**Trajectory:** the rate of change in primary productivity over time.
		Performance: local productivity relative to other similar vegetation types in similar land cover types or bioclimatic regions throughout the study area.
		State: recent changes in primary productivity as compared to a baseline period.
	Land Cover: Land cover change can be measured using using satellite imagery	
	Soil Carbon: changes in soil organic carbon (SOC)	

Because Trend.Earth uses data from various different sources, there is no single reference year.

Materiality

Land degradation is considered both an **impact** and a dependency of commodity production. If commodity production is occurring in areas where land is degrading, then it is possible that the degradation is a negative impact of the intensive production activities. Conversely, commodity production is **dependent** on the state of the land and will be negatively affected if the land is degrading.

Indicators

The following perspectives were used for the land theme:

- **Absolute indicator:** ha of crop production on degrading land
- **Relative indicator:** % of a country's crop production on degrading land

Limitations

Because Trends.Earth is based on satellite imagery, it cannot account for covered agricultural land such as greenhouses. Other methodological limitations are described in the Trends.Earth documentation.

CLIMATE CHANGE

Greenhouse Gas (GHG) emissions allow comparisons of the global warming impacts of different gases. Agriculture contributes to GWP through enteric fermentation (methane emissions from animals' digestive systems), manure management, agricultural waste burning activities as well as land management practices that lead to direct emissions from soil.

EDGAR is a multipurpose, independent, global database of anthropogenic emissions of greenhouse gases and air pollution on Earth. EDGAR provides independent emission estimates compared to those reported by European Member States or by Parties under the United Nations Framework Convention on Climate Change (UNFCCC), using international statistics and a consistent IPCC methodology.

EDGAR v6.0 provides annual GHG emission data by sector. The following data relating to crop and livestock production was selected for use in the GMI:

- **Crops:**
  - Agricultural waste burning (CH_4, CO_2, N_2O)
  - Agricultural soils (CH_4, CO_2, N_2O)
  - Indirect N_2O emissions from agriculture
- **Livestock:**
  - Enteric fermentation (CH_4)
  - Manure management (CH_4, N_2O)

Emissions of different GHG species are converted to CO_2-eq using the Global Warming Potential (GWP) characterization factors from the ReCiPe method for lifecycle impact assessment. We chose to use characterization factors from the Hierarchist (100yr) perspective.

While EDGAR v6.0 provides data from 1970 to 2018, we use data from 2010 so that the emission locations are better aligned with the MapSPAM production maps which are also from 2010.

Allocation

While EDGAR specifies total GHG emissions for agriculture and livestock production, it does not allocate it by the type of commodity, for example corn or cattle. If more than one product is produced in the same parcel of land, then that impact needs to be allocated appropriately.

- **Crops:** GHG emissions from crops refer not to emissions from the crops themselves but to the soil and waste burning. GHG emissions per parcel were therefore allocated based on total production volume. For example if, according to the EDGAR data, agricultural waste burning was responsible for 100kgs of GHG emissions from a parcel of land, and that land was used to produce equal amounts of corn and soybean, then those emissions would be equally distributed between corn and soybeans. However if there was more soybean production than corn, then the soybean would get a proportional share of the emissions.

- **Livestock:** GHG emissions from livestock refer to the emissions of animal manure and enteric fermentation. Since the manure composition and rates of enteric fermentation of animals varies by type, the GHG emissions also vary. To account for this, we use GHG emission factors for enteric fermentation and manure management by livestock type as recommended by the IPCC. For example, if, according to the EDGAR data, manure management was responsible for 100kgs of air pollutants emitted from a parcel of land and that land was used to produce 10 cattle and 100 chickens. However, since managing cattle manure emits almost 100 times more GHG pollutants than chicken manure, then 90% of the GHG emissions would be allocated to cattle production.

Materiality

GHG emissions are considered an impact. If commodity production is emitting GHG pollutants, then that has a negative **impact** on global climate change.

Indicators

The following perspectives were used for the climate change theme:

- **Absolute indicator:** tonnes CO_2-eq
- **Relative indicator:** tonnes CO_2-eq per tonne of production

Limitations

The GHG emission calculations are limited to certain types of activities and therefore do not capture the life cycle emissions of crop production. In particular, the following sources would need to be calculated in order to complete the picture:

- Emissions from Land Use and Land Cover Change (LULCC)
- Uptake of CO_2 from the crops themselves

Opportunity: *Consider using LCA factors to fill these gaps.*

While GHG emissions from crop production activities might not vary by crop as much as for livestock production, there still are some differences. Because we allocate the climate change impact based on tonnes produced only and not the emission factors associated with individual crops (like we are doing with livestock) those differences are not being captured.

Opportunity: *Consider using crop specific emissions factors as part of the allocation.*

AIR POLLUTION

From smog hanging over cities to smoke inside the home, Air Pollution poses a major threat to health and climate. Agriculture contributes to air pollution through manure management, agricultural waste burning activities as well as land management practices that lead to direct emissions from soil.

EDGAR is a multipurpose, independent, global database of anthropogenic emissions of greenhouse gases and air pollution on Earth. EDGAR provides independent emission estimates compared to what is reported by European Member States or by Parties under the United Nations Framework Convention on Climate Change (UNFCCC), using international statistics and a consistent IPCC methodology.

EDGAR v5.0 provides annual air pollutant emission data by sector. The following data relating to crop and livestock production was selected for use in the GMI:

- **Crops:**
  - Agricultural waste burning (NH_3, NMVOC, NO_x, $PM_{2.5}$, SO_2)
  - Agricultural soils (NH_3, CO_2, NO_x, $PM_{2.5}$)

- **Livestock:** Manure management (NMVOC, NO_x, $PM_{2.5}$, PM_{10})

Emissions of NH_3, NMVOC, NO_x, SO_2, and $PM_{2.5}$ were converted to Disability Adjusted Life Years (DALYs) using the characterization factors from the ReCiPe method for life-cycle impact assessment. DALY is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. We chose to use characterization factors from the Hierarchist (100yr) perspective. The characterization factors for PM10 were taken from van Zelm et al, 2007.

The characterization factors for NH_3, SO_2, $PM_{2.5}$ and PM_{10} are from particulate matter mechanisms while the characterization factors for NMVOC are from photochemical ozone formation mechanisms. The characterization factors for NO_x are from both.

While EDGAR v5.0 provides data from 1970 to 2015, we use data from 2010 so that the emission locations are better aligned with the production maps which are also from 2010.

Allocation

While EDGAR specifies total air pollution emissions for agriculture and livestock production, it does not allocate it by the type of commodity, for example corn or cattle. If more than one product is produced in the same parcel of land, then that impact needs to be allocated appropriately.

- **Crops:** Air emissions from crops refer not to emissions from the crops themselves but to the soil and waste burning. We used weight-based allocation using total production weight to allocate air emissions to specific crops per parcel of land. For example if, according to the EDGAR data, agricultural waste burning was responsible for 100kgs of air pollutants emitted from a parcel of land, and that land was used to produce equal amounts of corn and soybean, then those emissions would be equally distributed between corn and soybeans.

- **Livestock:** Air emissions from livestock refer to the emissions of animal manure. Since the manure composition of animals varies by type, the air pollution also varies. To account for this, we use emission factors for manure management by livestock type as recommended by the IPCC. While these factors are for GHG pollutants not air pollutants, they are nonetheless reasonable factors to use for the allocation. For example, if, according to the EDGAR data, manure management was responsible for 100kgs of air pollutants emitted from a parcel of land and that land was used to produce 10 cattle and 100 chickens. However, since managing cattle manure emits almost 100 times more pollutants than chicken manure, then 90% of the air emissions would be allocated to cattle production.

Materiality

Air pollution is considered an impact. If commodity production is emitting air pollution, then that can potentially have a negative **impact** on humans and the environment.

Indicators

The following perspectives were used for the air pollution theme:

- **Absolute indicator:** DALYs
- **Relative indicator:** DALYs per tonne of production

Limitations

While air pollutant emissions from crop production activities might not vary by crop as much as for livestock production, there still are some differences. Because we allocate the air pollution impact based on tonnes produced only and not the emission factors associated with individual crops (like we are doing with livestock) those differences are not being captured.

Opportunity: *Consider using crop specific emissions factors as part of the allocation.*