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Sustainability Insights Risk Assessment Summary Methodology

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Introduction

A methodology to estimate environmental and social risks of agricultural trade flows

To achieve a climate neutral and green economy, as well as to achieve the UN Sustainable Development Goals, the European Commission has developed a legislative framework that requires companies to identify and prevent, mitigate and account for actual and potential adverse impacts within their operations, supply chains and business relationships. Wageningen University & Research has developed a tool with the aim of providing insights into the environmental and social risks of agricultural trade flows at different geographical levels. This document provides a summary of the methodology that is used in the tool.

PLEASE CLICK ON THE THEME OF YOUR CHOICE

Themes

The sustainability insights dashboard covers 8 human rights risks and 8 environmental risks

The dashboard covers 8 subthemes related to human rights risks and 8 subthemes related to environmental risks, split across two methodologies (Figure 1). The selected themes were chosen to, combined, cover the most relevant sustainability risks in global agricultural supply chains. They are aligned with major international standards and (regulatory) frameworks in the field of Corporate Sustainability Reporting and Responsible Business Conduct, such as: the UN Guiding Principles, OECD Guidelines, Corporate Sustainability Reporting Directive (CSRD), the EU Deforestation Regulation (EUDR), and the EU due diligence legislation (CSDDD). For each theme we define one or several indicators to approach the identified risks. The final risk score for each theme is country and commodity sector-specific and is (if possible) disaggregated into regional risk scores. The methodologies for human rights and environmental risks are provided separately.

Human Rights Risks

A human rights risk refers to 'a risk of having an adverse impact on the people involved in the supply chain of an agri-commodity'. The basis of the selection of 8 human rights themes can be found in relevant UN declarations and ILO conventions. We focus on violations that take place at the first two stages of the supply chain: i.e. at the level of cultivation and the first processing stage. It is in these stages that most human rights risks materialise for different stakeholders and higher percentages of vulnerable workers are present such as women, children, migrants, and minorities.

Environmental Risks

An environmental risk is a harmful effect on the environment as a result of the cultivation and trade of an agri-commodity. For the selection of 5 environmental risk categories (climate change, eutrophication, acidification, water use and ecotoxicity) as well as national scores we rely on Life Cycle Assessment (LCA), which quantifies environmental impact in a standardised and commonly accepted manner. The LCA approach is complemented with spatial analysis, focusing on 3 indicators (biodiversity, water stress, deforestation) for sub-national risk scores. The environmental risk analysis produces scores at the level of cultivation and primary processing.

Figure 1 Risk themes included in the dashboard

Human rights risks

General approach

For each theme, human rights risk scores are developed in five steps moving from national data to regional to sector-specific risk scores (as depicted in Figure 2).

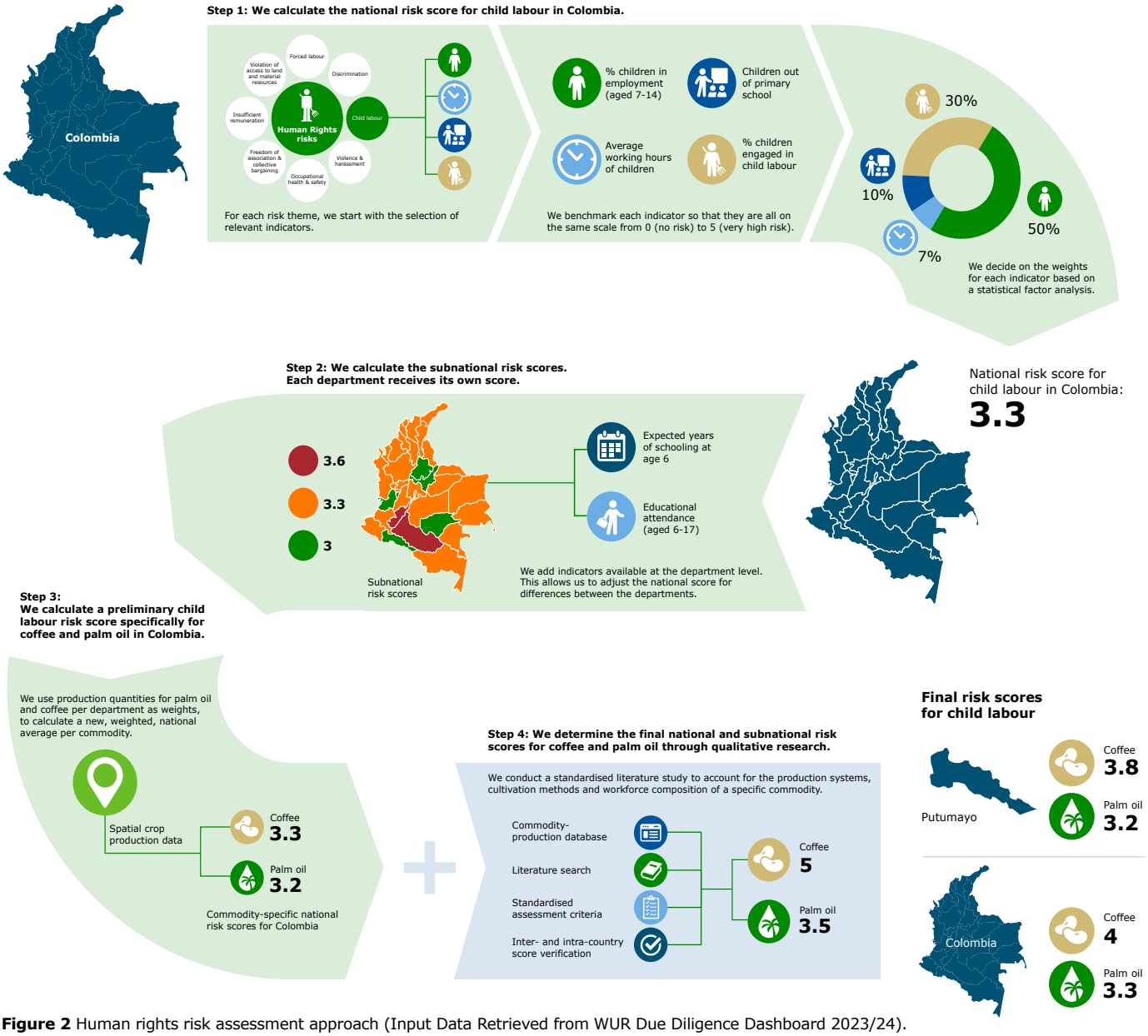

Figure 2 Human rights risk assessment approach (Input Data Retrieved from WUR Due Diligence Dashboard 2023/24).

Step 1: Calculation of the national risk score

We start by calculating a national risk score by searching for indicators from independent data sources which are related to each human rights theme. We distinguish between 4 different types of indicators: 1) direct indicators, which are directly related to the concept we are trying to capture, 2) severity indicators, which relate to the severity of the concept we are trying to capture, 3) proxy indicators, which are less related to the concept we are trying to capture, but which serve as a proxy and 4) legal framework indicators, which are indicators showing the policies of specific countries. In most cases, legal framework indicators are not direct indicators, as laws do not always represent practice. The selection of the indicators depends on the availability of data. When there are no direct indicators available, we use proxies instead. In addition to relevance to the theme, indicators are also required to meet three other criteria. First, we rely on data sources which have a history in data collection, are transparent about their methods, and provide updates regularly (this is important as a risk assessment also needs to be updated on a regular basis). Second, we look for data sources that are independent (as far as possible), meaning government (UN, ILO, World bank, OECD), research centres (World Policy Center), or a consortium of NGOs and government. Third, data should preferably cover more than 100 countries (this is important for upscaling of the number of countries and commodities covered). Furthermore, we check the indicators for reliability, as well as for the reference year. If we find highly outdated data entries, defined as more than 10 years old, then we exclude them from our analysis.

a. Each indicator used is benchmarked into risk scores between 0 and 5, based on reports and other publications providing insights on what would be low, medium or high values for each indicator.
b. We create a weighted average of the different indicators used for each theme. The indicator weights for generating the national risk score are determined using a statistical factor analysis, which is a technique that is used to reduce a large number of variables into fewer numbers of factors. This technique extracts maximum common variance from all variables and puts them into a common score.

Step 2: Calculation of the sub-national risk score

Using sub-national data pertinent to the individual themes allows us to estimate risks at a more granular level. This data enables us to proceed with step 3, which enhances the accuracy of national estimates per commodity. Publicly available data at the sub-national level are generally more limited, and the available indicators are often less closely aligned with the themes we aim to capture. When we have been able to identify sub-national indicators, the national risk score is adjusted for differences in sub-national indicators. To calculate the sub-national risk score, we start by importing the data for the sub-national indicators, and by calculating the median value of each indicator for each country. For each sub-national region we then calculate the fraction of the national median for each indicator. This gives an indication of how a specific region performs on the selected indicator compared to the overall national level. We divide the fractions of the median into 7 different correction categories (no correction, small score increase, small score decrease, medium score increase, medium score decrease, large score increase and large score decrease), which will then be used to correct the national score for sub-national differences by increasing or decreasing the risk score by the value of corresponding correction category. The value of the correction categories (e.g., +0.5) differs for each theme and depends on the validity of the sub-national indicators. Sub-indicators that are more related to the concept we are trying to capture in the theme receive higher correction categories. For the correction categories we try to follow a normal distribution.

Step 3: Calculation of the commodity-specific national risk score

This step is conducted only if sub-national indicators are available. A commodity-specific national risk score is calculated by taking a weighted average of all sub-national scores within a specific country, using the commodity harvested area (MAPSPAM, 2020). We use the harvested areas, which is the area in hectares dedicated to the production of a specific crop, but also accounting for multiple harvests of a crop on the same plot. We use the harvested areas as harvests are often labour-intensive, and each harvest therefore increases the risk of human rights issues. The MAPSPAM data are presented at the pixel level, where each pixel represents an area of 10x10 kilometres. The harvested area is aggregated to the first sub-national disaggregation level (ADM1, e.g. provinces). The shares of the production for each region within a country are then used as weights for the calculation of the commodity-specific national risk score. For example, if 10% of Brazil's soy production would be coming from its state Parana, the sub-national risk score of Parana would be multiplied by 0.10. The sum of all soy-producing regions in Brazil would then be taken to get the commodity-specific national risk score.

Step 4: Identifying the commodity risk score

To increase validity of the prevalence of certain risks and their specifics in the production of individual commodities, we engage in a standardised literature review that results in a commodity risk score. This score aims to enrich and

complement the quantitative assessment of national risks. During this process, we gather information to fill data gaps from previous steps, supplement national-level data with qualitative insights, and provide commodity-specific information. As the agricultural sector and the specific features of the production of a commodity bring with them specific risks and specific risk levels, the commodity risk score is based on a literature review that is standardised along thematic questions and clear assessment criteria – operationalised in a benchmarking table – for identifying commodity-specific risks. These thematic questions and assessment criteria are detailed in the commodity assessment guidelines as part of a longer protocol document developed by WUR. The assessment of qualitative information is based on a three-step approach:

1. Creation of a commodity-production database by identifying the specific features of the production of a particular commodity (production systems, cultivation methods, workforce etc). This provides researchers with an overview of these topics, which is required to make an accurate assessment of risks.
2. The assessment of commodity risk scores (0-5): Following the guidelines outlined in the long protocol, the researcher assigns a score of 0-5 to each of the human rights themes based on available information in the literature sources.
3. Validation of commodity risk scores: To avoid researcher bias and to ensure the internal (thematic), and intra- and inter-country consistency of the risk scores, a 'validation meeting' with other researchers preceeds the finalisation of commodity risk scores.

Step 5: Combining into a single risk score

The (commodity-specific) national risk scores and the commodity risk scores are combined into one score using weights that depend on the strength of the national-level indicators in capturing the theme.

Theme-specific information

The following sections provide more details on the definitions of the 8 human rights risk themes and the indicators used for calculating the (sub-)national scores.

Child labour

Definition The definition used for child labour is taken from the ILO: 'Child labour refers to work that: is mentally, physically, socially or morally dangerous and harmful to children, and/or interferes with their schooling by depriving them of the opportunity to attend school, obliging them to leave school prematurely, or requiring them to attempt to combine school attendance with excessively long and heavy work. Whether or not particular forms of work can be called child labour depends on the child's age, the type and hours of work performed, the conditions under which it is performed (harmful or not), and the objectives pursued by individual countries. The answer varies from country to country, as well as among sectors within countries.'

Indicators We use different types of indicators to approximate the risk of child labour occurring and distinguish between direct indicators and severity indicators. Child labour prevalence (Unicef)[1] and children in employment (World Bank)[2] are the direct indicators of child labour. Severity is captured by the average number of hours worked (World Bank)[3] and school drop-out rates (World Bank)[4] – higher number of hours worked indicate that children are more likely to work longer hours, worsening the risk; higher drop-out rates are an indication that children are more likely to work instead of attending schooling or are unable to combine work and schooling. For sub-national adjustments we consider two proxy indicators: the expected years of schooling at age 6 and the mean of the educational attendance variables for all age classes between 6 and 17 taken from the Global Data Lab.[5]

Violence and harassment

Definition The definition used for violence and harassment is based on the ILO: 'Everyone has the right to work free from violence and harassment, including gender-based violence and harassment. The elimination of violence and harassment in employment and occupation are part of the foundations of the rule of law.' We assess the risk based on likelihood of violence and harassment occurring at place of work and the legislative protection against it included in national law.

Indicators We use three indicators to approximate the risk of violence and harassment occurring. The direct indicator comes from the World Risk Poll[6] database, funded by the Lloyd's Register Foundation, which represents the outcome on survey questions regarding violence and threats of violence at work among other topics. We have selected two questions relevant to the theme: whether a respondent directly experienced violence themselves and/or physical abuse at workplace, or whether a respondent witnessed violence and/or physical abuse at workplace. A proxy indicator indicating the prevalence of intimate partner

violence has been chosen to be included from two different sources (WHO[7] and SIGI)[8] and averaged for the available countries to function as a proxy for violence at the workplace. Herein, it is assumed that higher prevalence of domestic violence is associated with higher prevalence of violence at work. This average forms the second indicator. A final proxy indicator is a legal framework indicator that originates from the index Workplace Gender Discrimination and Sexual Harassment by the World Policy Centre,[9] which indicates the adequacy of national legislation to prevent and act upon workplace gender discrimination and sexual harassment. For calculating the national risk score, we adjusted the index by only selecting harassment legislative information, to prevent confoundedness with the theme discrimination. For this theme we do not have sub-national disaggregations.

Definition Forced labour can be defined as 'all work or service which is exacted from any person under the menace of any penalty and for which the said person has not offered himself voluntarily' (ILO convention 29, 1930). Forced labour can take different forms (debt bondage, trafficking and other forms of modern slavery), it can be imposed by different actors (state, private and individuals), can be observed in different types of economic activities and takes place all over the world. Following the ILO, Forced Labour encompasses the 'traditional' practices of forced labour as debt bondage, slavery and slave-like practices but also 'new forms' of forced labour such as human trafficking. The concept of modern slavery is frequently used to refer to this broader category of forced labour practices.

Indicators We use different types of indicators to approximate the risk of forced labour and use a combination of a direct indicator, a severity indicator and two legal framework indicators to assess forced labour. The estimated population in modern slavery (Walk Free)[10] in a given country is a direct indicator of forced labour. The vulnerability score (Walk Free)[11] is used to complement the direct indicator by assessing the drivers of modern slavery at a country level. Additionally, a government response index (Measurement, Action, Freedom dataset)[12] is included. This index assesses the actions taken by a government to respond to modern slavery. Finally, a binary variable is included that indicates whether or not a country has ratified two main social security conventions to protect migrant workers (namely: Equality of Treatment (Social Security) Convention, 1962 and Migrant Workers Conventions, 1975), as migrants are a group that is particularly vulnerable to forced labour. If at least one of the two conventions was signed, the national risk score was decreased. As there is a strong relation between migrant workers and the risk of forced labour or other types of labour exploitation (see e.g. Zimmermann and Kiss, 2017),[13] we look at sub-national differences in migration from the migration data portal[14] as a proxy for sub-national adjustments of the national risk score.

Definition The ILO defines Discrimination as follows: 'Discrimination is any distinction, exclusion or preference made on the basis of race, colour, sex, religion, political opinion, national extraction or social origin, which has the effect of nullifying or impairing equality of opportunity or treatment in employment or occupation. The terms employment and occupation include access to vocational training, access to employment and to particular occupations, and terms and conditions of employment' (ILO convention 111, 1958). The United Nations Officer for High Commission emphasises that discrimination is often directed at groups who are vulnerable and disadvantaged in the society. The vulnerable groups in this case include women, minorities, migrants, people with disability and indigenous peoples. Discrimination could also be against any individual's race, religion, sexual orientation and gender identity.

Indicators We use three legal framework indicators to approximate the national risk of discrimination. We were not able to find any indicators directly measuring discrimination at the workplace. Several databases, however, measure and index gender discrimination as well as policies targeting workplace discrimination, which are the closest indicators capturing discrimination and discriminatory practices at workplace. The first indicator is a manually computed Workplace Discrimination indicator from the World Policy Center,[15] which is derived from 105 binary variables indicating whether there is a policy towards certain types of work-related discrimination. The second indicator is the mean of selected variables provided by the OECD's Social Institutions & Gender Index (SIGI).[16] The aim of the index is to 'measures discrimination against women in social institutions across 179 countries' (OECD). Similar to the WPC compiled indicator, we have identified variables relevant for the theme of workplace discrimination or discrimination at large present in the index and calculated a mean value per country. These

are 6 variables that span across themes on restricted access to productive and financial resources, restricted civil liberties and discrimination. The third indicator is the Country Policy and Institutional Assessment (CPIA)[17] composed by the World Bank as part of the CPIA database funded by the International Development Association (IDA), which provides an index value based on country performance assessed against 16 criteria to capture how socially inclusive and equitable policies are with regards to gender, use of public resources, social protection, and labour. For the sub-national adjustments we use two proxy indicators from the Demographics and Health Surveys (DHS)[18] programme: the relative difference between men and women in terms of being employed (having worked in the last 12 months), as well as in terms of land ownership.

Definition Freedom of association is a fundamental human right that is part of the Universal Declaration of Human Rights of 1948. It enables the participation of non-state actors (including trade unions) in economic and social policy. The ILO defines freedom of association as 'the right of workers and employers to form and join organisations of their own choosing' (ILO Convention 87, 1948). Collective bargaining is closely linked to freedom of association and is defined as 'a key means through which employers and their organisations and trade unions can establish fair wages and working conditions, and ensure equal opportunities between women and men' (ILO convention 98, 1949). These rights are central in the functioning of effective labour markets and governance structures in a country.

Indicators We use three indicators to approximate the national risk of the lack of freedom of association and collective bargaining. The first indicator is calculated by taking the highest value of either the trade union density or the collective bargaining coverage rate. The highest value is used because both rates are usually close to each other, and for countries with large differences between both, it is assumed that labourers are protected by either one of the labourer protection measure (International Labour Organization, 2022).[1],[19][20][21] These two indicators are good proxies, but there are other factors that can lead to under or overestimation of collective bargaining if not accounted for. First, strong social security frameworks may lower rates, as workers perceive less need for union membership when their rights are secured by the government. Second, the efficacy of union enrollments is influenced by various factors such as government involvement in the private sector and transparency. To address these issues, two additional indices are added to the national risk score calculation. The 'level of compliance with labour rights' by the ILO[22] assesses adherence to freedom of association and collective bargaining rights among member states. The ITUC global rights index[23] evaluates the risk of worker rights violations, considering legal and practical aspects. These indices provide insights beyond the trade union and collective bargaining rates, reflecting governmental efforts and practical observations of labour rights compliance. For this theme we do not have sub-national disaggregations.

Definition Secure access to land and material resources (e.g. water, forests, infrastructure) are fundamental human rights for individuals and groups of peoples to secure livelihoods, housing or shelter, and poverty reduction. The right of access to land is defined as: 'The ability to use land and other natural [and material] resources, to control the resources and to transfer the land rights to the land to take advantage of other opportunities' (FAO, 2006). Access impacts how individuals or groups of peoples can own, use, develop and control land and other material resources. Material resources can be natural (e.g. water, forest land and home lands) and man-made (e.g. infrastructure, sanitation facilities, schools). In no case a people may be arbitrarily deprived of its property (including land, forest and waters) or its own means of subsistence. Expanding operations may cause depletion of and conflict over access to land and material resources. Especially when land ownership or land usage agreements are informal or contested. In the case of Indigenous Peoples, the right of Free, Prior and Informed Consent (FPIC) is formalised in the UN Declaration on the Rights of Indigenous Peoples (UNDRIP). The violations of the rights of Indigenous Peoples are of a particular concern within this theme as well as other minority groups that

1 Trade union density and collective bargaining coverage rates have a correlation of 0.7. Some countries are exceptional and have a high collective bargaining coverage rates and a low trade union densities; the Netherlands, for example, has 75.6% and 15.4% respectively. In these countries, there is less need for joining trade unions as workers are well protected by national legislation and collective agreements. Using the highest value instead gives a fairer representation of the risk than taking, for example, the average.

face a specific vulnerable position to the violation of access to land and material resources.

Indicators We use three indicators to approximate the national risk regarding access to land and material resources. The first indicator is a computed indicator based on two indicators from the LandMark portal. This first indicator is calculated as the proportion of land formally acknowledged by the government as being held by indigenous peoples and communities, compared to the total land they occupy in each country.[24] The second indicator is the percentage of people not having any documents demonstrating their right to live or use any of their properties. It is one of the PRINDEX indicators assessing whether respondents have access to formal documentation, informal documentation or have no documentation.[25] The last indicator used looks at whether there are any 'customary, religious or traditional practices or laws that discriminate against women's legal rights regarding land to own, use, make decisions and use as collateral' (Ferrant et al.,, 2020).[26] The aim is to capture any legal (or other) practices that disable women from fully exercising their land rights. This data is collected as part of the OECD's Social Institutions and Gender Index (SIGI).[27] At the moment we do not have sub-national scores for this theme yet, but they are expected to be added in 2025, as the LandMark portal is working on a new dataset including harmonized sub-national data.

Occupational health and safety

Definition Occupational health and safety refers to the right of workers to be protected from sickness, disease and injury arising from their employment (ILO conventions 187, 155 and 161; 2006, 1981, 1985). Examples are issues as unsafe buildings, not having the appropriate protection gear at the workplace and the work with toxic materials. Following the ILO, an occupational injury is defined as 'any personal injury, disease or death resulting from an occupational accident; an occupational injury is therefore distinct from an occupational disease, which is a disease contracted as a result of an exposure over a period of time to risk factors arising from work activity. A case of occupational injury is the case of one worker incurring an occupational injury as a result of one occupational accident.'

Indicators The approach used for occupational health and safety has significantly changed over time. In earlier versions of the human rights risk scores, the scores for occupational health and safety were strongly dependent on ILO indicators on occupational indicators. These included fatal and non-fatal occupational injuries in agriculture as prevalence indicators, and the percentage of days worked lost due to cases of occupational injury with temporary incapacity for the agricultural sector. However, upon examining these indicators, we have serious doubts about the reliability of these data. We found large differences in the reported amount of injuries depending on whether the data came from insurance or from administrative data, with countries reporting based on insurance data having much higher numbers of occupational injuries. At the same time, there appeared to be plenty of literature on occupational health and safety, which generated high-quality commodity risk scores through the standardised literature review. We therefore decided that we would use these scores as the main scores for occupational health and safety, as occupational health and safety is very dependent on the production characteristics of a specific commodity in any case, and to only use a proxy for the national risk scores. For this proxy we use selected indicators from the Global Health Security Index.[28] The selected index indicators are related to available human resources for the healthcare system, healthcare access and public health vulnerabilities. For the sub-national adjustments we use a proxy indicator: the health insurance coverage from the DHS.[29]

Insufficient remuneration

Definition With insufficient remuneration we refer to low wages for agricultural workers and low incomes for farmers. Minimum wages have been defined by the ILO as 'the minimum amount of remuneration that an employer is required to pay wage earners for the work performed during a given period, which cannot be reduced by collective agreement or an individual contract' (ILO, 1970). The definition refers to the binding nature of a minimum wage. The purpose of a minimum wage is to protect workers against disproportionate low wages. In many countries however agricultural workers earn less than the minimum wage or when they earn a minimum wage this is by far not enough to reach a living wage, i.e. the minimum income necessary for a worker to achieve a decent standard of living. For insufficient remuneration we therefore focus on the latter: incomes or wages sufficient for a decent standard of living.

Indicators For insufficient remuneration we use a different approach compared to the other themes, due to the amount of data that is available and the calculations that can be made with them. The final indicator that we

calculate is the area of the living income gap. As we want to measure not only the prevalence of the living income gap (e.g. 'Thirty per cent of the people earn less than the living income benchmark'), but also the severity of the living income gap, we use the Lorenz curve, which measures the distribution of income/wealth, to calculate what we refer to as the 'area of the living income gap'. On its Poverty and Inequality Platform, the World Bank publishes the survey mean consumption or income per capita, fitted to a Lorenz distribution.[30] For each income percentile, it presents the average daily per person income or consumption. For each percentile, we calculate the difference between this income/consumption value and the living income benchmark, which we retrieve from the WageIndicator Foundation.[31] More specifically, we create a score between 0 and 1 showing the red 'area' as opposed to the green 'area' in figure 3.

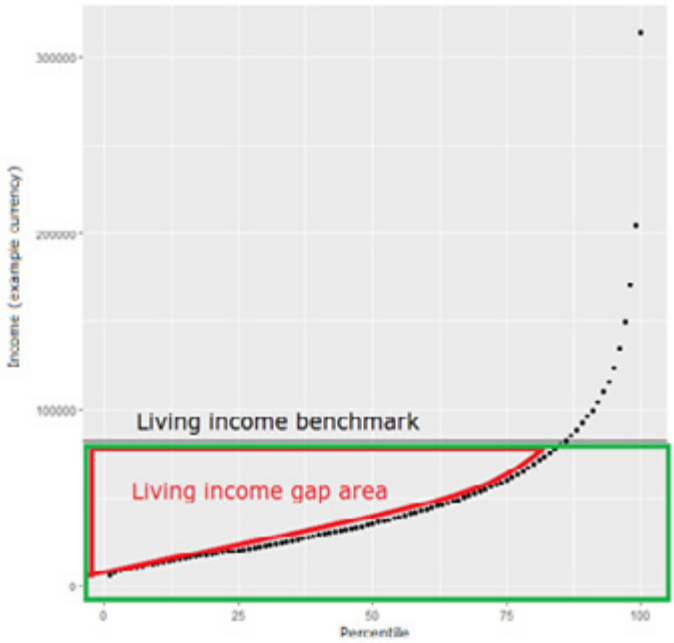

Figure 3 The area of the living income gap

Environmental risks

General approach

The environmental risks in the dashboard can be defined as a potential harmful effect to the environment as a result of the cultivation and (if applicable) primary processing of an commodity (in case of intermediate products). In this project we use both Life Cycle Assessment (LCA) and spatial approaches to assess the environmental risks for the selected commodities.

We rely on the Life Cycle Assessment (LCA) because it quantifies environmental impact throughout the entire life cycle of a product in a standardised and commonly accepted way. LCA is rooted in natural sciences and considers multiple environmental impacts, that allows the user to get an more integrated approach towards sustainability issues at national level. The spatial approach allows users to get more insights into where specific risks appear at sub-national levels. The achievable level of detail, however, depends on the available spatial crop production data on one hand and the risk-related datasets on the other. For this project we rely on existing spatial datasets with global coverage, possibly overlooking available superior datasets with a higher quality, but that are only available for specific regions or countries.

The dashboard covers the environmental risks shown in Table 1. This table also shows whether the environmental risks are calculated by means of LCA and/or spatial approaches. For water use/water stress a combined approach is used, where national level scores in the dashboard present the LCA scores for water use, and where the sub-national level scores present the spatial scores for water stress.

Table 1 Assessment (LCA and/or spatial) per environmental theme

Environmental topic	LCA	Spatial
Acidification	X	
Biodiversity		X
Climate change, total • Climate change, fossil • Climate change, biogenic • Climate change, land use and land use change • Climate change, peat oxidation	X	
Deforestation		X
Eutrophication • Marine eutrophication • Freshwater eutrophication	X	
Freshwater ecotoxicity	X	
Water stress		X
Water use	X	

The LCA approach is divided into four steps

Step 1: Goal and Scope Definition

In this step, the scope, system boundary, functional unit and objectives of the LCA are defined. The functional unit (FU) quantifies the performance of the product under study and serves as a reference unit. In this methodology, the functional unit (FU) is defined as 1 tonne of product at the farm gate (for raw materials) or leaving the country (for intermediate products). The methodology does not account for market mixes of raw materials and intermediate products; environmental impacts are solely based on domestic production, ignoring trade flows. System boundaries outline the life cycle stages and processes included in the analysis, excluding those beyond the cut-off rule. This methodology adopts a cradle-to-farm (raw commodities) or processing gate (intermediate products) approach, encompassing all activities related to crop and animal cultivation and further processing into intermediate products, aligning with the defined FU.

Step 2: Life Cycle Inventory (LCI)

This step involves the collection and quantification of data on the inputs, outputs, and emissions associated with the product being evaluated. Life Cycle Inventories are derived from agri-food-specific databases, primarily Agri-footprint 6.3 and the World Food Life Cycle Database 3.5, chosen per commodity for consistent comparability. Products not covered by these databases are modeled by LCA experts from Wageningen Research in alignment with aforementioned methodologies.

Multifunctional processes, i.e. processes producing multiple outputs, require allocation of inputs and emissions. Following ISO 14044:2006, allocation shall be avoided by sub-dividing processes or expanding the system to include co-products. When unavoidable, allocation is based on physical relationships or economic value. Both databases use economic allocation by default, ensuring interoperability between the two databases. GHG emissions from deforestation are modeled per PAS 2050-1:2011 guidelines, considering only direct land use changes (dLUC). Emissions are amortised over 20 years with an equal weight method, and allocated specifically to expanding crops, excluding emissions from biomass burning and peatland drainage. Nitrogen mineralization emissions are included. It should be denoted that deforestation is not the only form of land conversion considered in this methodology. Also conversions from grassland, perennial and annual crops are considered.

Fertiliser and plant protection product emissions are modeled to account for substances released into soil, water, and air during cultivation. More specific information on emission modelling can be found in the Agri-footprint and WFLDB methodology documents.

Step 3: Life Cycle Impact Assessment (LCIA)

This step evaluates the potential environmental impacts of inputs and outputs (e.g. emissions, waste) gathered in the LCI phase. Environmental impacts are classified into environmental themes, so-called 'impact categories'. Each environmental impact category has its own characterisation model (e.g. IPCC 2021 for climate change). Selected impact categories include climate change, freshwater and marine eutrophication, land use, water consumption, and freshwater ecotoxicity, based on state-of-the-art characterisation models. This selection aligns with the goal and scope and comprehensively addresses urgent environmental issues in agri-commodity value chains.

Step 4: Interpretation

This step concludes the assessment by evaluating the conclusions and ensuring they are well-substantiated. Results are presented as characterised results per impact category (e.g. kg CO2 eq. for climate change) and additionally translated into risk scores to facilitate risk identification and evaluation. Risk scores range from 1-5, with classes increasing exponentially. The lower limit is 0, and the upper limit is the highest impact of the product-country combination in the dashboard, plus a 10% safety margin. This safety margin is applied to make sure the boundaries of the risk classes change whenever a product is added with a higher impact than in the current database. Characterised results are relative expressions and do not predict impacts on category endpoints, exceeding of threshold, safety margins or risks. The risk score is herewith a relative risk score in comparison to other producing countries (i.e. sourcing product A from country X is likely to have more/less environmental risk than sourcing product A from country Y).

The risk scores allow for comparison of product-country combinations and intra-product category comparisons (i.e. soy with soy, and maize with maize).

The spatial analysis is divided into two steps

Spatial data refers to information about the physical location and characteristics of objects in the real world. These data can be represented using vector data, which use graphical representations of the real world, or raster data, which present data in a grid of pixels. There are many publicly available sources of spatial data, including OpenStreetMap, the World Resource Institute, remotely

sensed imagery, and the UNEP Environmental Data Explorer. GIS software extensions, such as ArcGIS or QGIS, provide a wide range of spatial analysis and modeling tools for both raster and feature data. Many commodities have global coverage in terms of spatial data and clear spatial patterns, which allows for the creation of risk maps using a spatial analysis method that needs the following two basic steps.

Step 1: Data collection for the spatial risk analysis
In this analysis all available relevant spatial data related to the commodities and their environmental risks are collected. The process is similar for all indicators. On the one hand, the patterns of the harvested area are identified, and, on the other hand, the overlaid specific pressure layers such as deforestation, protected areas, baseline water stress, etc. are selected. This step includes data pre-processing: processing the collected data to make them usable for analysis, which may include cleaning, filtering, and aggregating the data to a suitable spatial resolution. The data should also be georeferenced to a common coordinate system.

Step 2: Overlaying of patterns
The second step is the overlay of the commodity pattern with the given pressures, and aggregating them to any spatial (e.g. administrative) unit of interest , as can be seen in Figure 4. The figure shows all data sources used for the analyses for all three spatial risk themes. Which data source was used for each risk theme can be found in the sections below.

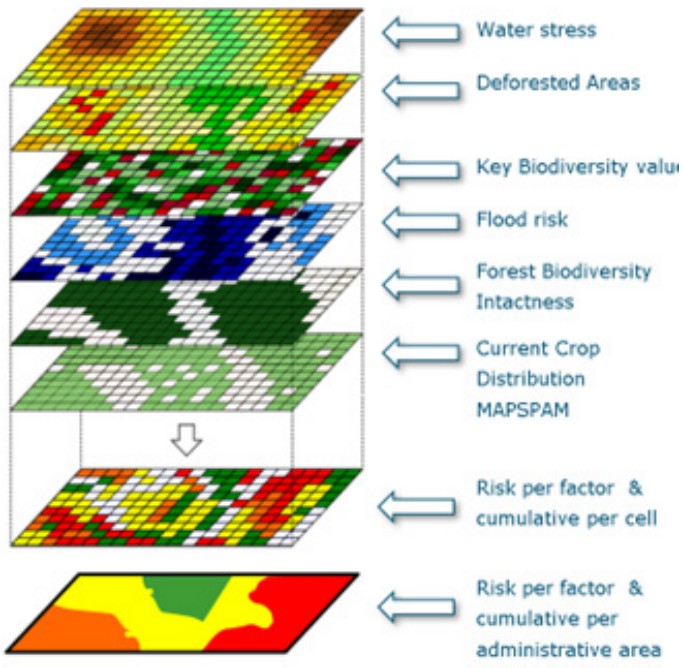

Figure 4 Visual representation of the spatial overlay of pressure and commodity production patterns to derive risks per administrative region

Theme-specific information

Acidification

Definition The impact category acidification measures the potential of a product or process to contribute to the increase of acid content in terrestrial and aquatic ecosystems. It addresses the environmental impacts due to the release of acidifying substances in the environment. Emissions of for example NO_x, NH_3, and SO_x lead to the release of hydrogen ions (H^+) when gases are mineralised. The protons contribute to the acidification of soils and water when they are released in areas where the buffering capacity is low, resulting in forest decline and lake acidification.

Indicators Accumulated exceedance (AE) in mol H^+ equivalents. This indicator takes into account both the area exceeded and the magnitude of exceeded. AE is set to zero where critical loads are not exceeded. It should be denoted that the same AE can arise from a large exceedance and small exceeded area, or a small exceedance and a large area.

Climate Change

Definition This theme describes changes in average global temperatures and weather patterns in a given period of time (i.e., 100 years). These changes are related to the emission of greenhouse gas emissions to air. The greatest contributor is generally the combustion of fossil fuels, such as coal, oil, and natural gas.

Indicators For climate change we use Global Warming Potential (GWP) over 100 years in kg CO2 equivalents (IPCC, 2021). GWP is the potential contribution of a substance to the greenhouse effect. The effects are measured over a specified time horizon of 100 years, using the baseline model of 100 years of the IPCC (2021). The GWP is normalised to carbon dioxide. This means that all GHG emissions (CH_4, N_2O, SF6, HFCs, and CFCs) are compared to the equivalent amount of the GWP of 1 kg of carbon dioxide. Climate change is a combination of four sub-indicators: Climate change – fossil, climate change – biogenic, climate change – land use and land use change, climate change – peat oxidation.

Eutrophication

Definition Eutrophication stands for excessive levels of nutrients in the environment caused by emissions of nutrients to air, water and soil. Eutrophication is a process that sees the environment becoming enriched with nutrients. Eutrophication includes all impacts due to excessive levels of nutrients in the environment caused by emissions of nutrients to air, water and soil. N emissions are mainly caused during the application of fertilisers, but also during combustion processes. P emissions are mainly caused by sewage treatment plants for urban and industrial effluents, but also leaching from agricultural land.

Indicators For eutrophication we use two indicators:

- Fraction of nutrients reaching marine end compartment, expressed in kilogram of Nitrogen equivalents for marine eutrophication. The EUTREND model (Struijs et al., 2009) as implemented in ReCiPe is used.
- Fraction of nutrients reaching freshwater end compartment, expressed in kilogram of Phosphorus equivalents for freshwater eutrophication. The EUTREND model (Struijs et al., 2009) as implemented in ReCiPe is used.

Ecotoxicity

Definition Freshwater ecotoxicity addresses the toxic impacts on an ecosystem, that damage individual species and change the structure and function of the ecosystem. Ecotoxicity is the result of a variety of different toxicological mechanisms cause by the release of substances with a direct effect on the health of the ecosystem (Zampori and Pant, 2019).

Indicators For freshwater ecotoxicity we look at comparative toxic unit for ecosystems (CTU_e) based on the USEtox 2.1 model (Fantke et al., 2021), adapted as in Saouter et al. (2018).

Water use

Definition Water use represents the use of water in such a way that the water is evaporated, incorporated into products, transferred to other watersheds or disposed into the sea. Water that has been consumed is not available anymore in the watershed of origin for humans nor for ecosystems (ReCiPe, 2016). Water use is there with the sum of consumed water (i.e. the difference between water extraction and water discharges).

Indicators Water Consumption Potential is measured in m^3 water equivalents consumed.

Water stress

Definition Water stress occurs when water demand exceeds supply or when poor water quality limits its use. It results from factors like population growth, industrial activity, and climate change, leading to shortages, reduced agricultural yields, and ecological impacts. By combining data on water stress with crop production patterns, we estimate a risk score of crop-related water stress.

Indicators To generate the risk scores for water stress, we depend on the Aqueduct Water Risk Atlas, Aqueduct 4.0 , which is the latest iteration of the World Resources Institute's water risk framework designed to translate complex hydrological data into intuitive indicators of water-related risk.[32] Aqueduct contains 13 water risk indicators, covering aspects of quantity, quality, and reputational concerns, sourced from open-source, peer-reviewed data providers. These indicators are transformed into 5-scale risk scores per sub-basin based on severity of the water issues they represent. One of these indicators is 'baseline water stress', which assesses the ratio of total water demand to available renewable surface and groundwater supplies. It reflects the pressure on water resources, considering demands from domestic, industrial, and agricultural sectors against available supplies. This indicator aids in pinpointing regions facing significant water scarcity, guiding strategic resource management. To create a risk score on water stress we combine this data source with the MAPSPAM Crop Areas, which includes crop area, yield, and production at a 5-minute grid resolution. We then aggregate the spatial patterns to the ADM1 level (the highest-level sub-national disaggregation), so that for each sub-national region we have the absolute area of land falling in each risk class from Aqueduct as well as the share of land falling in each Aqueduct risk class. The final risk score is calculated by applying a weighted average of the land within each of the 5 risk classes from Aqueduct.

Land use / deforestation

Definition The EU deforestation regulation (EUDR, EU Regulation 2023/1115) mandates companies to assess and mitigate risks of sourcing illegally harvested timber. This involves analysing supply chains,

verifying suppliers' compliance with laws, and identifying risks like illegal logging. Companies must implement mitigation measures, such as sourcing from certified suppliers and maintaining detailed records. Continuous monitoring and review are required to ensure effectiveness. Although creating a globally applicable procedure is challenging, a spatial estimate of deforestation risks related to crop harvesting can be made at a sub-national level. However, a lack of up-to-date global information on crop and deforestation patterns limits precision.

Data sources To generate the risk scores on deforestation, we combine three different data sources:

- Intact Forest Landscapes (IFL),[33] which identifies the world's unfragmented forest landscapes, large enough to retain all native biodiversity and showing no signs of human alteration as of the year 2020. This layer also shows the reduction in the extent of Intact Forest Landscapes from 2000 to 2020.
- Protected areas and strictly protected areas (IUCN IA/B,II) from the World Database on Protected Areas (WDPA),[34] displaying areas that are legally protected according to various designations (e.g., national parks, state reserves, and wildlife reserves) and managed to achieve conservation objectives
- Tree cover loss,[35] 2001-2020. In this data set, tree cover'' is defined as all vegetation greater than 5 meters in height, and may take the form of natural forests or plantations across a range of canopy densities. 'Loss' indicates the removal or mortality of tree cover and can be due to a variety of factors, including mechanical harvesting, fire, disease, or storm damage. As such, 'loss' does not equate to deforestation. The term 'deforestation' is nevertheless frequently used because these events have the potential for deforestation, and further investigation is required to confirm this. Currently, the indicator uses the timeframe of the total loss 2001-2020.
- MAPSPAM Crop Areas,[36] which includes crop area, yield, and production at a 5-minute grid resolution, used to estimate the total harvest in deforested areas.

The risk scores are then determined using the logic in Table 2.

Table 2 Deforestation risk score calculation and weighing rules

Minimum mapping unit = 10 ha harvested			**% of total harvest in deforested areas (2001-2020)**					
		Risk	**Very low**	**Low**	**Medium**	**High**	**Extremely High**	**No crop / No deforestation**
Category WDPA and IFL	Base Risk		<5%	5-10%	10-25%	25-50%	>50%	0%
Not Protected; Outside current or former IFL area (2000-2020)	% Deforestation based	1				4	5	0
Not Protected; Inside former IFL area (<2020)	Medium	3				4	5	0
Not Protected; Inside current IFL area (2020)	High	4				4	5	0
Protected; Outside current or former IFL area (2000-2020)	High	4				4	5	0
Protected; Inside current or former IFL area (2005-2020)	Extremely High	5					5	0
Strictly protected (IUCN I, II or III); In- or outside IFL area	Extremely High	5					5	0

Biodiversity loss

Definition Will be added in Q4 2024
Indicators Will be added in Q4 2024

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