

## CHAPTER 8.

# Land use and leakage

*This chapter provides requirements, recommendations, and options to account for and report the “land use” and “land carbon leakage” accounting categories. The former quantifies a company’s annual agricultural land use impact, and the latter quantifies the GHG impacts of displaced food or feed production (i.e., land carbon leakage) due to corporate actions.*

## 8.1 Overview

Agricultural land is an input to agricultural production and typically requires the loss of carbon from native vegetation and soils. Regardless of when agricultural land was cleared, the total quantity of agricultural land required by a company contributes to global land pressure that leads to land use change emissions from net global land use change.<sup>1</sup> Accounting for agricultural land use helps to quantify a company’s contribution to global land use and conversion pressure.

In the land sector, where land area is finite and competition for land is increasing, there is a high potential for land carbon leakage, in which displacement of food or feed production drives agricultural land expansion, leading to land use change beyond the lands in a company’s operations or value chain (Figure 8.1). By quantifying land carbon leakage, companies can properly account for these impacts and aim to reduce their total emissions.

Companies are required to account for the following:

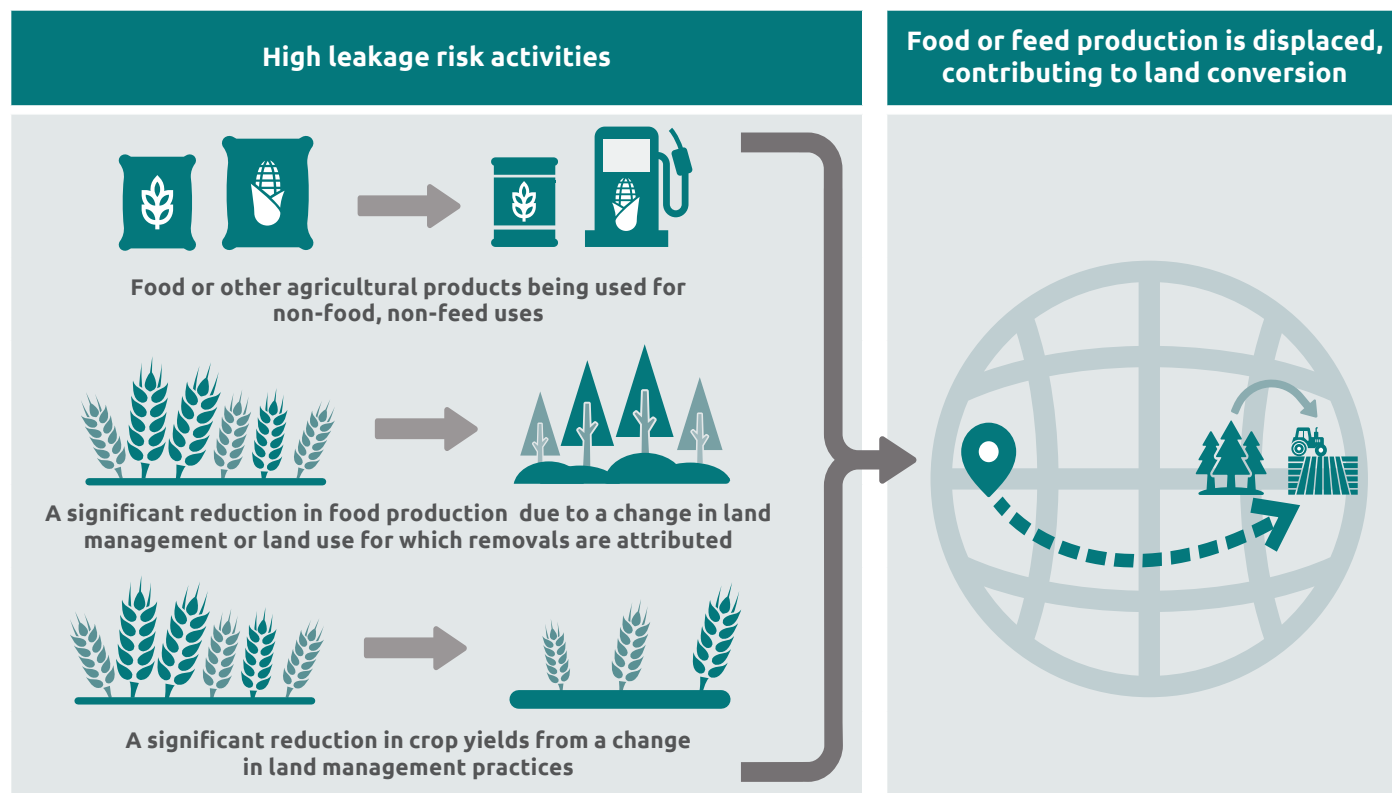
- Land occupation, measured in hectares (Requirement 12).
- Land carbon leakage, measured in carbon dioxide equivalent (CO<sub>2</sub>e) (Requirement 13). Land carbon leakage is calculated as the amount of carbon lost from plants and soils from the conversion of native ecosystems to agricultural land to replace the quantity and type of reduced or diverted food or feed production due to corporate actions, using the carbon opportunity cost approach.

Companies are recommended to account for the following (see “Detailed reporting for land use” Recommendation in 8.3):

- Land occupation, measured in hectares, disaggregated by land use category (e.g., cropland, grassland, etc.).
- Carbon opportunity cost (COC) of land use, measured in CO<sub>2</sub>e. The “land use” accounting category can also be calculated in carbon terms, instead of hectares (i.e., land occupation), using the COC approach. The COC of land use is the total amount of carbon lost from plants and soils on land occupied by agriculture relative to native vegetation.



Figure 8.1 Land carbon leakage



## 8.2 Requirements

### 8.2.1 Accounting requirements

#### REQUIREMENT 12:

##### *Land use accounting*

Companies **shall** account for agricultural land occupation (in hectares) in scope 1 and scope 3 for each scope 3 category.

#### REQUIREMENT 13:

##### *Land carbon leakage accounting*

If companies implement activities with high risk for land carbon leakage (specified below) and as a result report reduced GHG emissions, increased removals, or reduced emissions relative to use of an alternative non-biogenic product, but also reduce or divert food or feed production on agricultural land, they **shall** quantify land use-related GHG impacts of displaced food production, and report such leakage separately in the “land carbon leakage” accounting category relative to scope 1 and scope 3 for each scope 3 category.

- **Activities with high risk for land carbon leakage:** Companies **shall** quantify land carbon leakage if any of the following activities occur in a company’s operations or value chain in the reporting year:
  - Use of food or other agricultural products for non-food, non-feed use (e.g., crop-based biofuels or bio-based feedstocks).

- Significant reduction in food production that occurs over the long-term, resulting from a change in land management or land use for which land management CO<sub>2</sub> removals are attributed (e.g., change in land use from cropland to forest land), except where such a change is made to improve the long-term sustainability of food production.
- Significant reduction in crop yields per hectare that occurs over the long-term, resulting from a change in cropland management practices (e.g., practices that reduce chemical inputs but also significantly reduce crop yields), except where such a change is made to improve the long-term sustainability of food production.
- **Quantification approach:** Companies **shall** quantify land carbon leakage using the annualized, average carbon stock losses from the conversion of native ecosystems to agricultural land to replace the quantity and type of reduced or diverted food or feed production at average yields (“carbon opportunity cost”).<sup>2</sup>



## 8.2.2 Reporting requirements

### Reporting requirements for land use

Companies **shall** report:

- Land occupation in hectares under the “land occupation” accounting subcategory under “land use” separately from the physical GHG inventory.

Additionally, they **shall** disclose in their GHG report the yields and factors used to calculate land occupation. If companies choose to report “carbon opportunity cost of land use,” they shall disclose the factors used.

### Reporting requirements for land carbon leakage

Companies with high leakage risk activities in their operations or value chain **shall** report:

- Leakage under the “land carbon leakage” accounting category separately from the physical GHG inventory.

Companies **shall** disclose the following information in their GHG report:

- **Activities with a high risk for land carbon leakage:** Whether there are high leakage risk activities in their operations or value chain and a description of those activities.
  - If companies have high leakage risk activities and account for and report “land carbon leakage,” they **shall** disclose in their report the total quantity of reduced or diverted food or feed crop(s), the land carbon leakage boundary (or boundaries), and corresponding carbon opportunity cost factor(s) used to calculate land carbon leakage.
  - If companies do not have high leakage risk activities or if this requirement is not applicable, and they do not account for and report “land carbon leakage,” they **shall** provide justification.

## 8.3 Recommendations

### Detailed reporting for land use

Land use, when measured in hectares, does not differentiate between different types of land or the ability of those lands to store carbon, which can vary widely globally due to factors such as rainfall and temperature. Companies **should** go beyond reporting total scope 1 and scope 3 land occupation in hectares using one or both of the following approaches:

- **Disaggregating by land type:** Separately report scope 1 and scope 3 agricultural land occupation in hectares by land use category (e.g., cropland, grassland) in the “land occupation” accounting subcategory under “land use.”
- **Quantifying the carbon opportunity cost of agricultural land use:** Separately report scope 1 and scope 3 agricultural land use using the carbon opportunity cost (COC) metric in the “COC of land use” accounting subcategory under “land use.” COC factors can be represented in units of CO<sub>2</sub>e per unit product or per unit area of land. See the *Guidance* for how to account for the land use category using the COC metric.

## 8.4 Guidance on the requirements and recommendations

### 8.4.1 Relationship between the land use change-related metrics

Most pathways for stabilizing the climate at acceptable levels require halting deforestation and the conversion of other natural ecosystems, as well as restoring natural ecosystems on hundreds of millions of hectares of current agricultural land.<sup>3</sup> At the same time, the world faces a global “land squeeze”: at least 70 percent of the planet’s land is already used to meet human needs,<sup>4</sup> and demands for agricultural products are expected to grow by 50–60 percent between 2019 and 2050.<sup>5</sup>

Due to rising demand for agricultural products and a finite global land area, competition for land is growing, and agricultural land is expanding into carbon-rich terrestrial ecosystems. Croplands expanded by 218 million hectares (Mha) on a gross basis, and 102 Mha on a net basis, between 2003–2019.<sup>6,7</sup> Land use change emissions were roughly 5 Gt CO<sub>2</sub> per year between 2007–16 on a net basis, equal to around 10 percent of total global emissions.<sup>8</sup>

Companies contribute to global land use pressures—and to pressures on natural ecosystems and land use change emissions—through both the total *quantity* of agricultural land used in the reporting year in their operations and value chain, as well as *where* in the world that agricultural land is located (i.e., if that land area has, or has not, experienced recent land conversion). Moreover, every hectare of land already provides *some* benefit to humanity (e.g., for food, feed, or fiber production, fuel production, carbon storage, ecosystem services); this holds true for managed lands, natural lands, highly productive lands, and degraded lands. Increasing land demand for one use necessarily comes at the expense of another.

To account for a company’s contribution to emissions from agricultural land expansion, this *Standard* requires multiple metrics. The land use change (LUC) emissions metrics in Chapter 7 (direct and statistical land use change emissions) measure annual emissions from gross, recent expansion of agricultural land due to activities on lands in a company’s operations or value chain. Yet, regardless of when agricultural land was cleared, the total quantity of agricultural land use by a company contributes to global land pressure that leads to land use change emissions from net global land use change. Therefore, a full accounting of a company’s contribution to land use change includes a combination of both recent land use change emissions (quantified by the direct and statistical land use change metrics) and a measure of the company’s contribution to global agricultural land use (quantified by the land use and land carbon leakage metrics).



**Table 8.1** Description of land use and land carbon leakage accounting categories

Accounting category	Accounting subcategory	Description	Calculation approach	Reporting units
Land use (Required)	Land occupation (Required)	The amount of agricultural land occupied in the reporting year to produce products in a company’s operations and/or value chain, measured in hectares.	“Direct” or “statistical” land occupation	Hectares
	Land occupation, disaggregated by land use type (Optional)			
	Carbon opportunity cost of land use (Optional)	The total amount of carbon lost from plants and soils on land occupied by agriculture relative to native vegetation, measured in carbon dioxide equivalent (CO <sub>2</sub> e).	Carbon opportunity cost	CO <sub>2</sub> e
Land carbon leakage (Required)	N/A	Land carbon leakage occurs when companies implement actions that aim to reduce GHG emissions, increase removals, or reduce emissions relative to the use of an alternative non-biogenic product, but also reduce or divert food or feed production on agricultural land.  Reduced or diverted food or feed production increases total land use requirements globally, the resulting emissions from which are estimated by the average carbon loss from plants and soils to replace that crop, at average yields (i.e., the carbon opportunity cost).	Carbon opportunity cost	CO <sub>2</sub> e

## Land use

The “land use” accounting category quantifies a company’s contribution to global agricultural land use (Table 8.1). Land use in this *Standard* is required to be reported in hectares in the “land occupation” accounting subcategory.

Translating land use into carbon terms can also provide information to inform companies’ decisions regarding agricultural land use and land use efficiency, from a climate perspective. The capacity of land to store carbon in vegetation and soils can vary widely from one hectare to another, due to factors like rainfall, temperature, and soil type. Reporting land use in hectares cannot differentiate between types of land used for agriculture from this perspective.

Therefore, companies are also recommended to quantify land use in their operations and value chain expressed in units of CO<sub>2</sub>e, by calculating the carbon opportunity cost (COC) of the company’s agricultural land use (Table 8.1). The carbon opportunity cost metric quantifies land use in terms of the land’s forgone ability to store carbon. Another recommended way for companies to quantify their land use is to calculate land occupation in hectares differentiated by land use type (e.g., hectares of cropland versus hectares of pastureland).

Changes in a company’s land use, particularly land use intensity metrics, reflect contributions to land conversion pressure, either positive or negative. As discussed in Chapter 17, failure to increase land use efficiency sufficiently to meet rising global food and feed demands contributes to global net land use change, while increases in land use efficiency that exceed the scope of rising demand reduce net land use change.

## Land carbon leakage

At nearly 5 billion hectares,<sup>9</sup> agriculture is by far the world’s largest productive use of land, and cropland and pastureland continue to expand into tropical forests.<sup>10</sup> Food and feed production account for the vast majority of agricultural land, with food and feed crops produced on 97 percent of the world’s cropland.<sup>11</sup> Food and feed products are also difficult to replace with non-land-based substitutes at meaningful scales (e.g., marine aquaculture production—some of which uses land-based feeds—accounts for less than 1 percent of calories in the global food supply).<sup>12</sup>

Leakage occurs when corporate actions to reduce emissions and/or increase removals within their inventory lead to increased emissions and/or decreased removals outside of their inventory boundary. In the land sector, where land area is finite but demand for food and other land-based products is growing, there is a high potential for leakage via land use change driven by agricultural land expansion.

Land carbon leakage occurs when corporate actions lead to the displacement of food and feed production to lands beyond their operations or value chain, contributing to agricultural expansion and land use change. Quantifying land carbon leakage accounts for GHG impacts associated with the production and sourcing of land-based products that are not already accounted for as land emissions within a company’s operations or value chain (i.e., scope 1 and scope 3 land emissions) and accounts for GHG impacts related to the production and sourcing of land-based products that might otherwise be overlooked.

The IPCC identifies certain mitigation activities in the land sector that are at a high risk of increasing competition for land.<sup>13</sup> These activities aim to reduce GHG emissions, increase removals, or reduce emissions relative to the use of alternative, non-biogenic products, but that also reduce or divert food or feed production on agricultural lands, resulting in land carbon leakage. As set forth in Requirement 13, this *Standard* requires companies to quantify and report land carbon leakage when certain high-leakage-risk activities occur in a company’s operations or value chain in the reporting year. These high-risk triggering conditions are discussed further in Section 8.4.3.

### 8.4.2 Accounting guidance for land use

#### Required and optional land use metrics

The “land occupation” accounting subcategory quantifies (in hectares) the contribution of a company’s activities to total global demand for agricultural land, information that can inform more efficient uses of land and reduce pressure on natural ecosystems. Calculating land occupation in hectares is simple and relatively easy to calculate and communicate, as the metric requires little (or no) new data collection that is not already used to calculate and report other accounting categories in this *Standard*. Tracking land occupation can illuminate important tradeoffs. For example, agricultural intensification may increase fertilizer-related land management production emissions but also reduce the total amount of land needed to produce a given quantity of product, reducing pressure on the finite global land resource and freeing up land for other purposes (e.g., for carbon storage or habitat).

Land occupation reported in hectares cannot readily be compared to other accounting categories in the GHG inventory. Optionally expressing land use in carbon terms (i.e., by reporting the “carbon opportunity cost of land use” accounting subcategory) provides information on land use impacts and land use efficiency more directly in terms of carbon costs and benefits. To understand the carbon costs of a company’s land use across different regions and land use types, companies can optionally report land use in units of CO<sub>2</sub>e by applying the carbon opportunity cost (COC) calculation approach. Table 8.2 compares the metrics to account for and report a company’s land use impacts.

**Table 8.2** Benefits and challenges of land use metrics in this Standard

Accounting category	Accounting subcategory	Benefits and challenges
Land use	Land occupation (Required)	<p><b>Benefits:</b> Calculating and reporting land use in hectares is simple and relatively easy to calculate and communicate, as the metric requires little or no new data collection that is not already needed to calculate and report other inventory categories. Yield data to calculate land occupation is readily available in databases. Reporting land use in hectares provides a simple way to track the contribution of a company’s activities to total global demand for agricultural land and can incentivize more efficient use of agricultural land, reducing pressure on natural ecosystems.</p> <p><b>Challenges:</b> Information in hectares cannot readily be compared to other accounting categories in this <i>Standard</i>, and does not provide a complete, differentiated picture of the cost of land use in terms of land’s ability to sequester and store carbon.</p>
	Land occupation disaggregated by land use type (Optional)	<p><b>Benefits:</b> See above. In addition, reporting land occupation disaggregated by land use type provides additional information about a company’s land use impacts in its operations and value chains.</p> <p><b>Challenges:</b> See above.</p>
	Carbon opportunity cost of land use (Optional)	<p><b>Benefits:</b> Expressing land use in terms of its “carbon opportunity cost” translates hectares to carbon terms and provides useful information to inform climate-efficient land use decisions.</p> <p><b>Challenges:</b> Calculating the carbon opportunity cost of land use requires data on natural and productive carbon stocks. These average reference data are subject to some uncertainty and, although available in the academic literature, are less readily available in current databases.</p>

### Time boundary for land use accounting

When companies account for scope 1 or scope 3 land occupation, an annual time boundary is applied. When accounting for land occupation using land occupation factors (i.e., yields), it is recommended that companies use at least a three-year simple moving average yield, when data are available, to account for annual yield fluctuations due to non-anthropogenic factors and to better capture the long-run yield trend. Ideally, a company should use the most recent three years (or greater) of yield data, inclusive of the reporting year. However, publication of official yield statistics for the current (i.e., reporting) year is often delayed by up to a few years, which may limit the ability to use the most recent, consecutive three-year period. In this case, it is recommended that companies use the most recent three-year (or greater) period of available yield data. Companies should disclose the data years included in the simple moving average.

When optionally calculating and reporting the “carbon opportunity cost of land use” subcategory, the company’s land use impact is often annualized. Because carbon losses from land conversion occur quickly, but production of food, feed, or other land-based products on agricultural land can continue for many years, annualizing distributes the carbon losses from the land conversion across the products produced on that converted land over many years.<sup>14</sup> Therefore, to express a company’s land use in carbon terms, the difference between native and productive (agricultural) carbon stocks on lands in a company’s scope 1 or scope 3 boundary is first calculated and converted to CO<sub>2</sub> equivalent, and that amount is then typically annualized by dividing by a certain number of years (see Equations 8.3 and 8.4). Productive carbon stock represents the average carbon stock, including all land-based carbon pools, on productive lands in the scope 1 or scope 3 spatial boundary in the reporting year. Researchers have used a range of time periods for annualizing the carbon opportunity cost, with many in the 20–35-year range, with others using discount rates or reporting the full (i.e., non-annualized) COC value.<sup>15</sup>

## Spatial boundary for land use accounting

When companies account for scope 1 or scope 3 land use (including land occupation and, optionally, the carbon opportunity cost of land use), they account for lands that are included within their scope 1 or scope 3 spatial boundaries (see Requirement 5). Requirements and guidance for setting the scope 1 or scope 3 spatial boundaries, and the lands that are included or excluded with those boundaries, are set forth in Chapter 5 in the *Standard and Guidance*.

For example, when accounting for scope 1 or scope 3 land occupation, companies select a yield factor corresponding to the average yields on lands within the scope 1 or scope 3 spatial boundary. When optionally accounting for scope 1 or scope 3 carbon opportunity cost of land use, companies select a COC factor corresponding to the annualized, average difference between native and productive carbon stocks on lands within the company's scope 1 or scope 3 spatial boundary.

Note that scope 1 and scope 3 spatial boundaries are distinct from the land carbon leakage boundary used to account for land carbon leakage (for guidance on setting the land carbon leakage boundary, see Section 8.4.3).

## Avoiding double counting between land use and other accounting categories

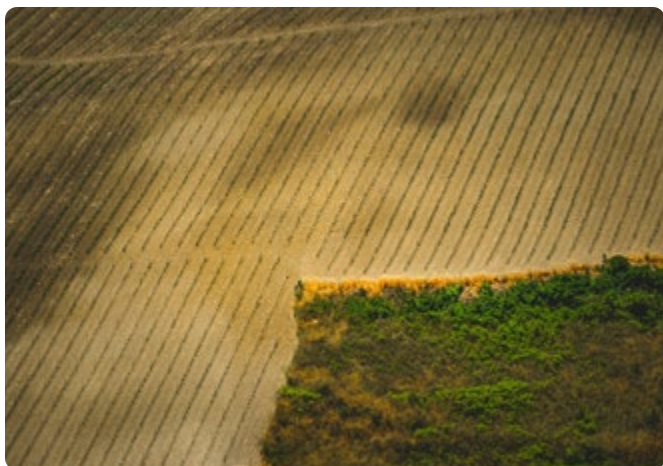
If companies choose to optionally account for and report the “carbon opportunity cost of land use” subcategory, this subcategory must be reported separately from other accounting categories, including “land emissions.” If companies additionally choose to report aggregated information, they should avoid double counting if the carbon opportunity cost of land use metric is aggregated with other inventory metrics (e.g., with land use change emissions and other land emissions accounting subcategories, such as in a target-setting context). For example, if a farm that a company sources from underwent a land use change in the land use change assessment period, emissions from that recent land use change are accounted for as scope 3 land use change emissions (see Chapter 7). The scope 3 carbon opportunity cost of land use quantifies a similar impact (i.e., the foregone ability of land to sequester and store carbon, calculated as carbon losses relative to native carbon stocks) and, therefore, the company's scope 3 carbon opportunity cost of land use should not be aggregated with such land emissions.

### 8.4.3 Accounting guidance for land carbon leakage

#### Required and optional calculation approaches for land carbon leakage

Land carbon leakage is quantified as the annualized, average carbon stock losses from the conversion of native ecosystems to agricultural land to replace the quantity and type of reduced or diverted food or feed production, at average yields. Land carbon leakage is required to be quantified using the carbon opportunity cost (COC) calculation approach and is measured in units of carbon dioxide equivalents (CO<sub>2</sub>e). In general, to calculate land carbon leakage, companies multiply the quantity of reduced or diverted food or feed by an average (e.g., global, regional, or national) carbon opportunity cost (COC) factor, corresponding to average carbon stocks and yields in the land carbon leakage boundary. For guidance on setting the land carbon leakage boundary and selecting or calculating the corresponding COC factor, see “Setting the land carbon leakage boundary” below.

Leakage effects in the land sector are well-known, but predicting the location and extent of the marginal leakage impact due to activities in a company's operations or value chain is difficult. The COC calculation approach provides a relatively simple, conservative, and transparent method to estimate land carbon leakage that can be applied in a standardized way across all agricultural products, in all parts of the world. Given the rising global demand for agricultural land and products projected through 2050, the COC quantification approach assumes that reduced or diverted food or feed production will be replaced at average yields and at average land carbon costs within a land carbon leakage boundary. Unlike other leakage calculation approaches, the COC calculation approach attributes land carbon leakage to a company's individual production or consumption activities using



only biophysical data and does not seek to simulate market-mediated effects due to activities by other actors (e.g., reductions in food consumption, increases in yield), whether in a certain sector or across the entire economy. Avoided cropland expansion and avoided land use change emissions attributable to the activities of other entities (e.g., via reduced food consumption and other market-mediated effects) are not attributed to the activity of the reporting company, whose own high-leakage-risk activities reduce or divert food or feed production.

Because the COC quantification approach assumes 1:1 replacement at average yields and does not seek to model rebound and other market-mediated effects,

the COC calculation approach may provide more conservative (i.e., higher) land carbon leakage values compared to other calculation approaches. However, the conservative assumption of 1:1 replacement is in part balanced by less conservative biophysical assumptions, i.e., that the leakage impact occurs at average yields and average land carbon costs in the land carbon leakage boundary. Although it cannot be observed directly, if the “true” displaced production of reduced or diverted food or feed crops occurs on land with carbon stocks above the average (e.g., in the tropics) and at yields below the average (e.g., in lower-income countries) of those within the land carbon leakage boundary, the COC calculation approach may underestimate the “true” (albeit unobserved) land carbon leakage cost. Recent analysis has shown that commodity-driven deforestation in the tropics can cause more land clearing beyond that which is ultimately productively used for agriculture (e.g., due to associated land speculation, deforestation carried out to strengthen land tenure claims, and fires started in agricultural lands that spread to adjacent forest areas),<sup>16</sup> suggesting that the “true” market-mediated land carbon cost of a marginal net increase in demand for agricultural land on hectares of tropical deforestation could be higher than 1:1 in some regions.

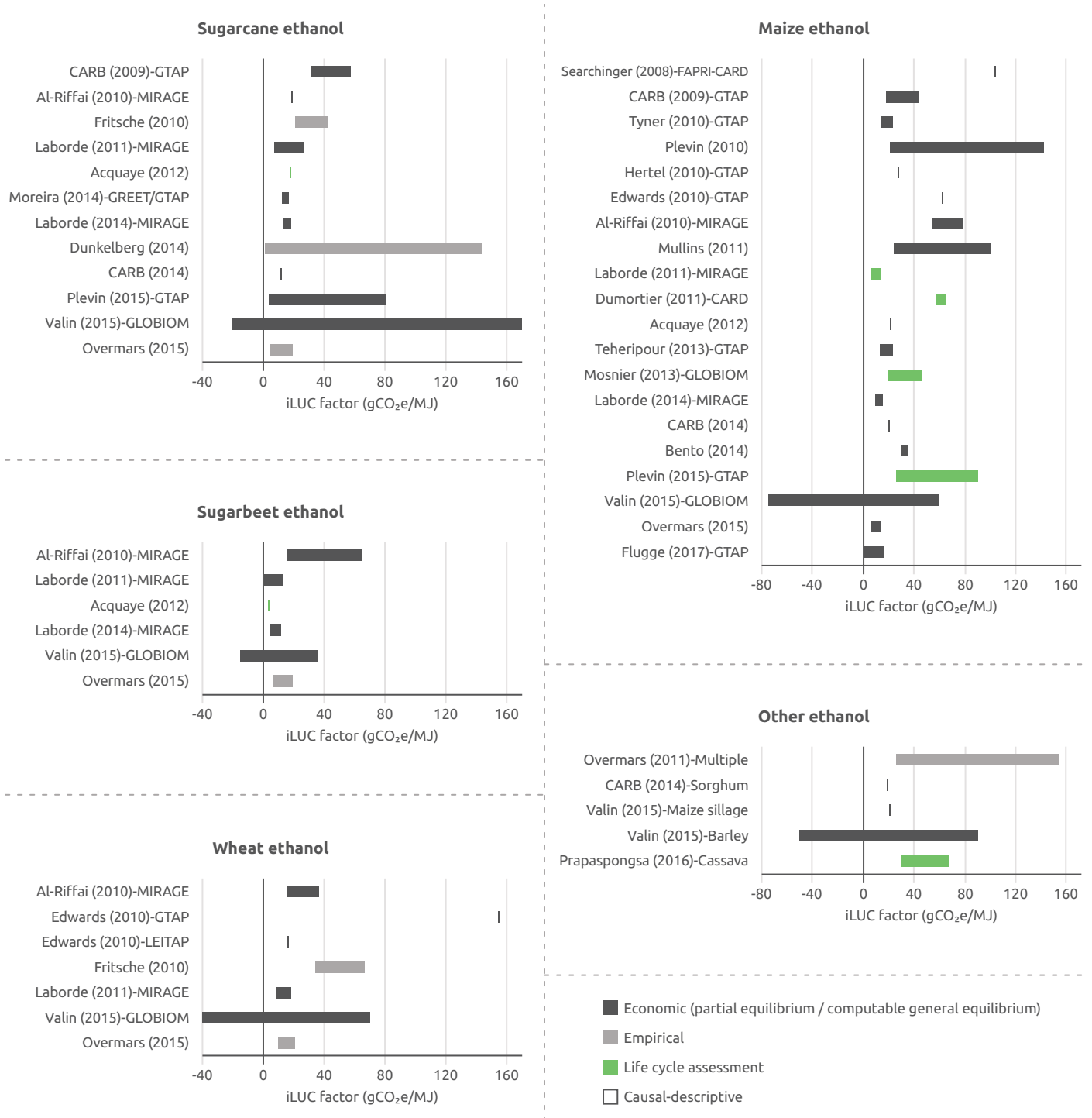
## Optional parallel leakage estimates for regulations and GHG programs

If regulations or GHG programs separately specify how leakage quantification is applied for the purposes of a regulation or program, companies may report parallel leakage estimates using that approach, in addition to quantifying and reporting land carbon leakage using the COC calculation approach. For example, some major climate policies and programs, especially for biofuels, have adopted specific indirect land use change (iLUC) models. Companies that follow this *Standard* may optionally report land carbon leakage values using iLUC models or other methods, separately and alongside values using the COC calculation approach required by this *Standard*.

Standard economic analysis and econometric models used to estimate iLUC rely on many assumptions that present challenges for transparency, standardization, and interoperability. Because model assumptions can vary widely, leakage estimates based on partial or general equilibrium modeling approaches can lead to a wide range of leakage emission factors, even for the same product, produced using the same management practices, in the same geography (Figure 8.2).

For example, models may make varying assumptions about how other entities boost crop yields in response to higher crop demand, and/or varying assumptions about the area into which cropland expansion occurs (e.g., cropland expansion into grassland instead of forest).<sup>17</sup> Other implicit or explicit assumptions can raise moral implications: for example, if crop calories diverted to biofuels are not replaced (e.g., some models assume 20–50 percent non-replacement),<sup>18</sup> models effectively “credit” biofuel use with the reduced GHG emissions that occur when people eat less food.

**Figure 8.2** Sample indirect land use change (iLUC) emission factors for crop-based biofuel feedstocks

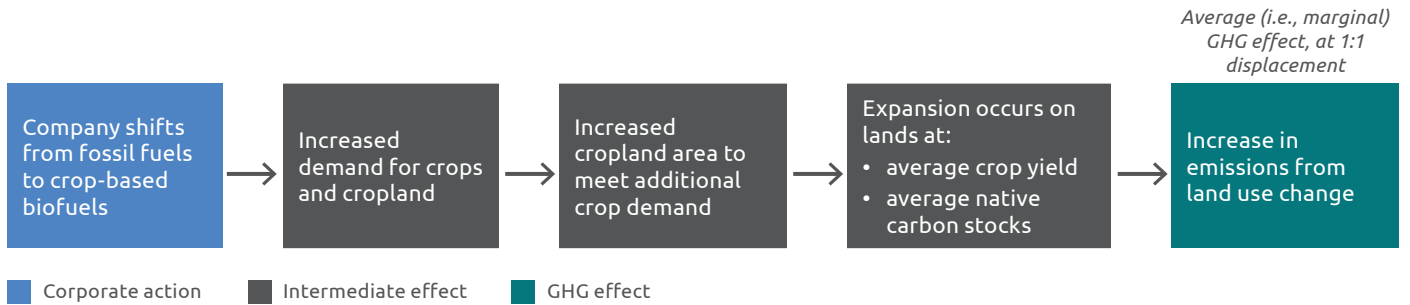


Source: Reproduced from Figure 3 in Woltjer et al. (2017). The complete list of references in the figure can be found in Woltjer et al. (2017).

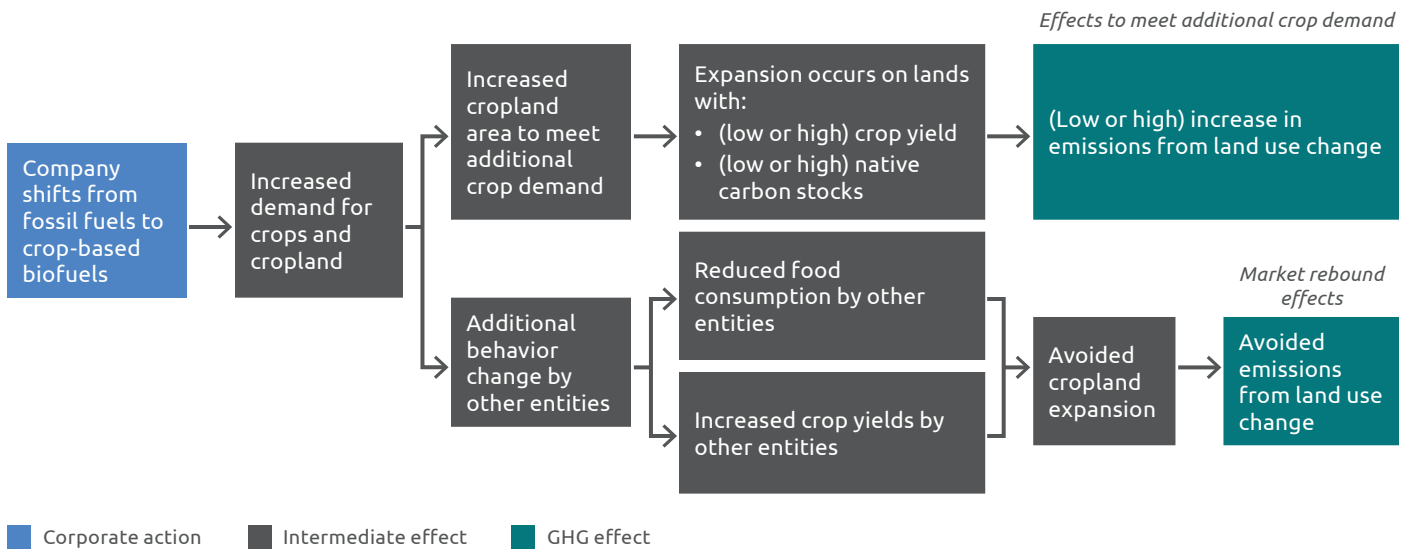
Note: See Figure 4 in Woltjer et al. (2017) for sample iLUC factors for biodiesel.

The COC and iLUC calculation approaches to estimate leakage make different assumptions, which can be represented by causal chain diagrams that map the intermediate effects and resulting GHG emissions due to activities that displace food and feed production. Figures 8.3 and 8.4 contrast an example causal chain for calculating land carbon leakage effects using the COC calculation approach and the iLUC approach. Table 8.3 highlights some of the benefits and challenges of different calculation approaches to quantify leakage.

**Figure 8.3** Example of a causal chain depicting the carbon opportunity cost calculation approach for land carbon leakage (required)



**Figure 8.4** Example of a causal chain depicting the indirect land use change (iLUC) calculation approach for land carbon leakage (optional)



**Table 8.3** Required and optional parallel leakage calculation approaches

Accounting category	Calculation approach	Required or optional?	Benefits and challenges
Land carbon leakage	Carbon opportunity cost	Required	<p><b>Benefits:</b></p> <ul style="list-style-type: none"> <li>• Conservatively accounts for 1:1 displacement of reduced or diverted food or feed production onto natural lands, in line with the conservativeness principle.</li> <li>• Uses only biophysical data and assumes no market rebound effects (e.g., how other entities adjust their own consumption or production activities); this results in a standardized metric that does not vary widely across scientific studies and assumptions, increasing comparability, consistency, and feasibility.</li> <li>• Calculation is relatively straightforward, as it requires only biophysical values, does not make economic assumptions, and does not require complex modelling.</li> </ul> <p><b>Challenges:</b></p> <ul style="list-style-type: none"> <li>• Average, native (i.e., reference) carbon stock amounts can be difficult to estimate precisely and can be uncertain.</li> <li>• Conservatively assigning a 1:1 land carbon leakage cost to activities that reduce or divert food or feed production could disincentivize consumption of some bio-based products and incentivize consumption of fossil-based products.</li> <li>• Calculation approach may be unfamiliar, and therefore challenging initially, due to limited application of the COC metric outside the academic sphere.</li> </ul>
	Indirect land use change (iLUC) emissions	Optional	<p><b>Benefits:</b></p> <ul style="list-style-type: none"> <li>• iLUC models are well-established in the bioenergy context, and emission factor databases are publicly available.</li> <li>• iLUC models attempt to simulate market-mediated effects in a sector, or across the entire economy, due to activities that reduce or divert food or feed production, which some consider a more comprehensive approach to quantifying leakage.</li> </ul> <p><b>Challenges:</b></p> <ul style="list-style-type: none"> <li>• iLUC models are complex, and their assumptions vary widely, producing a wide range of emission factors, even for the same product, in the same geography, produced the same way (see Figure 8.2). When applied to corporate GHG accounting, this variation reduces comparability, consistency, as well as transparency and feasibility, and can send misleading signals about which actions to take or avoid.</li> <li>• The assumption in iLUC models of reductions in other entities' food consumption as a climate "benefit" of biofuel consumption represents a moral risk of these models' use for leakage quantification.</li> <li>• Most existing iLUC models and databases are for bioenergy feedstocks only, with far less data available for other agricultural products, posing feasibility issues for land carbon leakage quantification, especially for activities that reduce or divert food or feed crops beyond the bioenergy context.</li> </ul>

## Conditions that trigger the required quantification and reporting of land carbon leakage

As set forth in Requirement 13, land carbon leakage is required to be quantified and reported under certain triggering conditions. The IPCC specifies certain GHG mitigation actions (i.e., "response options") that could greatly increase the competition for land if applied at scale, posing tradeoffs and reducing the overall mitigation potential of these actions.<sup>19</sup> Companies are required to quantify land carbon leakage if any of the following high-leakage-risk activities occur in a company's operations or value chain in the reporting year:

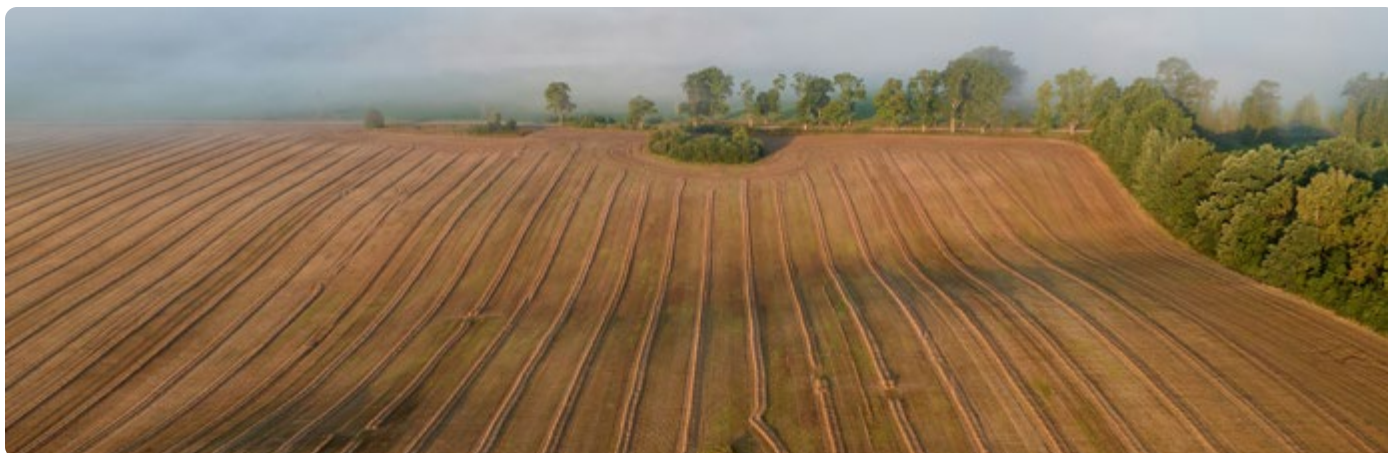
- 1. Use of food or other agricultural products for non-food, non-feed use (e.g., crop-based biofuels or bio-based feedstocks).** Leakage impacts due to activities that divert the use of food, feed, or other agricultural products for non-food, non-feed uses are well-established.<sup>20</sup> Examples of such activities include the use of oilseeds, grains, and other purpose-grown crops as feedstocks to produce crop-based biofuels and other bio-based materials (e.g., bioplastics). The IPCC has recognized that land used to grow feedstocks for bioenergy (with or without carbon capture and storage) increases land competition and could greatly increase demand for land conversion (*high confidence*).<sup>21</sup>

Activities in a company's operations or value chain associated with the production or consumption of fiber crops (e.g., bamboo, hemp) or other inedible industrial crops (e.g., rubber) and such crops with food or feed co-products (e.g., cotton, flax) are not generally considered to result in reduced GHG emissions, increased removals, or reduced emissions relative to use of an alternative non-biogenic product (IPCC, 2019b) and thus not generally subject to Requirement 13. However, in cases where a company purchases a biogenic product grown on dedicated land and as a result reports reduced emissions relative to the use of an alternative non-biogenic product (e.g., shifting from sourcing polyester fabric to sourcing cotton for textiles), Requirement 13 applies.

- 2. Significant reduction in food production that occurs over the long term, resulting from a change in land management or land use for which land management removals are attributed (e.g., change in land use from cropland to forestland), except where such a change is made to improve the long-term sustainability of food production.** Examples of such activities include afforestation and reforestation of agricultural land, or land management changes (e.g., tree planting) on existing agricultural land, if food production is significantly reduced.<sup>22</sup> The IPCC has recognized that afforestation and reforestation could greatly increase land competition and demand for land conversion if applied at scale (*high confidence*).<sup>23</sup>
- 3. Significant reduction in crop yields per hectare that occurs over the long term, resulting from a change in cropland management practices (e.g., a practice that reduces chemical inputs but also significantly reduces crop yields), except where such a change is made to improve the long-term sustainability of food production.** Some mitigation activities can reduce agricultural land management emissions but incur a significant yield penalty, which can drive land use change to make up for the forgone food production.<sup>24</sup>

## Time boundary for land carbon leakage accounting

Because carbon losses due to land conversion to replace reduced or diverted food or feed crops on lands in the land carbon leakage boundary can occur quickly, but production of food, feed, or other land-based products on those lands can continue for many years, the difference between native and productive carbon stocks on lands in a company's land carbon leakage boundary is annualized by dividing by a certain number of years (see Equations 8.3 and 8.4). This *Guidance* recommends that companies should apply a 20-year annualization period, which corresponds to the IPCC default period for land transition. Researchers, however, have used other time periods for annualizing leakage values, with many in the 20–35-year range.<sup>25</sup>



## Setting the land carbon leakage boundary

A carbon opportunity cost (COC) factor, like an emission factor, can be calculated at a global, continental, national, or sub-national level (see calculation guidance in Section 8.5.4). For example, just as an average national emission factor corresponds to average practices on attributable productive lands in the corresponding jurisdictional scope 3 spatial boundary, an average national COC factor corresponds to the national average carbon stock lost on land to replace, at average national yields, the food or feed crops in the corresponding national jurisdiction land carbon leakage boundary (that have been reduced or diverted by a high-risk activity in the reporting company's operations or value chain).

The land carbon leakage boundary determines the lands that are included in the analysis when calculating land carbon leakage using the COC calculation approach. The marginal carbon stock loss to replace the reduced or diverted food or feed crop (e.g., maize) is assumed to be the average carbon stock loss (i.e., the average difference between native and productive carbon stocks) on lands that produce maize within the land carbon leakage boundary. For example, if a company sets a global land carbon leakage boundary, all lands globally that produce maize are included within the global land carbon leakage boundary. Applying a global average COC factor for maize assumes that reduced or diverted maize will be replaced on the margin on land with a global average land carbon cost to produce maize (i.e., the average land carbon cost to produce maize within a global land carbon leakage boundary). Likewise, applying a global COC factor assumes that the reduced or diverted maize is replaced at the average maize yield on lands that produce maize in the global land carbon leakage boundary. Companies define a land carbon leakage boundary, and apply a corresponding COC factor, when calculating land carbon leakage for each agricultural product reduced or diverted by each high-leakage-risk activity that occurs in a company's operations or value chain in the reporting year.

Note that the land carbon leakage boundary is distinct from a company's scope 1 or scope 3 spatial boundaries (see Chapter 5) used to account for emissions, removals, and land use (including land occupation and, optionally, the carbon opportunity cost of land use). In contrast to a scope 1 or scope 3 spatial boundary, the land carbon leakage boundary defines the land to which food or feed reduced or diverted by a company's activities is likely to be displaced. More precisely, the lands included in the land carbon leakage boundary are then averaged in terms of their yield and foregone carbon stocks, defining a profile of the land where food or feed production, on average, is likely to be replaced. The land carbon leakage boundary can include the same lands in the reporting company's scope 1 or scope 3 spatial boundaries, but can also encompass lands that lie *outside* those spatial boundaries as well, following the guidance below. This is because land carbon leakage is by definition an indirect impact: activities in a company's operations or value chain that reduce or divert food or feed production increase total global land use requirements, the marginal emissions from which are estimated by average carbon stock

losses to replace that crop, at average yields. The average land profile within the land carbon leakage boundary may include, but is not limited to, the lands included in a company's scope 1 or scope 3 spatial boundaries.

For example, a company that has traceability to a national jurisdiction for the soy feedstock for the soybean-based renewable diesel it sources in the reporting year would set a national jurisdiction scope 3 spatial boundary and account for land emissions and land use on attributable productive lands in that scope 3 spatial boundary (see Chapter 5 for further details). When accounting for land carbon leakage attributable to the production of renewable diesel in its value chain, the company should set a land carbon leakage boundary following the guidance below. If the company sets a global land carbon leakage boundary, the global land carbon leakage boundary would include lands in the national scope 3 spatial boundary (i.e., used to account for land emissions and land use), as well as lands beyond that scope 3 spatial boundary. If the company sets a national land carbon leakage boundary identical to the national scope 3 spatial boundary, these two boundaries would include the same lands.

The land carbon leakage boundary and the corresponding COC factor that companies apply to account for scope 1 and scope 3 land carbon leakage depend on the level of traceability a company has to the sourcing lands in its value chain for the product whose production is reduced or displaced, and the characteristics of the market for that relevant food or feed crop. When setting the land carbon leakage boundary and calculating or selecting the corresponding COC factor to account for scope 1 or scope 3 land carbon leakage, companies should follow the following guidance (and see Figure 8.7):

- **Use global COC factors as default:** In general, the reporting company should set a global land carbon leakage boundary and apply a corresponding global average COC factor when accounting for scope 1 or scope 3 land carbon leakage. Many, if not most, markets for major food and feed commodities are global. Companies should provide justification if a sub-global COC factor is applied to calculate land carbon leakage (i.e., if replacement of reduced or displaced food or feed production is assumed to occur on average lands and at average yields within a continental, national, sub-national, etc., land carbon leakage boundary).
- **Market characteristics:** When the reporting company can establish more refined levels of traceability (e.g., to a national jurisdiction of origin) for the food or feed crop or commodity product that they source, they should consider the characteristics of the market for that displaced food or feed crop. Some commodities and crop products are predominantly produced for, and traded across, global markets, while others are produced and traded primarily within continental markets (e.g., Europe or South America) or domestic markets (i.e., are not internationally traded). Calculating and applying a regional or national average COC factor assumes that reduced or diverted food or feed crops will be replaced on land at a regional or national average carbon cost and at regional or national average yields.

As set forth in the reporting requirements for land carbon leakage in Section 8.2.2, companies must disclose the COC factor(s) and corresponding land carbon leakage boundary (or boundaries) (e.g., global, regional, national, etc.) that are applied to calculate and report land carbon leakage. Companies should provide justification if a sub-global COC factor is applied to calculate land carbon leakage.

## Avoiding double counting between land carbon leakage and other accounting categories

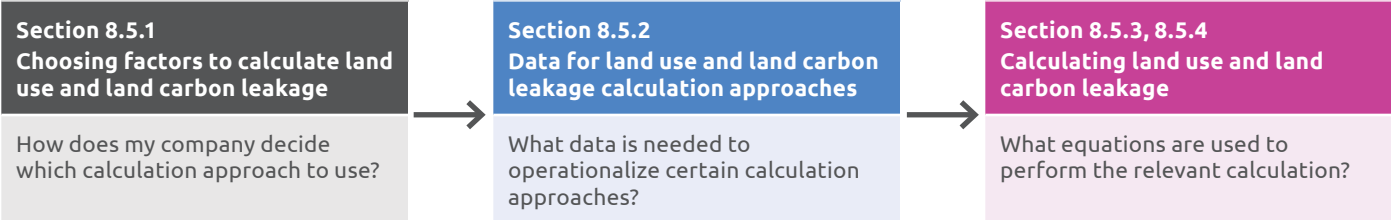
Land carbon leakage and other accounting categories must be reported separately. As set forth in Requirement 32, if companies additionally choose to report a single value that aggregates emissions or nets land emissions and land management CO<sub>2</sub> removals, this value must include, at a minimum, the accounting categories specified in Requirement 32, and that value is reported separately as "total emissions." The categories specified in Requirement 32 include "fossil fuel and industrial emissions," "land emissions," and "land carbon leakage."

Generally, double counting between land emissions and land carbon leakage is not a concern as land emissions occur on lands in a company’s operations and value chain, whereas land carbon leakage occurs on lands within a land carbon leakage boundary where food and feed production are displaced to (see “Setting the land carbon leakage boundary” above.) When aggregating “land use change-related” accounting categories (e.g., in the “total emissions” category), double counting can occur in cases where the high-leakage-risk activity that caused leakage is also associated with LUC emissions estimated at broader spatial scales using proxy data (i.e., statistical LUC emissions; see Chapter 7). In such cases, companies should follow the recommendation in Section 20.3 in the *Standard* (see “Avoiding double counting between sLUC and leakage emissions”) by deducting any double-counted statistical LUC (sLUC) emissions from the “total emissions” accounting category. Double counting is not an issue when adding land carbon leakage and LUC emissions estimated using dLUC metrics. For an example of how to account for and report the “total emissions” category and deduct sLUC emissions, see Section 20.4.2.

## 8.5 Calculating land use and land carbon leakage

The following sections provide guidance on calculating the land use and land carbon leakage accounting categories.

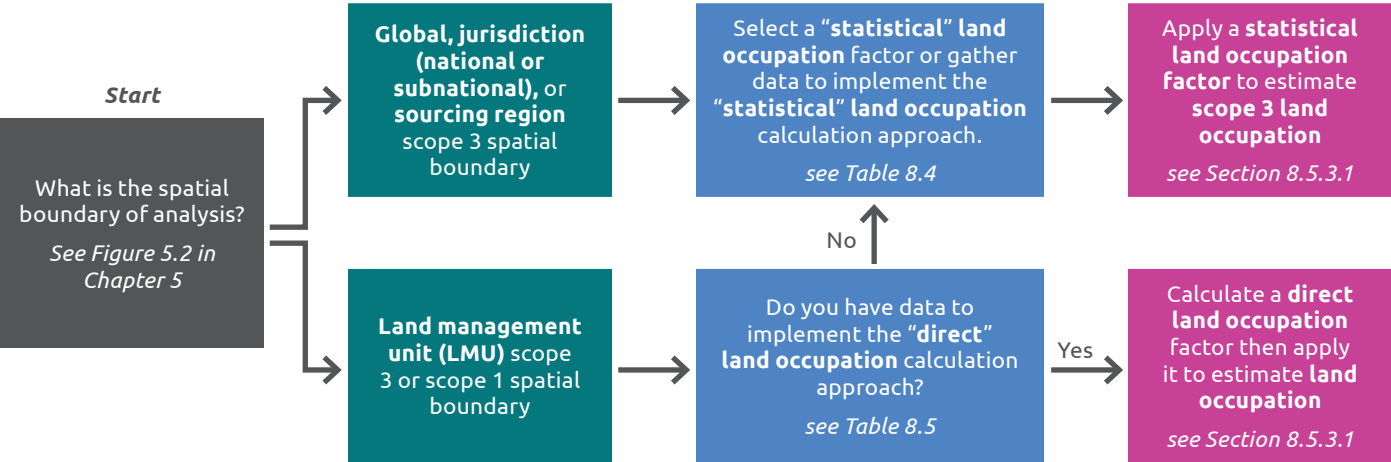
Figure 8.5 Overview of Section 8.5



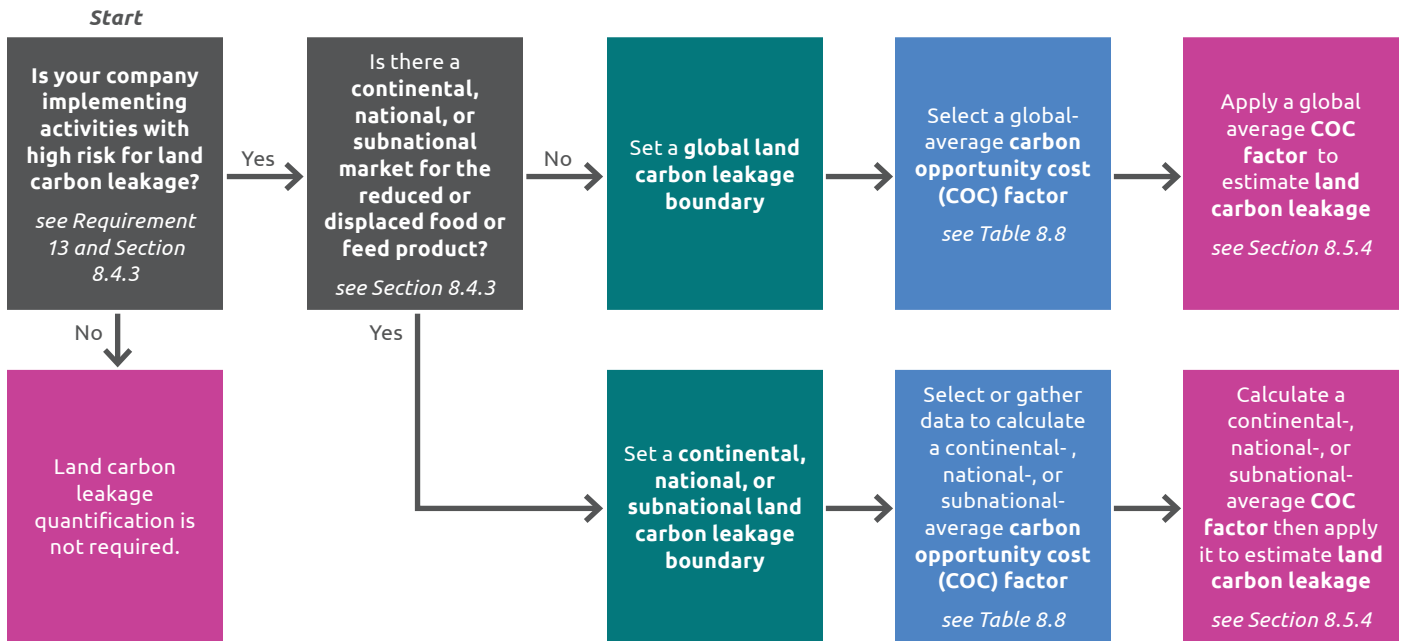
### 8.5.1 Choosing factors to calculate land use and land carbon leakage

Figure 8.6 and Figure 8.7 provide a decision tree to help companies select a land occupation calculation approach and to select a carbon opportunity cost factor to calculate land carbon leakage, respectively.

Figure 8.6 Decision tree for calculating land occupation



**Figure 8.7** Decision tree for choosing a carbon opportunity cost factor to calculate land carbon leakage



### 8.5.2 Data for land use and land carbon leakage calculation approaches

Sections 8.5.2.1 and 8.5.2.2 describe the types of data needed to implement land use and land carbon leakage calculation approaches, respectively.

#### 8.5.2.1 Data for land use calculation approaches

Tables 8.4–8.6 in this section provide an overview of the data needed to calculate land occupation (“statistical” or “direct” land occupation) and the carbon opportunity cost of land use.

**Table 8.4** Data needed for calculating “statistical” land occupation

Data	Description
Average yield data for the sourcing area	To estimate “statistical” land occupation, secondary (i.e., average) yield data are needed that represent average yields on productive lands in the scope 3 spatial boundary (e.g., jurisdiction or sourcing region). If available (e.g., from a database), land occupation factors can be applied directly.

**Table 8.5** Data needed for calculating “direct” land occupation

Data	Description
LMU-specific yield data	To estimate “direct” land occupation, primary (i.e., LMU-specific) yield data are needed that represent LMU-specific yields on productive lands in the scope 3 spatial boundary (e.g., the LMU or set of LMUs).
Shapefiles and other LMU-level production data	If LMU-level yield data are unavailable, the reporting company can also utilize spatial data (i.e., LMU shapefiles) and other LMU-level production data to estimate LMU-level yields indirectly.

**Table 8.6** Data needed for calculating the carbon opportunity cost of land use, in units CO<sub>2</sub>e (optional)

Data	Description
<b>Scope 1 or scope 3 land occupation (in hectares)</b>	Scope 1 or scope 3 land occupation (in hectares) is calculated using Equation 8.1. Data needed to calculate land occupation are presented in Tables 8.4 and 8.5.
<b>Carbon opportunity cost (COC) factor</b>	<p>A COC factor represents the average total quantity of carbon lost from vegetation and soils on land occupied by agriculture relative to native carbon stocks. COC factors can be expressed as tonnes of CO<sub>2</sub>e per unit area or per unit product (see Equations 8.3 and 8.4). COC factors can be drawn from the peer-reviewed literature (see Table 8.7). Accounting tools are under development to support carbon opportunity cost of land use calculations.</p> <p>To calculate a COC factor, the following data are needed:</p> <ul style="list-style-type: none"> <li>• <b>Average native carbon stocks on lands within the scope 1 or scope 3 spatial boundary.</b> Average native carbon stock data represent the average native, potential carbon stock, including all land-based carbon pools, on productive lands in the scope 1 or scope 3 spatial boundary. Native, potential carbon stocks are the best estimate of the total carbon stocks on land that would have existed in the absence of the productive land use. Native, potential carbon stock values can be drawn from dynamic global vegetation models (e.g., models included in the Inter-Sectoral Impact Model Intercomparison Project), biome-level average reference values (e.g., Tier 1 estimates given in IPCC national inventory guidance), or the peer-reviewed literature.<sup>26</sup></li> <li>• <b>Average productive carbon stock data within the scope 1 or scope 3 spatial boundary.</b> Average productive carbon stock data represent the average carbon stock, including all land-based carbon pools, on productive lands in the scope 1 or scope 3 spatial boundary. Productive carbon stocks are the total carbon stocks on land under a productive land use within the spatial boundary in the reporting year (e.g., total carbon stocks on land that produces wheat). Average carbon stock values on productive lands (i.e., average carbon stock factors on lands that produce the product in the scope 1 or scope 3 spatial boundary) can be drawn from IPCC national inventory guidance,<sup>27</sup> carbon stock data from national GHG inventories, or the peer-reviewed literature. Average carbon stock factors used to account for land management net biogenic CO<sub>2</sub> emissions (see Chapter 9) can also be used.</li> <li>• <b>Average yield data within the scope 1 or scope 3 spatial boundary.</b> Average yield data for the relevant crop on lands in the scope 1 or scope 3 spatial boundary.</li> </ul>

The carbon opportunity cost (COC) metric has been established in peer-reviewed literature since the late 2000s and has been calculated for all major crops and livestock products and at multiple geographic scales. Table 8.7 provides a non-exhaustive list of citations that can be a source for COC factors. Different researchers have called this metric by different names, but the concept is identical across these studies. Note that COC factors can be calculated per unit of product or per unit area.

**Table 8.7** Select literature review of carbon opportunity cost

Study	Name of metric	Geographic scale and product coverage	Carbon opportunity cost factor(s) provided
Nguyen et al. (2010)	Opportunity cost of land use	EU; beef, alternative production systems	kg CO <sub>2</sub> /m <sup>2</sup> ; kg CO <sub>2</sub> e/kg product
West et al. (2010)	Carbon–crop tradeoff index (tonnes of carbon lost per tonne of crop)	Global (tropics, subtropics, temperate, boreal, polar); crops	tC/ha; tC/t product
Schmidinger and Stehfest (2012)	Land use change related to additional production; “missed potential carbon sink” of land occupation	Brazil and several EU countries; livestock products	kg CO <sub>2</sub> e/kg product

**Table 8.7** Select literature review of carbon opportunity cost (cont.)

Study	Name of metric	Geographic scale and product coverage	Carbon opportunity cost factor(s) provided
Searchinger et al. (2018)	Carbon opportunity cost	Global; 70+ crops, livestock products, bioenergy feedstocks	tC/ha; kg CO <sub>2</sub> e/kg product
Yang and Tan (2021)	Land carbon loss	Global, 15 regions and countries; 14 crops, livestock products, and wood products	tC/ha; tC/t product
Yang et al. (2022)	Carbon opportunity cost	30 provinces in China; crops, livestock products	tC/t product
Yang et al. (2024)	Land carbon loss	31 provinces in China; 26 different crops and livestock products	tC/ha; tC/t product
Waite et al. (2026)	Carbon opportunity cost	Global, 9 regions and 5 countries; nearly 90 agricultural products	tC/ha; kg CO <sub>2</sub> e/kg product

Note: The list of citations provided in this table is not exhaustive.

### 8.5.2.2 Data for land carbon leakage calculation approaches

To calculate land carbon leakage, companies select an average COC factor corresponding to lands in the land carbon leakage boundary and multiply the quantity of food or feed that is reduced or diverted by the high-leakage-risk activity in the company’s operations or value chain by that COC factor. An overview of the data needed to calculate land carbon leakage is provided in Table 8.8.

**Table 8.8** Data to calculate land carbon leakage

Data	Description
Quantity of reduced or diverted food or feed	<p>The quantity of reduced or diverted food or feed production due to the high-leakage-risk activities in a company’s operations or value chain, specified in Requirement 13.</p> <ol style="list-style-type: none"> <li>For the use of food or feed or other agricultural products for non-food, non-feed use, this quantity is equivalent to the total mass or volume of crops purchased for such uses. For example, the total mass of soybeans that is used to produce the volume of soybean-based renewable diesel purchased by the reporting company in the reporting year.</li> <li>For reductions in food production from changes in land management or land use to which removals are attributed, this quantity is calculated as the total quantity (in mass or volume) of food production (or production estimated using average yields) prior to the change in land management or use minus total production in the reporting year. For example, the total quantity of wheat that was produced on the given land area prior to the change in land use or management, minus wheat production in the reporting year. If records are available, use of a three-year (or greater) average of production volumes prior to the change in land use or management should be used for the most representative comparison.</li> <li>For reductions in food production from long-term change in cropland management practices, this quantity is equivalent to the decrease in the volume of crop production relative to production (or production estimated using average yields) under the previous land management. For example, the total quantity of maize that was produced on the given land area prior to the change in land management (e.g., under conventional practices) minus maize production in the reporting year (e.g., under lower-input production practices). If records are available, use of a three-year (or greater) average of production volumes prior to the change in land management should be used for the most representative comparison.</li> </ol>

**Table 8.8** Data to calculate land carbon leakage (cont.)

Data	Description
<p><b>Carbon opportunity cost (COC) factor</b></p>	<p>A COC factor represents the average total quantity of carbon lost from vegetation and soils on lands in the land carbon leakage boundary where food or feed production is displaced to, relative to native carbon stocks on such lands. COC factors can be expressed as tonnes of CO<sub>2</sub>e per unit area or per unit product (see Equations 8.3 and 8.4). COC factors can be drawn from the peer-reviewed literature (see Table 8.7). Accounting tools are under development to support land carbon leakage calculations.</p> <p>To calculate a COC factor, the following data are needed:</p> <ul style="list-style-type: none"> <li>• <b>Average native carbon stocks on lands within the land carbon leakage boundary.</b> Average native carbon stock data represent the average native, potential carbon stock, including all land-based carbon pools, on productive lands within the land carbon leakage boundary. Native, potential carbon stocks are the best estimate of the total carbon stocks on land that would have existed in the absence of the productive land use. Native, potential carbon stock values can be drawn from dynamic global vegetation models (e.g., models included in the Inter-Sectoral Impact Model Intercomparison Project), biome-level average reference values (e.g., Tier 1 estimates given in IPCC national inventory guidance), or the peer-reviewed literature.<sup>28</sup></li> <li>• <b>Average productive carbon stock data within the land carbon leakage boundary.</b> Average productive carbon stock data represent the average carbon stock, including all land-based carbon pools, on productive lands in the land carbon leakage boundary. Productive carbon stocks are the total carbon stocks on lands under a productive land use within the land carbon leakage boundary (e.g., total carbon stocks on land that produces wheat). Average carbon stock values on productive lands (i.e., average carbon stock factors on lands that produce the displaced product in the scope or scope 3 spatial boundary) can be drawn from IPCC national inventory guidance,<sup>29</sup> carbon stock data from national GHG inventories, or the peer-reviewed literature. Average carbon stock factors used to account for land management net biogenic CO<sub>2</sub> emissions (see Chapter 9) can also be used.</li> <li>• <b>Average yield data within the land carbon leakage boundary.</b> Average yield data for the relevant crop (i.e., the food or feed crop displaced by the high-leakage-risk activity) on lands in the land carbon leakage boundary.</li> </ul>

### 8.5.3 Calculating land occupation

The following sections provide guidance for calculating land occupation (Section 8.5.3.1) and, optionally, the carbon opportunity cost of land use (Section 8.5.3.2).

#### 8.5.3.1 Calculating land occupation

##### CALCULATING SCOPE 1 LAND OCCUPATION

In general, when calculating scope 1 land occupation, the reporting company will know the specific land area(s) used to produce agricultural products on lands the reporting company owns or controls. To calculate scope 1 land occupation, the reporting company may therefore use various data sources, including property title or survey information, shapefiles, satellite or remotely sensed information, direct measurement, or a combination thereof.

Scope 1 land occupation includes:

- Agricultural land used to produce agricultural products on land the reporting company owns or controls, including both cropland and pastureland
- Cropland includes land temporarily fallowed in a crop rotation system

Scope 1 land occupation excludes:

- Land area that is not involved in agricultural production
- Permanently fallowed land
- Non-productive lands

## Calculating scope 3 land occupation

In general, scope 3 land occupation for agricultural crop products is calculated using product yields to convert from the quantity of a sourced product to hectares. The calculation approach for scope 3 land occupation depends on the level of traceability a company has for a sourced product, and the corresponding scope 3 spatial boundary that is set (see Figure 8.6). Companies use the “statistical” land occupation calculation approach when traceability is limited to a jurisdiction or sourcing region of origin. Companies use the “direct” land occupation calculation approach when traceability is established to the LMU- or harvested area-level.

### CALCULATING “STATISTICAL” SCOPE 3 LAND OCCUPATION

When companies have traceability only to a jurisdiction or sourcing region level (or have no traceability, i.e., setting a global scope 3 spatial boundary) in their value chain, companies apply the “statistical” land occupation calculation approach. This calculation approach applies secondary (i.e., average) yield data that correspond to average production on attributable productive lands in the scope 3 spatial boundary (e.g., jurisdiction or sourcing region).

An overview of the steps for calculating scope 3 land occupation using the “statistical” land occupation calculation approach is shown in Table 8.9.

**Table 8.9 Overview of steps of the statistical land occupation calculation approach**

Step	Reference
<b>Step 1:</b> Determine the average yield for the sourced product within the sourcing jurisdiction or region	
<b>Step 2:</b> Adjust statistical yield where multi-cropping or intercropping are prevalent (if applicable)	<b>Box 8.1</b>
<b>Step 3:</b> Calculate the statistical land occupation of the sourced product	<b>Equation 8.1</b>
<b>Step 5:</b> Calculate the total scope 3 statistical land occupation	

### STEP 1: DETERMINE THE AVERAGE YIELD FOR THE SOURCED PRODUCT WITHIN THE SOURCING JURISDICTION OR REGION

Companies first select an average yield (e.g., kg per ha) that corresponds to average production on attributable productive lands in the scope 3 spatial boundary (e.g., jurisdiction or sourcing region). It is recommended that companies use at least a three-year simple moving average yield, when data are available, to account for annual yield fluctuations due to non-anthropogenic factors and to better capture the long-run yield trend. Ideally, a company should use the most recent three years of yield data, inclusive of the reporting year. However, publication of official yield statistics for the current (i.e., reporting) year is often delayed by up to a few years, which may limit the ability to use the most recent, consecutive three-year period. In this case, it is recommended that companies use the most recent three-year period of available yield data. Companies should disclose the years included in the simple moving average.

National yield data are available in many databases, including FAOSTAT and databases maintained by the Departments of Agriculture of some major exporting countries. However, reliable subnational crop yields should be applied where available and where companies have traceability to a subnational jurisdiction.



## STEP 2: ADJUST STATISTICAL YIELD WHERE MULTI-CROPPING OR INTERCROPPING ARE PREVALENT (IF APPLICABLE)

If a company has traceability only to a jurisdiction or sourcing region of origin, the specific cropping system in the life cycle of the sourced product is unknown, and therefore, allocation methods cannot be used to directly allocate land occupation across outputs of the specific cropping system. However, attributable productive lands in the scope 3 spatial boundary may be characterized by a common, dominant multi-output cropping system for the crop sourced by the reporting company. In this case, it may be appropriate to adjust the scope 3 land occupation calculation to reflect the land use efficiency of that dominant multi-output cropping system (Box 8.1).

### Box 8.1 Adjusting statistical land occupation for multi-output cropping systems

Production of a crop sourced by a company in the reporting year may be traceable to a jurisdiction or sourcing region that is characterized by a common double- or multi-cropping production system. For example, the *safrinha* system (a second crop of maize typically following soy) accounts for approximately 75 percent of total maize production in Brazil, concentrated in a few particular states.<sup>30</sup> Alternatively, the sourcing jurisdiction may be characterized by multiple harvests of the same crop on the same land area in the same year.

If, for example, Company A sources all the maize from producers in a sourcing region characterized by the *safrinha* system, and Company B sources all the soy from those same producers in that sourcing region, the total combined scope 3 land occupation attributed to these purchases could exceed the physical productive land area that produced these crop products in the sourcing region in the reporting year.

When a company sources a product from a jurisdiction that is characterized by a common, widespread multi- or intercropping system, a “correction” factor may be appropriate to adjust the scope 3 land occupation calculation to reflect the land use efficiency of that widespread cropping system. For example, if each crop were produced on the same hectare over a six-month period, then the land occupation for each would be adjusted downward by half.

LCA databases and other resources may provide land occupation factors and/or yield factors that have already been adjusted (e.g., through allocation or other methods) to reflect the land use efficiency of dominant cropping systems for a given crop in a given sourcing region. When selecting statistical yield data or land occupation factors, companies should be aware of whether statistical data have, or have not, already been adjusted for multi-cropping or multiple harvests.

**STEP 3: CALCULATE THE STATISTICAL LAND OCCUPATION OF THE SOURCED PRODUCT**

Once an appropriate yield factor has been selected for a given product, the next step is to calculate the product’s statistical land occupation, using Equation 8.1. Note that, when calculating the scope 3 land occupation of animal products (e.g., meat carcasses and cuts, dairy products, tallows, hides, etc.), total land occupation must include both the land occupation to raise and graze livestock (i.e., in pens, barns, paddocks, pastures, or range, etc.) and the land occupation of croplands or pasturelands used for feed production that is consumed by the livestock over the animal’s life cycle (e.g., grass, hay, silage, oil crops, protein feeds, other dietary supplements, etc.). For further guidance, see “Calculating scope 3 land occupation of animal products, live animals, and feeds” below.

**Equation 8.1 Calculating product land occupation**

$$LO_{k,a} = Q_{k,a} \times \left[ \frac{1}{Y_{k,a}} \right]$$

Description	Unit	Source
$LO_{k,a}$ Product land occupation, for product $k$ sourced from assessment area $a$ , in the inventory reporting year	ha	Calculated
$Q_{k,a}$ Quantity of product $k$ sourced by the reporting company from assessment area $a$ , in the inventory reporting year	tonne	User input
$Y_{k,a}$ Average product yield (selected or calculated)* for product $k$ , in assessment area $a$	tonne (ha) <sup>-1</sup>	User input
$k$ Product produced in assessment area $a$		User input
$a$ Assessment area (i.e., all attributable productive lands in the global, jurisdiction, sourcing region, or LMU scope 3 spatial boundary)		User input

*Note:* \*Average product yields should be estimated over a 3+ year time period corresponding to a simple moving average yield using the most recent three-year period of available yield data.

**STEP 4: CALCULATE TOTAL SCOPE 3 STATISTICAL LAND OCCUPATION**

To calculate total land occupation in the scope 3 inventory, companies sum all product land occupation across all sourced goods and services. Companies can also optionally report their total land occupation disaggregated across land use types (e.g., hectares of cropland, pastureland, etc.).

**Calculating “direct” (i.e., farm-level) scope 3 land occupation**

In cases where the reporting company has complete traceability to specific LMUs that produced the agricultural products that a company sources, the company may have access to farm- and product-specific (i.e., primary) yield data or other relevant data to calculate land occupation. In this case, the reporting company should use farm- and product-specific yields and/or other data to calculate scope 3 land occupation.

In the case where a company has complete traceability to the LMU(s) of origin, but does not have access to LMU-level yield data, the reporting company can also utilize spatial data (e.g., shapefiles) or other LMU-level data to manually estimate LMU-level land occupation and/or yields to calculate scope 3 land occupation (e.g., by dividing total farm production by total production area).

An overview of the steps for calculating scope 3 land occupation using the “direct” land occupation calculation approach is shown in Table 8.10.

**Table 8.10 Overview of steps of the direct land occupation calculation approach**

Step	Reference
<b>Step 1 (if applicable):</b> Determine the productive area within LMU polygons and farm-level production	
<b>Step 2:</b> Gather LMU-level yield data	
<b>Step 3:</b> Calculate the direct land occupation of the sourced product	<b>Equation 8.1</b>
<b>Step 5:</b> Calculate the total scope 3 land occupation	

**STEP 1: DETERMINE THE PRODUCTIVE AREA WITHIN LMU POLYGONS AND FARM-LEVEL PRODUCTION (IF APPLICABLE)**

When companies set an LMU-level scope 3 spatial boundary, ideally, the reporting company will have access to LMU yield data for the sourced product. However, in cases where yield data are not available, companies may be able to estimate LMU-level yield indirectly, using other types of data. For example, companies that have shapefiles of the LMUs in their value chain may be able to estimate yields by dividing total productive area by total production. Note that the total LMU productive area may need to be allocated across the multiple outputs of a cropping system implemented on the LMU. Cropland includes land temporarily fallowed in a crop rotation system.

**STEP 2: GATHER LMU-LEVEL YIELD DATA**

When companies set an LMU-level scope 3 spatial boundary, the reporting company will ideally have access to LMU yield data for the sourced product. Companies should work with suppliers to gather necessary data to calculate scope 3 land occupation. Yield data can be sensitive, however. If LMU-level yields are not available, companies may be able to estimate yields indirectly, following Step 1.

**STEP 3: CALCULATE THE DIRECT LAND OCCUPATION OF THE SOURCED PRODUCT**

Once an appropriate yield factor has been selected for a given product, the next step is to calculate the product’s direct land occupation, using Equation 8.1.

**STEP 4: CALCULATE TOTAL SCOPE 3 DIRECT LAND OCCUPATION**

To calculate total land occupation in the scope 3 inventory, companies sum all product land occupation across all sourced goods and services. Companies can also optionally report their total land occupation disaggregated across land use types (e.g., hectares of cropland, pastureland, etc.).



## Calculating the scope 3 land occupation of animal products, live animals, and feeds

When calculating the scope 3 land occupation of animal products (e.g., meat carcasses and cuts, dairy products, tallows, hides, etc.), total land occupation must include both the land occupation to raise and graze livestock (e.g., in pens, barns, paddocks, pastures, or range, etc.) and the land occupation of croplands or pasturelands used for feed production that is consumed by the livestock over the animal's life cycle (e.g., grass, hay, silage, oil crops, protein feeds, other dietary supplements, etc.). For this reason, calculating land occupation of live animals and animal products is more complex than for agricultural crops, and assumptions (e.g., about feed baskets and feed conversion efficiencies) can greatly influence calculations.

The land occupation requirements of animal production systems differ greatly by production system and across sourcing areas. When calculating the scope 3 land occupation of animal products or live animals, companies should use the best available data and make reasonable assumptions that reflect available supply-chain information regarding sourcing regions, production systems, feed baskets, and so on. In many cases, a company that procures animal products will have limited traceability to where that livestock was raised or limited knowledge of the livestock production system, including the feed requirements in the life cycle of the animal. Livestock production systems (e.g., pasture versus feedlot systems), feed use efficiencies, and feed baskets (e.g., grass-fed versus supplemented compound feed) differ widely around the world and entail very different land occupation requirements.

When calculating the land occupation of animal feeds, companies follow the same calculation guidance for calculating land occupation as for all other non-feed crop products (see Equation 8.1). Companies that raise

livestock or work directly with livestock producers are likely to have more complete information about the annual total feed intake and composition of feed baskets, whether grown on-farm or purchased, including grazed intake. Still, specific details about where purchased feed products (including co-products and by-products) were produced, and relevant yields of those feed products, may not be known. The country that exports a feed crop or product may not be the same country where the raw feed crop or product was grown or produced. Companies should use the best available data and make conservative assumptions.

When estimating the land occupation of compound feeds, companies should either try to back-calculate the amounts of raw products for the purpose of estimating total product land occupation (e.g., using the product formulation or recipe) or use reasonable yield assumptions to simplify the exercise without unduly sacrificing accuracy (e.g., categorizing each mixed product according to its primary ingredient or its top three ingredients).

LCA databases exist that include land occupation factors for animal products, and these databases can be used to calculate scope 3 land occupation, provided that they fully account for the land areas used to raise livestock as well as for feed requirements.

### 8.5.3.2 Calculating the carbon opportunity cost of land use, in units of CO<sub>2</sub>e

To quantify the cost of a company’s agricultural land use in carbon terms, companies are recommended to also account for the scope 1 and scope 3 carbon opportunity cost of land use in a company’s operations and value chain by multiplying scope 1 or scope 3 land occupation by a carbon opportunity cost (COC) factor. The carbon opportunity cost of land use is calculated using Equation 8.2.

**Equation 8.2** Calculating the carbon opportunity cost of land use, in units of CO<sub>2</sub>e

$$LU\_COC_{k,a} = LO_{k,a} \times COC_{k,a}$$

Description	Unit	Source
<i>LU_COC<sub>k,a</sub></i> Carbon opportunity cost (COC) of land use, for product <i>k</i> , on lands within the assessment area <i>a</i> in the inventory reporting year	tonne CO <sub>2</sub> e	Calculated
<i>LO<sub>k,a</sub></i> Product land occupation, for product <i>k</i> sourced by the reporting company from assessment area <i>a</i> , in the reporting year	ha	Equation 8.1
<i>COC<sub>k,a</sub></i> COC factor, for product <i>k</i> , calculated within assessment boundary <i>a</i>	tonne CO <sub>2</sub> e (ha) <sup>-1</sup>	Equation 8.3
<i>k</i> Product produced in assessment area <i>a</i>		User input
<i>a</i> Assessment area (i.e., all attributable productive lands in the global, jurisdiction, sourcing region, or LMU scope 3 spatial boundary)		User input

If a company has already calculated scope 1 or scope 3 land occupation using the calculation guidance in Section 8.5.3.1, land occupation values in hectares can be multiplied by COC factors expressed per hectare (i.e., kg CO<sub>2</sub>e per ha; see Equation 8.3). If a company starts its scope 3 analysis with activity data on agricultural products relevant to its value chain (e.g., tonnes of produced or purchased agricultural products), the carbon opportunity cost of land use can be calculated by multiplying those product volumes by COC factors expressed per quantity of

product (i.e., kg CO<sub>2</sub>e per kg product; see Equation 8.4). The COC factor that is selected corresponds to the level of traceability a company has for the product it sources and the lands in the corresponding scope 1 or scope 3 spatial boundary (see Requirement 5; for further guidance, see Section 8.4.2).

To calculate a carbon opportunity cost factor, data are needed on average native and productive carbon stocks for lands within the relevant assessment area (see Table 8.6).

Because land carbon losses occur quickly, but production of food, feed, or other land-based products can continue for many years, the difference between average native and productive carbon stocks is often annualized. Companies may use an annualization period (i.e., using Equations 8.3 and 8.4) to annualize the carbon opportunity cost (e.g., in the 20–35-year range, as is prevalent in the peer-reviewed literature).<sup>31</sup> Companies may instead annualize using a discount rate (e.g., 4 percent).<sup>32</sup> Although annualization is recommended for annual inventory reporting, companies may choose to report the full (non-annualized) carbon opportunity cost (i.e., using Equations 8.3 and 8.4 but with an annualization period of one year).<sup>33</sup> In all cases, when reporting the carbon opportunity cost of land use, companies should disclose and justify the annualization approach used (if any).

When calculating the scope 1 carbon opportunity cost of land use (or when a company has complete traceability to the LMU level), LMU-level COC factors can be applied to calculate the carbon opportunity cost of land use, if LMU-level data are available (see Table 8.6). If the LMU a company sources from underwent a land use change prior to the land use change assessment period (e.g., more than 20 years prior to the reporting year), a company may be able to use historical remote sensing or other survey data to estimate potential native carbon stocks on that specific LMU. However, even if historical land use/land cover data are available, LMU-level COC factors may still be highly uncertain, and companies may apply a sourcing region- or jurisdiction-level average COC factor as a proxy for LMU-level COC factors.

**Equation 8.3** Calculating the per-hectare carbon opportunity cost factor

$$COC_{k,a} = \frac{(C_{nat_{k,a}} - C_{prod_{k,a}}) \times \frac{44}{12}}{AnP}$$

Description	Unit	Source	
<i>COC<sub>k,a</sub></i>	Carbon opportunity cost factor, for product <i>k</i> , calculated for assessment area <i>a</i>	tonne CO <sub>2</sub> e (ha) <sup>-1</sup>	Calculated
<i>C<sub>nat<sub>k,a</sub></sub></i>	Average native carbon stock in land-based carbon pools on lands that produce crop <i>k</i> , in assessment area <i>a</i>	tonnes C (ha) <sup>-1</sup>	User input
<i>C<sub>prod<sub>k,a</sub></sub></i>	Average productive carbon stock in land-based carbon pools on lands that produce crop <i>k</i> in assessment area <i>a</i>	tonnes C (ha) <sup>-1</sup>	User input
<i>AnP</i>	Annualization period	year	User input
<i>44/12</i>	Conversion factor: C to CO <sub>2</sub>		Constant
<i>k</i>	Product produced in assessment area <i>a</i>		User input
<i>a</i>	Assessment area (i.e., all attributable productive lands in the global, jurisdiction, sourcing region, or LMU scope 3 spatial boundary)		Sections 8.4.2

**Equation 8.4 Calculating the per-product carbon opportunity cost factor**

*COC of land use calculations:*

$$COC_{k,a} = \frac{(C_{nat_{k,a}} - C_{prod_{k,a}}) \times \frac{44}{12}}{Y_{k,a} \times AnP}$$

*Land carbon leakage calculations:*

$$COC_{kDIV,lcl} = \frac{(C_{nat_{kDIV,lcl}} - C_{prod_{kDIV,lcl}}) \times \frac{44}{12}}{Y_{kDIV,lcl} \times AnP}$$

Description	Unit	Source	
$COC_{k,a}$	Carbon opportunity cost factor, for product $k$ , calculated for assessment area $a$	tonne CO <sub>2</sub> e (tonne product) <sup>-1</sup>	Calculated
$COC_{kDIV,lcl}$	Carbon opportunity cost factor, for the diverted or reduced product $kDIV$ , calculated for the land carbon leakage boundary $lcl$	tonne CO <sub>2</sub> e (tonne product) <sup>-1</sup>	Calculated
$C_{nat_{k,a}}$	Average native carbon stock in land-based carbon pools on lands that produce crop $k$ , in assessment area $a$	tonnes C (ha) <sup>-1</sup>	User input
$C_{nat_{kDIV,lcl}}$	Average native carbon stock in land-based carbon pools on lands that produce the diverted or reduced product $kDIV$ , in the land carbon leakage boundary $lcl$	tonnes C (ha) <sup>-1</sup>	User input
$C_{prod_{k,a}}$	Average productive carbon stock in land-based carbon pools on lands that produce crop $k$ in assessment area $a$	tonnes C (ha) <sup>-1</sup>	User input
$C_{prod_{kDIV,lcl}}$	Average productive carbon stock in land-based carbon pools on lands that produce the diverted or reduced product $kDIV$ in the land carbon leakage boundary $lcl$	tonnes C (ha) <sup>-1</sup>	User input
$Y_{k,a}$	Average annual yield* of product $k$ in assessment area $a$	tonnes (ha) <sup>-1</sup>	User input
$Y_{kDIV,lcl}$	Average annual yield* of the diverted or reduced product $kDIV$ in land carbon leakage boundary $lcl$	tonnes (ha) <sup>-1</sup>	User input
$AnP$	Annualization period	year	User input
$44/12$	Conversion factor: C to CO <sub>2</sub>		Constant
$k$	Product produced in assessment area $a$		User input
$kDIV$	Diverted or reduced product		User input
$a$	Assessment area (i.e., all attributable productive lands in the global, jurisdiction, sourcing region, or LMU scope 3 spatial boundary)		Section 8.4.2
$lcl$	Land carbon leakage boundary associated with the diverted or reduced product $kDIV$		Section 8.4.3

*Note:* \*Average product yields should be estimated over a 3+ year time period corresponding to a simple moving average yield using the most recent three-year period of available yield data.

### **Case study: The Coolfood Pledge—Accounting for and reporting scope 3 agricultural land occupation and the carbon opportunity cost of land use**

The World Resources Institute's Coolfood<sup>a</sup> initiative helps food service organizations commit to and achieve a science-based target to reduce the climate impact of the food they serve. Coolfood calculates and tracks changes to scope 3 food- and agriculture-related emissions, as well as scope 3 agricultural land occupation (in hectares) and scope 3 carbon opportunity cost of agricultural land use (in CO<sub>2</sub>e).

Food service providers that sign the Coolfood Pledge commit to reducing their collective scope 3 agricultural value chain emissions (land management production emissions plus other fossil emissions from value chains), plus the carbon opportunity cost of their agricultural land use, by 25 percent between 2015 and 2030. The Pledge also has an accompanying intensity target of reducing scope 3 agricultural value chain emissions, plus scope 3 carbon opportunity cost of land use, by 38 percent per kcal between 2015 and 2030. As of 2024, more than 70 organizations had committed to the Coolfood Pledge, including contract caterers, restaurants, healthcare organizations, universities, and city governments.<sup>b</sup>

The Coolfood Pledge accounts for and reports collective progress on an annual basis using an open-source Excel-based calculator<sup>c</sup> that includes regional-level agricultural value chain emission factors and land occupation factors from Poore and Nemecek (2018), along with global-level carbon opportunity cost of land use factors from Searchinger et al. (2018). Each year, Coolfood Pledge members report the previous year's organization-wide food purchases by food type and weight, and the Pledge team calculates the group's scope 3 GHG emissions, agricultural land occupation, and carbon opportunity cost of land use associated with those annual food purchases. Coolfood has operated since 2019 and has reported on the group's progress every year since 2020.

Through this initiative, companies have access to their individual annual results and can use them for their own inventory accounting and reporting. Companies can meet Requirement 16 and Requirement 12 by using these data to account for and report their scope 3 land management production emissions and land occupation. Companies can also estimate their scope 3 carbon opportunity cost of land use to fulfill the recommendation on detailed reporting for land use.

Over time, the Coolfood Pledge group has increased the share of plant-based foods on the average plate served, while decreasing the share of animal-based foods, especially beef and lamb. This has led to reductions in scope 3 emissions, land occupation, and carbon opportunity cost of land use on both an absolute and intensity basis. Members serving an estimated 2.3 billion meals have reduced their collective agricultural land occupation by 14 percent since the base year,<sup>d</sup> to about 800,000 hectares in 2023. This reduction in land occupation has led to a reduction in the carbon opportunity cost of land use of 17 percent, reducing the annual carbon opportunity cost of their agricultural land use to 13.4 million tonnes of CO<sub>2</sub>e in 2023. This has occurred alongside a 13 percent reduction in the group's scope 3 agricultural value chain emissions to 3.8 million tonnes of CO<sub>2</sub>e in 2023.

*Notes:* a. See the initiative at [Coolfood](#); b. Cho and Santo 2024; c. Waite et al. 2019; d. The base year for the Coolfood GHG reduction target is 2015, but food purchase data from as far back as 2015 are unavailable for most members. The Coolfood Pledge team, therefore, accepts baseline data for any year between 2015 and 2022 for the purposes of establishing a group baseline, as detailed in Waite et al. (2019).

## 8.5.4 Calculating land carbon leakage

Sections 8.5.4.1 and 8.5.4.2 provide guidance for calculating land carbon leakage using the carbon opportunity cost calculation approach (required) and other leakage quantification approaches (optional), respectively.

### 8.5.4.1 Calculating land carbon leakage using the carbon opportunity cost calculation approach

In general, land carbon leakage is calculated by multiplying the quantity of reduced or diverted agricultural products by a carbon opportunity cost factor.

An overview of the steps for calculating land carbon leakage, whether scope 1 or scope 3, using the carbon opportunity cost calculation approach, is shown in Table 8.11.

**Table 8.11 Overview of steps to calculate land carbon leakage**

Step	Reference
<b>Step 1:</b> Determine if Requirement 13 is triggered	<b>Requirement 13, Section 8.4.3</b>
<b>Step 2:</b> Calculate the quantity of diverted or reduced food or feed production due to activities in a company's operations or value chain	
<b>Step 3:</b> Select or calculate a carbon opportunity cost factor	<b>Equation 8.4, Section 8.4.3</b>
<b>Step 4:</b> Calculate land carbon leakage (scope 1 or 3)	<b>Equation 8.5</b>

#### STEP 1: DETERMINE IF REQUIREMENT 13 IS TRIGGERED

Requirement 13 is a conditional requirement that is triggered when activities that are at high risk of inducing land carbon leakage occur in a company's operations or value chain. The reporting company should review Requirement 13 and the guidance in Section 8.4.3 to determine if land carbon leakage accounting is required.

#### STEP 2: CALCULATE THE QUANTITY OF DIVERTED OR REDUCED FOOD OR FEED PRODUCTION DUE TO ACTIVITIES IN A COMPANY'S OPERATIONS OR VALUE CHAIN.

If Requirement 13 is triggered (see section 8.4.3 for guidance on "Conditions that trigger the required quantification and reporting of land carbon leakage"), the first step is to quantify the amount of reduced or diverted food or feed product due to the high-leakage-risk activity in the reporting company's operations or value chain (see examples below and in Table 8.8).

**Case 1: Use of food or other agricultural products for non-food, non-feed use.** The total quantity of diverted food or feed is calculated as the total amount of an agricultural food or feed product that is used for non-food, non-feed purposes. For example, if the reporting company sources 100 tonnes of maize-based ethanol in the reporting year, the total diverted food or feed is calculated as the total quantity of raw maize feedstock to produce 100 tonnes of maize ethanol (e.g., using a yield of 0.4 tonnes of maize ethanol per ton of maize, the total diverted food or feed equates to  $100 / 0.4 = 250$  tonnes of raw maize).

**Case 2: Reduction in food production resulting from a change in land management or land use for which land management removals are attributed.** The total quantity of reduced food or feed production is calculated as the total amount that used to be produced annually before the change in land management or use minus the total amount in the reporting year, calculated across the relevant LMU. For example, if the reporting company used to produce 10 tonnes of beef on 100 hectares that are now under reforestation and produced 0 tonnes of beef in the reporting year, the total reduced food is 10 tonnes of beef.

**Case 3: Reduction in crop yields per hectare resulting from a change in cropland management practice.** The total quantity of reduced food or feed product is calculated as the total amount that used to be produced annually before the change in management practice, minus the total amount in the reporting year. For example, if the reporting company used to produce 100 tonnes of wheat on 12 hectares, and after the change in practice produced 80 tonnes of wheat in the reporting year, the total reduction in food is 20 tonnes of wheat.

### STEP 3: SELECT OR CALCULATE A CARBON OPPORTUNITY COST FACTOR

The COC calculation approach assumes that diverted or reduced food or feed production is fully replaced within the land carbon leakage boundary, at average yields and average land carbon costs, represented by a corresponding average COC factor. Selecting or calculating the COC factor depends on the level of traceability a company has to the sourcing area and the characteristics of the market for the relevant diverted or reduced food or feed product (see Section 8.4.3 for further guidance). Equation 8.4 defines how to calculate the COC factor per unit of product.



Companies should disclose and justify the land carbon leakage boundary (e.g., global, regional, or national), and the corresponding COC factor, that are used to calculate land carbon leakage, whether scope 1 or scope 3.

**STEP 4: CALCULATE LAND CARBON LEAKAGE**

Once the COC factor has been selected or calculated, Equation 8.5 is used to calculate land carbon leakage. Table 8.12 contains examples of land carbon leakage calculation for the three cases in Step 2 above. Box 8.2 contains an example of a company taking actions to mitigate land carbon leakage.

**Equation 8.5 Calculating land carbon leakage (scope 1 or scope 3)**

$$LCL_{kDIV} = Q\_DIV_{kDIV} \times COC_{kDIV,lcl}$$

Description	Unit	Source
<i>LCL<sub>kDIV</sub></i> Land carbon leakage attributable to activity that reduces or diverts food or feed product <i>kDIV</i> in the reporting year	tonne CO <sub>2</sub> e	Calculated
<i>Q\_DIV<sub>kDIV</sub></i> Quantity of reduced or diverted food or feed product <i>kDIV</i> in the reporting year	tonnes	User input
<i>COC<sub>kDIV,lcl</sub></i> Carbon opportunity cost factor for the diverted or reduced product <i>kDIV</i> , calculated for land carbon leakage boundary <i>lcl</i>	tonne CO <sub>2</sub> e (tonne product) <sup>-1</sup>	Equation 8.4
<i>kDIV</i> Diverted or reduced product		User input
<i>lcl</i> Land carbon leakage boundary associated with the diverted or reduced product <i>kDIV</i>		Section 8.4.3

**Table 8.12 Example of land carbon leakage calculation for three cases of diverted or reduced food or feed production**

	(a)	(b)	(c)	(d)	(e)
Case example	Commodity (reduced or diverted)	Land carbon leakage boundary	Amount of diverted or reduced product (t)	Carbon opportunity cost factor (t CO <sub>2</sub> e/t product)	Land carbon leakage (t CO <sub>2</sub> e) (e = c * d)
Case 1: Maize ethanol	Maize	Global	250	2.9	711
Case 2: Former beef production area under reforestation	Beef	Global	10	249.2	2,492
Case 3: Reduction in wheat yields	Wheat	Global	20	3.2	63

Note: Numbers may not total correctly due to rounding.  
 Source: Carbon opportunity cost factors from Waite et al. (2026).

**Box 8.2 Mitigating land carbon leakage in projects that generate land management CO<sub>2</sub> removals**

In Case 2 in Table 8.12, the total quantity of reduced food or feed production is calculated as the total amount that was produced before the change in land management or use minus the total amount produced in the reporting year, calculated across the relevant LMU. Land managers can mitigate land carbon leakage by increasing food or feed production beyond baseline levels in other parts of the same LMU.

For example, if the reporting company produced 10 tonnes of beef on 100 hectares that are now under reforestation and produced 0 tonnes of beef in the reporting year, the total reduced food is 10 tonnes of beef, equating to 2,492 t CO<sub>2</sub>e of land carbon leakage, as calculated in the table below.

However, if the same company only brings half of its production area (50 hectares) into reforestation, and doubles the productivity of beef on the other 50 hectares, the amount of beef produced in the full LMU remains 10 tonnes, and there is no reduction in food or feed production in the LMU, and no land carbon leakage. In this case, the company would report zero land carbon leakage.

If, instead, the company increases production of a different food or feed product to mitigate land carbon leakage, a more detailed calculation is necessary. For example, if the company brings half of its production area (50 hectares) into reforestation, and instead grows bananas instead of beef on the other 50 hectares (assuming a banana yield of 24.5 tonnes per hectare per year), 10 tonnes of beef have been displaced (reducing production and triggering land carbon leakage) but 1,225 tons of bananas have been grown instead (increasing production in the same area and mitigating leakage). The complete calculation is shown in the table below, and the company reports land carbon leakage of only 1,028 t CO<sub>2</sub>e. In this example, land carbon leakage is reduced, as the company is still using half of its land to produce food or feed, while the other half is under reforestation.

Under some circumstances, the total land carbon leakage estimate may even be negative, indicating “positive leakage” or avoided emissions. Avoided emissions cannot be reported as land carbon leakage, but such beneficial GHG impacts of corporate actions may be reported separately, as described in Chapter 16. In such cases, the amount of land carbon leakage reported is zero.

**Table B8.2-1 Example of land carbon leakage mitigation in a reforestation project (one year of reporting)**

	(a)	(b)	(c)	(d)	(e)
Element	Commodity	Land carbon leakage boundary	Amount of diverted or reduced product (tonnes)	Carbon opportunity cost factor (t CO <sub>2</sub> e/t product)	Land carbon leakage (t CO <sub>2</sub> e) (e = c * d)
Reduced food or feed production	Beef	Global	10	249.2	2,492
Increased food or feed production	Bananas	Global	(1,225)	1.2	(1,464)
<b>Total land carbon leakage</b>					<b>1,028</b>

*Note:* Increases in food or feed production and mitigation of land carbon leakage are shown as negative values in parentheses. Numbers may not total correctly due to rounding.

*Source:* Carbon opportunity cost factors from Waite et al. (2026).

### 8.5.4.2 Calculating leakage using optional calculation approaches

If regulations or GHG programs separately specify how an alternative leakage quantification approach is applied for the purpose of a regulation or program, companies should follow the methodologies specified by the regulation or program to account for leakage and separately report that leakage value, in addition to quantifying and reporting land carbon leakage using the COC calculation approach. For example, some major climate policies and programs, especially for biofuels policies, have adopted specific indirect land use change (iLUC) models that use economic assumptions to incorporate additional market feedback effects. Companies that follow this *Standard* may optionally report land carbon leakage values using iLUC models or other methods, alongside values using the required COC calculation approach.

This *Guidance* does not provide calculation guidance for calculating leakage using other optional calculation approaches.

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#### Endnotes

- 1 Ritchie and Roser 2019; Houghton and Nassikas 2017; Burney et al. 2010.
- 2 The carbon opportunity cost approach estimates leakage by assuming 1:1 replacement of displaced food via conversion of native ecosystems to agriculture, and as such, is relevant information to report. If regulations or GHG programs separately specify how the “land carbon leakage” category is applied for the purpose of their regulation or program, covered companies may report parallel leakage estimates in addition to carbon opportunity cost-based values.
- 3 IPCC 2022.
- 4 IPCC 2019b.
- 5 Falcon et al. 2022.
- 6 Potapov et al. 2022.
- 7 Hanson et al. 2022.
- 8 IPCC 2022.
- 9 FAO 2025.
- 10 Potapov et al. 2022; Goldman et al. 2020.
- 11 FAO 2025.
- 12 FAO 2025.
- 13 IPCC 2019b. In particular, see the [Summary for Policymakers](#) for this report, and the [Executive Summary of Chapter 6](#) (“Interlinkages between desertification, land degradation, food security and GHG fluxes: synergies, trade-offs and integrated response options”).
- 14 Researchers have expressed carbon opportunity cost of agricultural land use in two ways in the literature: 1. the “carbon loss” method, which attributes carbon losses from land conversion to agricultural products produced on the converted land; and 2. the “carbon gain” method, which attributes the amount of forgone carbon sequestration in a reporting year that would have occurred had the agricultural land been left to revert to native vegetation. The two approaches mirror each other (Schmidinger and Stehfest 2012). In both approaches, the total carbon opportunity cost is the difference between the native carbon stock and the productive (agricultural) carbon stock, and values are often annualized. The “carbon loss” method uses annualization to distribute the carbon losses over many years of production, and the “carbon gain” method uses annualization to estimate the forgone carbon sequestration that would occur in one year (since ecosystems would take many years to fully regenerate) or to estimate the average annual carbon gain over a multi-decade period of ecosystem regeneration.
- 15 See, e.g., Yang and Tan (2021), Nguyen et al. (2010), Schmidinger and Stehfest (2012), and Balmford et al. (2018) for examples using annualization periods. Other researchers have argued that applying a discount rate to the full (i.e., non-annualized) COC is a more appropriate annualization approach to reflect a higher value for GHG mitigation in the near term versus the future, even while agricultural production can continue indefinitely. For example, Searchinger et al. (2018) and Smith et al. (2019) applied a 4 percent discount rate to annualize COC. The 4 percent discount rate yields a similar annual COC value as an annualization period of 30–35 years. Researchers have given several different rationales for annualization periods, such as the transition period from one ecosystem state to another (e.g., Bartlett et al. 2024; Sandford et al. 2024) or the critical importance of the coming 30 years to mid-century for climate mitigation policy and action (e.g., Fehrenbach and Bürck 2022).

- 16 Pendrill et al. 2022.
- 17 Malins et al. 2020.
- 18 Hertel et al. 2010.
- 19 IPCC 2019b. In particular, see the [Summary for Policymakers](#) for this report, and the [Executive Summary of Chapter 6](#) (“Interlinkages between desertification, land degradation, food security and GHG fluxes: synergies, trade-offs and integrated response options”).
- 20 See, e.g., Woltjer et al. 2017; Malins et al. 2020; Lark et al. 2022; Chen et al. 2026; Escobar 2018; Helm et al. 2025.
- 21 IPCC 2019b, Summary for Policymakers, sec. B.3, p. 21. The IPCC also notes that “[t]he use of residues and organic waste as bioenergy feedstock can mitigate land use change pressures associated with bioenergy deployment, but residues are limited and the removal of residues that would otherwise be left on the soil could lead to soil degradation (high confidence).” Sec. B.3.3., p. 21.
- 22 Pendrill et al. 2019.
- 23 IPCC 2019b.
- 24 See, e.g., Smith et al. 2019; Balmford et al. 2025; Lobell and Villoria 2023.
- 25 See, e.g., Yang and Tan 2021, Nguyen et al. 2010, Balmford et al. 2018, and Smith et al. 2019 for examples of the annualization of carbon opportunity costs. For optional parallel leakage estimates using iLUC emissions, EU biofuel analyses use a 20-year annualization period, while US biofuel analyses use a 30-year period.
- 26 See, e.g., Ganzenmüller et al. 2025; Keith et al. 2024; Mo et al. 2022; Neumann et al. 2025.
- 27 E.g., Chapter 5 in Vol. 4 of the 2019 IPCC Refinement provides time-averaged and default maximum (at harvest) carbon stocks for perennial cropland monoculture and agroforestry systems.
- 28 See, e.g., Ganzenmüller et al. 2025; Keith et al. 2024; Mo et al. 2022; Neumann et al. 2025.
- 29 E.g., Chapter 5 in Vol. 4 of the 2019 IPCC Refinement provides time-averaged and default maximum (at harvest) carbon stocks for perennial cropland monoculture and agroforestry systems.
- 30 Colussi and Schnitkey 2021.
- 31 See, e.g., Yang and Tan 2021; Nguyen et al. 2010; Balmford et al. 2018.
- 32 See, e.g., Searchinger et al. 2018; Smith et al. 2019; Waite et al. 2026.
- 33 See, e.g., Hayek et al. 2021; Yang et al. 2022.

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