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# Quantifying agricultural and non-agricultural drivers of carbon stock change from land-use change

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## Key messages

- There is a "virtual shift" of agricultural lands from Europe, East Asia and North America to South America, Africa and Southeast Asia, and a "virtual shift" of forests in the reverse direction through reforestation and afforestation initiatives.
- The expansion of under-utilized lands (e.g. abandoned land, degraded land, low productivity land) has been the key driver of carbon stock change as a consequence of land-use change from 1995-2010.
- The carbon stock loss attributable to agricultural exports has increased drastically; from below 10% before 2000 to 17-30% since 2000.
- Territorially confined programs to mitigate carbon stock loss do not necessarily contribute positively to global carbon stock change, and may trigger different types of negative displacement and leakage effects.

## 1. Introduction

Carbon stock change as a consequence of land-use change (hereafter referred to as CSC-LUC), especially from deforestation, has been contributing to almost one third of total global anthropogenic greenhouse gas (GHG) emissions (Fearnside 2000, Baccini et al. 2013). One major driver of these land-use changes is the rapid expansion of agricultural production driven by growing domestic and international demand for, and trade in, agricultural commodities. Non-agricultural and non-productive drivers of LUC, such as logging, fire and degradation have also played an important role (Hosonuma et al. 2012), though are often not captured by LUC analyses. These drivers not only exacerbate deforestation, but also contribute to a loss of arable land, which often indirectly drives further agriculture-induced CSC-LUC in order to fill the production gap (Barona et al. 2010). These complex interactions are often challenging to capture (Wicke et al. 2012, Goh et al. 2015), especially in more globally oriented trade analyses. Furthermore, most existing studies do not clearly distinguish between the impacts caused by productive and non-productive drivers.

Under the DFID funded Large-Scale Investments in Food, Feed, and Energy project we sought to assess the relative magnitude of productive and non-productive drivers of LUC in different regions, and the role of different domestic and international end markets in driving CSC-LUC. The analysis was performed at two different geographical scales (regional and global) to highlight the effect of spatial aggregation. In the ***global approach***, all lands and forests are treated as global assets, and therefore all consumption, regardless of geographical region, will share the same liability. In the ***regional approach***, regions are treated as individual closed territories that are linked via trade.

This Infobrief will summarize key findings from this study and will show how territorially confined climate change mitigation programs and strategies fail to address underlying drivers of global carbon stock change adequately [1]. The results presented below are structured into three thematic components (1) allocation by land class to assign CSC-LUC to the expansion of different land classes; (2) allocation by trade to determine how much CSC-LUC is driven by export-oriented agricultural expansion; and (3) allocation by end uses to examine the impacts of consumption in different end markets.

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1 For more comprehensive results and detailed methodological information, see the full article: Goh et al. (2015) *Quantifying direct and indirect carbon stock change from land-use change: Connecting to consumption of agricultural products from global and regional perspectives* (in preparation). An early-view copy can be obtained from the first author.

## 2. Allocation by land classes

Based on the regional approach, as shown in Figure 1, South America, Africa and Southeast Asia are the largest sources of carbon stock loss (contributing to more than 90% of global CSC-LUC in 2010). The expansions of non-productive lands classes (in greyish colors) are on average the leading drivers of CSC-LUC. In terms of carbon stock gain, Europe has been the largest contributor over the past two decades, followed by East Asia and North America. It seems that there is a "virtual shift" of agricultural lands from these regions to South America, Africa and Southeast Asia, and a "virtual shift" of forests in the reverse direction through reforestation and afforestation initiatives.

Figure 2 shows a different picture when global and regional approaches are compared. Using the regional approach, substantial carbon stock gains and also higher carbon stock loss are detected – this is masked when an aggregated global approach is employed. The regional approach suggests that the gross carbon stock loss associated with the production of agricultural products grew by a factor of 2.6 between 1995 and 2003 and thereafter continued to exceed 1995 levels. However, by 2010, the carbon stock gain associated with reforestation and afforestation has more than doubled over 1995 levels. In both approaches, non-productive land classes account for a substantial share of carbon stock loss. The impact of non-productive lands appears to be less pronounced when applying a global approach however (33% compared to 36% of gross carbon stock loss shown by the regional approach). This suggests that in certain regions more arable land lost its productivity (e.g. by being abandoned or degraded), while in other regions more land has come under agricultural production. The global approach masks such regional variations since no significant net change to the total global agricultural land area has occurred.

When examining the types of crops contributing to CSC-LUC, the expansion of "temporary oil crops", "cereals" and "permanent meadow and pasture" is among the key agricultural drivers of CSC-LUC. The CSC-LUC caused by the expansion of "permanent meadow and pasture" appears to be more significant in the regional approach than the global approach. This suggests that after 2007, permanent meadow and pasture has been converted in some regions – for example, though reforestation - while new areas have been established in other regions (i.e. South America, as shown in Figure 3).

In contrast to popular perception, however, the global approach shows that "permanent oil crops" are a leading contributor of carbon stock gain. This could be attributed to the comparatively high carbon sequestration potential of permanent oil crops compared to other crops. Although certain individual oil palm plantations are undoubtedly directly associated with carbon stock loss through forest conversion, from a macro perspective, the cultivation of higher yield crops like oil palm could help to partly reduce the expansion rate of lesser productive and more land extensive oilseed crops such as soybean (although oil palm does not produce as much protein as soybean, they compete directly in the vegetable oil market and affect each other's supply-demand dynamics).

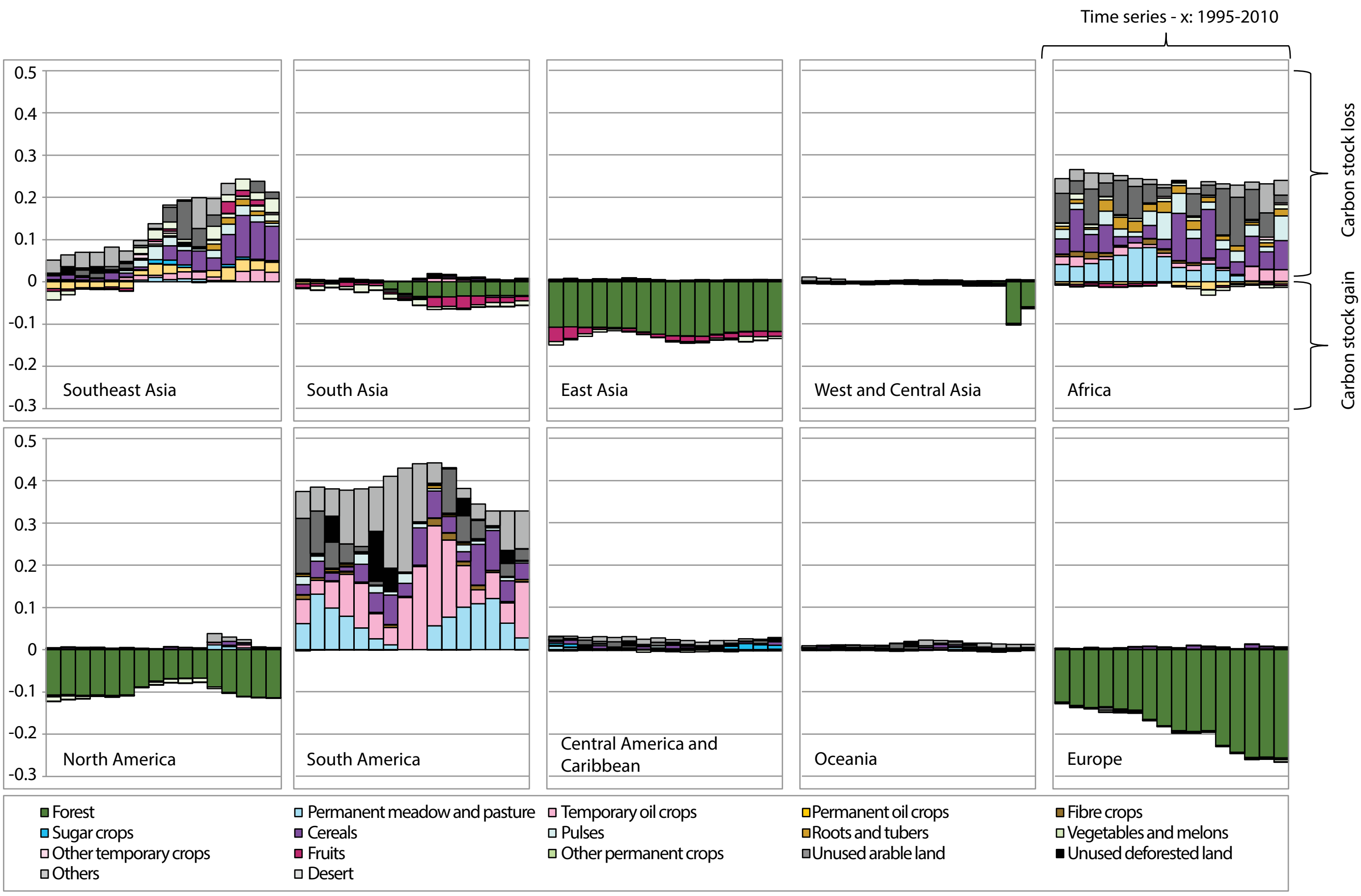


**Figure 1. Above- and below-ground CSC-LUC (y: billion tonnes C) allocated to land classes based on their expansion rates using the regional approach (x: 1995 – 2010)**

Note: "+" and "-" represent carbon stock loss and gain respectively

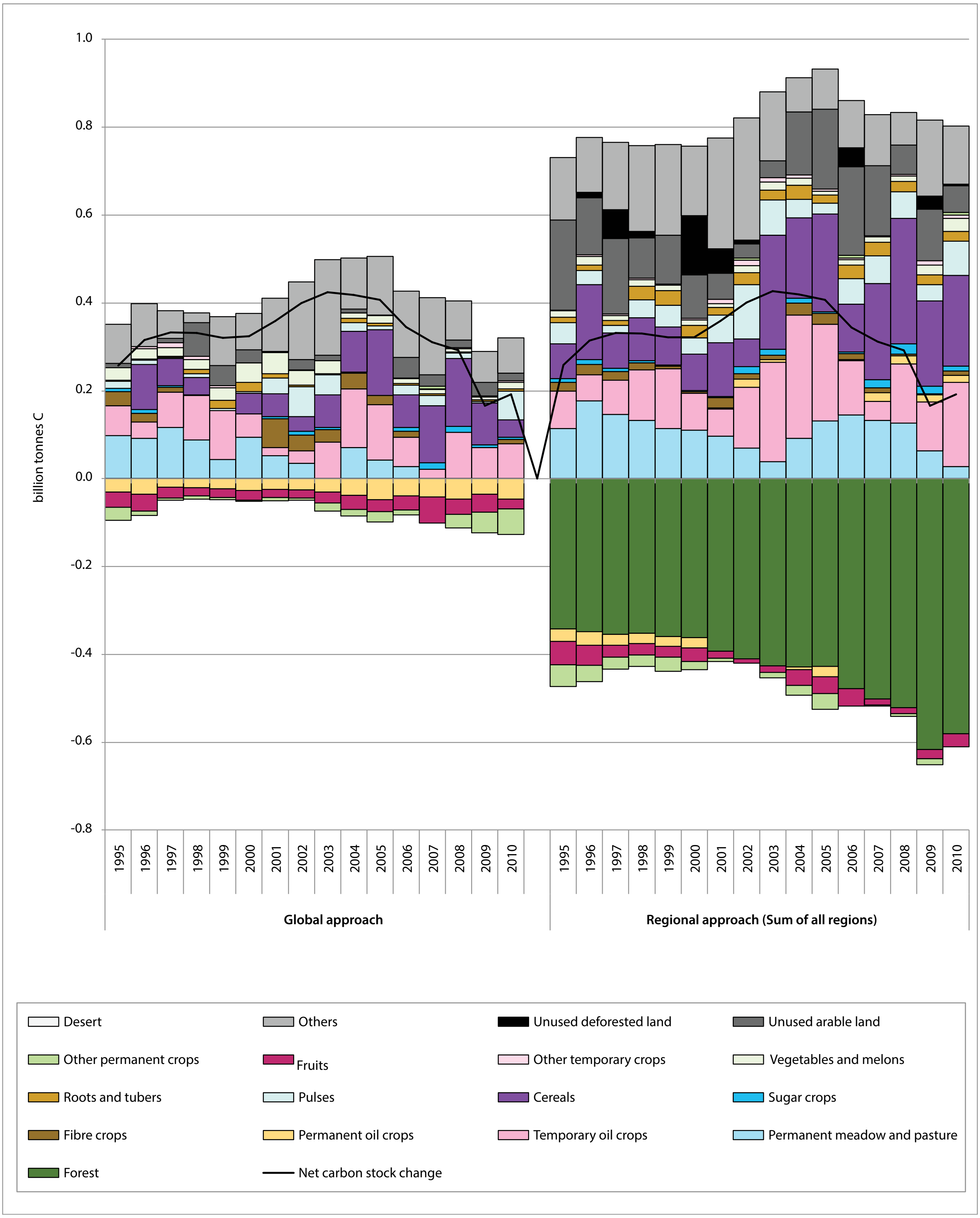


**Figure 2. Above- and below-ground CSC-LUC allocated to land classes based on their expansion rates using the global and regional approaches**

Note: "+" and "-" represent carbon stock loss and gain respectively

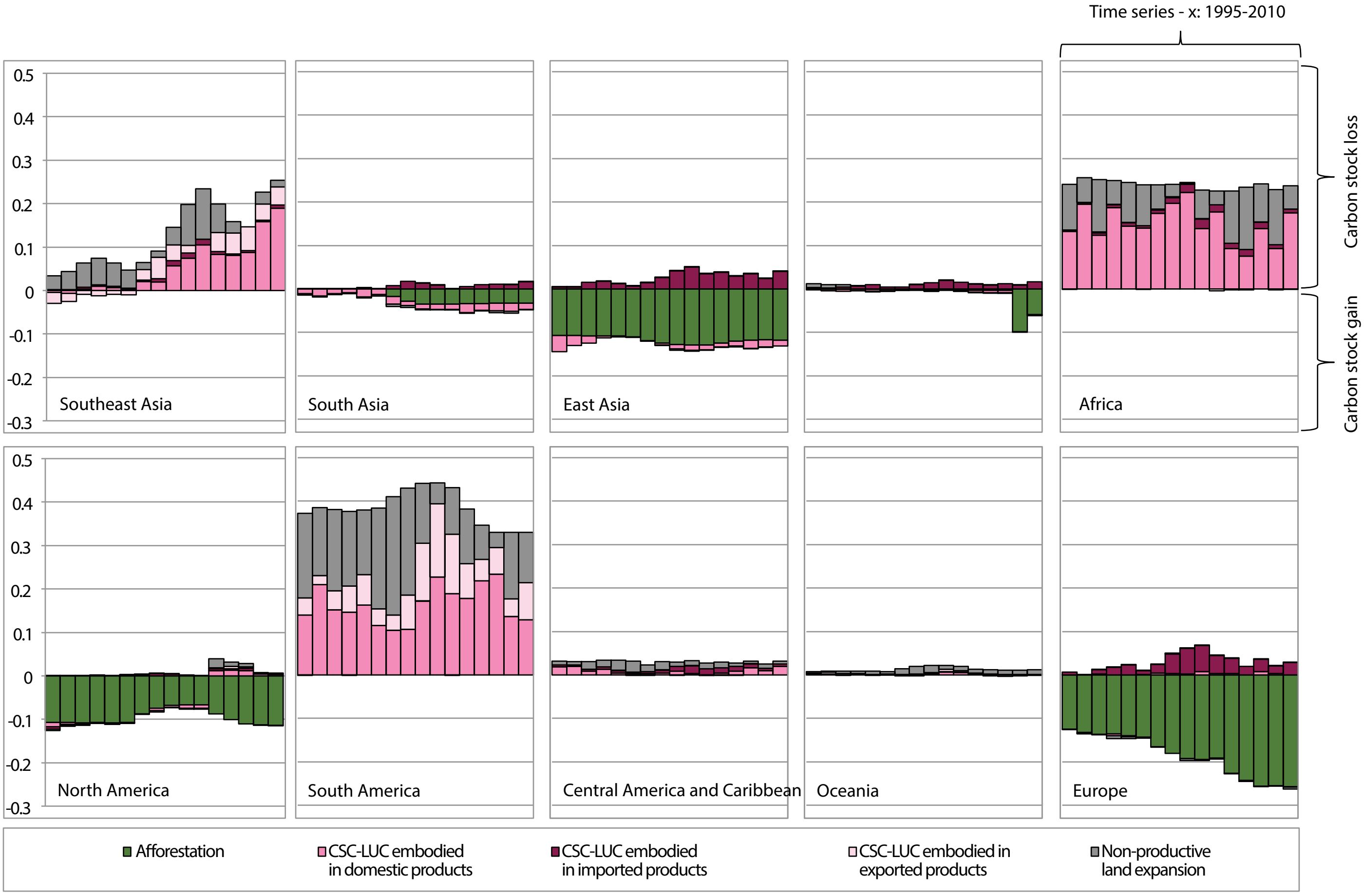


**Figure 3. Above- and below-ground CSC-LUC (y: billion tonnes C) allocated to regional consumption with trade using the regional approach (x: 1995 – 2010)**

Note: "+" and "-" represents carbon stock loss and gain respectively

## 3. Allocation by trade

Figure 3 shows how CSC-LUC can be allocated to domestic and international consumption. CSC-LUC is assumed to be embodied in the products and allocated to either domestic or foreign consumers (if the products were exported). For the expansion of "non-productive lands", CSC-LUC is allocated to the home region since expansion is unlikely to be directly linked to international markets. The results show that carbon stock loss attributable to agricultural exports has increased drastically; from below 10% before 2000 to 17-30% since 2000. The South American region is both the largest source and the largest exporter of CSC-LUC. Southeast Asia has followed a similar trend since 2000. In contrast, Africa has largely imported rather than exported products with embodied CSC-LUC. Meanwhile, consumers in Europe and East Asia are the largest off-takers of agricultural products with embodied CSC-LUC. Despite large export volumes, the North American countries on aggregate are not associated with exporting carbon stock loss since these are offset by gains from reforestation and afforestation.

## 4. Allocation by end use

The CSC-LUC can also be allocated to different end uses, as shown in Figure 4. For both approaches, "feed and animal-based products" were the main driver of carbon stock loss in the second half of the 1990s. However, the gap between "feed and animal-based products" and "plant-based products" narrowed over the 2000s. On the other hand, "liquid biofuels" contributed about 3% of annual global carbon stock loss for the global approach, and 2% for the regional approach in 2010. This carbon stock loss can primarily be attributed to biofuels derived from temporary crops that have experienced stable annual expansion (e.g. maize, soybean, and rapeseed). A large amount of carbon stock loss has been allocated to "non-productive lands". Likely causes include land degradation and abandonment (partly after intensive logging) and other human-induced and natural disasters (e.g. wildfires). Expansion of human settlements is comparatively insignificant, considering only around 0.5 – 1.5 % of "non-productive lands" are occupied by people (Potere and Schneider 2009).

## 5. Policy implications

Territorial distortions in CSC-LUC allocation can be observed when performing CSC-LUC analyses at different geographical levels. Results show that consumption of agricultural products in North America and Europe has been a leading driver of external CSC-LUC. However, due to domestic initiatives to increase forest cover, the CSC-LUC embodied in agricultural products imported from other regions was offset, and both regions became net sources of CSC-LUC gains. These results suggest that territorially

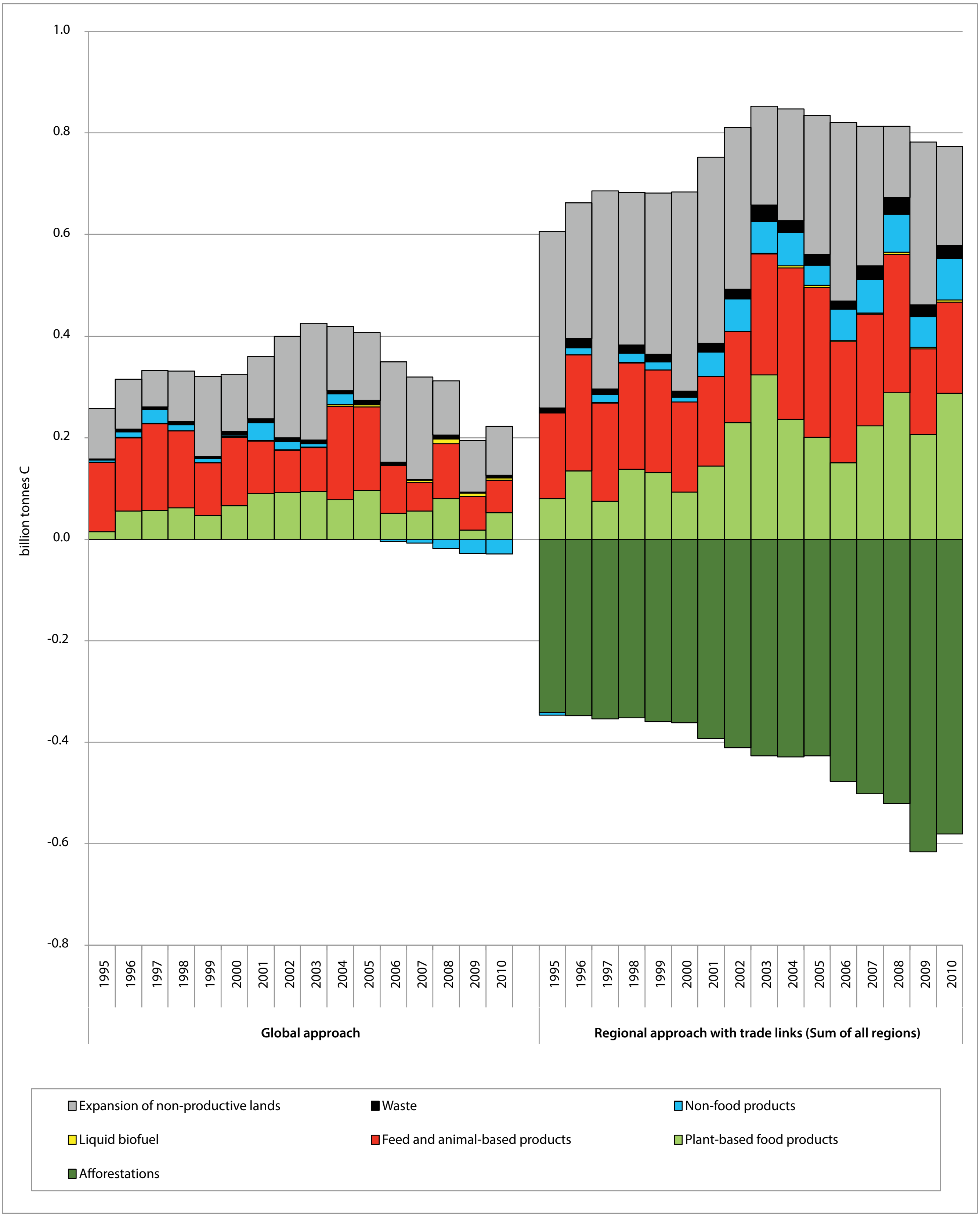


**Figure 4. Above- and below-ground CSC-LUC by regions and end uses using the regional approach**

Note: "+" and "-" represent carbon stock loss and gain respectively

confined mitigation programs do not necessarily contribute positively to global carbon stock change. For example, mitigation actions that aim to reduce LUC for the domestic production of agricultural products may trigger negative impacts in two ways: they may (i) increase imports from outside the territory, and (ii) reduce exports to outside the territory. If global demand remains unchanged or increases, which tends to be the case for most crops, both situations will stimulate more production outside the territory and inevitably increase pressure on global forests.

Different types of negative displacement and leakage effects can be anticipated should countries continue to pursue climate change mitigation programs and strategies through a territorial perspective (e.g. as is evidenced by the recent emergence of, for example, Nationally-Appropriate Mitigation Actions) or based on generalization (e.g. putting pressures on palm oil as a commodity but neglecting the underlying socioeconomic causes). This calls for greater alignment between domestic and global mitigation objectives, consideration of extraterritorial spillover effects associated with different policy options, and accounting for the interplay between a multitude of drivers, in order to adequately address the underlying causes of CSC-LUC.

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