Comments on World Resources Institute Land Sector and Removals Standard with Emphasis on its Carbon Opportunity Cost Calculation Tool

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We offer comments on the Greenhouse Gas Protocol Land Sector and Removals Standard v1.0 released January 30, 2026 (herein referred to a "LSRS") and the World Resources Institute Technical Note titled "Carbon opportunity cost calculation tool", Version 1.0, released March 2026 (herein referred to as "COC Tool"). The COC Tool Technical Note states that "Companies and other entities can use this tool to help fulfill the requirements and recommendations of the Greenhouse Gas Protocol Land Sector and Removals Standard v1.0."

In general, the LSRS provides qualitative sound methodologies to measure, report, and track greenhouse gas emissions. However, the carbon leakage and carbon opportunity cost requirements and associated technical guidance are not reflective of the current state and methodologies used in land use and land use emissions science. In the following we provide comments on several of the approaches provided in the LSRS and the COC Tool.

LSRS Approach 1:

Table 4.1 (page 16) of the LSRS requires carbon leakage and carbon opportunity cost reporting. For carbon leakage the document specifically states:

> "if companies implement activities with high risk for land carbon leakage but also divert feed or feed production on agricultural land shall quantify land use related GHG impacts of displaced food production and report such leakage separately in the land carbon leakage accounting category."

Figure 8.1 (page 48) in the LSRS states that high leakage risks also apply to:

> " food or other agricultural products being used for non-food, non-feed uses" as well as" a significant reduction in crop yields from a change in land management practices."

Section 8.2.1 (page 49) states that

> "activities with high risk for land carbon leakage" include "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."

Comment on LSRS Approach 1:

The LSRS approach appears to aim directly at discouraging biofuels and bioproducts but also carves out potential implications for food production. Regarding the later, it is not clear what "changes made to improve long term sustainability of food production" will mean in practice and which metric will be used to evaluate these long-term sustainable practices. Overall, we believe that encouraging conservation smart agricultural practices and maintain soils for future generations provides a better alternative than selectively discouraging agriculture by end-use. Distinguishing between feedstocks grown for biofuels or food ignores the fact that all agricultural land, unlike land used for warehousing and solar installations, is immediately available for food production if demand necessitates it. This specific concept has been documented in the induced land use literature in the past.[1]

LSRS Approach 2:

The LSRS in the COC Technical Note states that:

> "for this tool, because the state of the world at the time of publication is one of overall agricultural expansion and ongoing carbon losses of billions of tonnes of CO_2e per year from deforestation and land use change (Friedlingstein et al. 2025), the "carbon loss" approach and its equations are used."

Comment on LSRS Approach 2:

This is a gross simplification since it ignores that many regions around the world including many areas in Europe and the United States are in an agricultural reversion scenario.[2] Furthermore, Copenhaver and Mueller showed that agricultural land expansion and contraction is driven by complex factors. In the United States, for example, peak expansion

[1] Kloverpris, Jesper Hedal and Steffen Mueller. "Baseline time accounting: Considering global land use dynamics when estimating the climate impact of indirect land use change caused by biofuels"; Int J Life Cycle Assess; DOI 10.1007/s11367-012-0488-6; September, 2012

[2] Copenhaver, K., Hamada, Y., Mueller, S. and Dunn, J.B., 2021. Examining the characteristics of the cropland data layer in the context of estimating land cover change. ISPRS International Journal of Geo-Information, 10(5), p.281.

of agriculture occurred in the mid-1980s. Currently, depending on location the US agricultural footprint is either in reversion or expansion. However, Copenhaver and Mueller documented that even conversion to agriculture does not necessarily decrease soil carbon. This can be the case for land that reverted from peak 1980s agriculture into conservation reserve programs and back out into agriculture with high annual biomass production.[3] High resolution soil carbon emissions and sequestration factors have been developed for iLUC modeling as far as 15 years ago and are well documented.[4] Yet, the COC Tool (while citing the reference of spatially explicit stock estimates for native carbon stocks by Erb et al.) decides to simply average these stocks ("the default native carbon stock estimates in this tool represent the average (mean) of the values across the five maps presented by Erb et al.").

LSRS Approach 3:

The COC Tool Technical Note (page 1) states:

> "widespread use of the COC metric by companies and other entities has been limited by the lack of an easily accessible calculation tool."

The LSRS states (Endnote 2 on Page 50):

> "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."

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[3] Copenhaver, K.; Mueller, S.; Considering Historical Land Use When Estimating Soil Carbon Stock Changes of Transitional Croplands. Sustainability 2024, 16, 734. https://doi.org/10.3390/su16020734

[4] Qin, Z., Dunn, J. B., Kwon, H., Mueller, S., & Wander, M. M. (2016a). Soil carbon sequestration and land use change associated with biofuel production: empirical evidence. GCB Bioenergy, 8(1), 66-8; https://onlinelibrary.wiley.com/doi/full/10.1111/gcbb.12237

Qin, Z., Dunn, J. B., Kwon, H., Mueller, S., & Wander, M. M. (2016b). Influence of spatially-dependent, modeled soil carbon emission factors on life-cycle greenhouse gas emissions of corn and cellulosic ethanol. GCB Bioenergy. doi:10.1111/gcbb.12333; https://onlinelibrary.wiley.com/doi/full/10.1111/gcbb.12333

Z. Qin, C. Canter, J.B. Dunn, S. Mueller, H. Kwon, J. Han, M. Wander, M. Wang; Incorporating Agricultural Management Practices into the Assessment of Soil Carbon Change and Life-Cycle Greenhouse Gas Emissions of Corn Stover Ethanol Production; September 30, 2015; https://greet.es.anl.gov/publication-cclub-land-management

Zhangcai Quin, Jennifer B. Dunn, Hoyoung Kown, Steffen Mueller and Michelle Wander. Soil carbon sequestration and land use change associated with biofuel production: empirical evidence; GCB Bioenergy (2015), doi: 10.1111/gcbb.12237

Ho-Young Kwon, Steffen Mueller, Jennifer B. Dunn, Michelle M. Wander; Modeling state-level soil carbon emission factors under various scenarios for direct land use change associated with United States biofuel feedstock production; Biomass and Bioenergy (2013), http://dx.doi.org/10.1016/j.biombioe.2013.02.021

Comment on LSRS Approach 3:

The carbon leakage approach in the LSRS is essentially an iLUC calculation but with a highly simplified approach. The 1:1 replacement of displaced food calculation requirement completely ignores the existing science of iLUC modeling via multi-region, multi-sector Computable General Equilibrium (CGE) models such as GTAP and GLOBIOM that are coupled with spatially explicit carbon accounting models such as CCLUB or AEZ EF, or high-resolution spatial data. CGE models have been used for many carbon emissions reduction policies to quantify the impact of demand increases on supply via market-mediated effects. Market-mediated effects will significantly change the carbon impact of a product. Besides the omission to recognize market-mediated effects the LSRS also introduces a baseline of "native ecosystems" while providing only one, averaged reference carbon value. This ignores, for example detailed parameterizations available in the Argonne CCLUB, GTAP TEM, or Michigan State SALUS models which provide reference carbon values modeled for geographies at or below US county level boundaries."

The difference between the highly simplified LSRS approach and market mediated carbon calculation tools is significant: For corn ethanol, for example, the LSRS would require carbon leakage reporting and the tool shows an annualized COC per unit product of 2.94 tCO_2e/t ethanol which converts to a carbon opportunity cost of 110 gCO_2e/MJ.[5] In contrast, the latest iLUC value released by GTAP/GREET collaboration for corn ethanol is 5.76 gCO_2/MJ which reconverts to a carbon opportunity cost of 0.15 tCO_2e/t ethanol product, well below any COC listed for food products in the COC calculator tool. Moreover, the tool is perversely positioned to pit beef, butter, and cheese (with a COC of above 25 tCO_2/t product) against vegetables (generally less than 3 tCO_2/t product) and even vegetables against vegetables if the vegetables are produced with "a significant reduction in crop yields from a change in land management practices."

LSRS Approach 4:

In Chapter 8.1 (page 47) the LSRS states that:

> "land carbon leakage is calculated as the amount of carbon lost from plants and soils from conversion of native ecosystems to agricultural land to replace the

[5] Note that this value is very close to the iLUC value calculated in Searchinger 2008 et al. ("Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change." Science 319,1238-1 240; 2008) of 104 gCO2/MJ for corn ethanol. This may not necessarily be a total coincidence since the employed, rudimentary iLUC modeling practice and data in that paper relied heavily on forest conversions.

> quantity and type of reduced or diverted food or feed production due to corporate actions, using the carbon opportunity cost approach."

The COC Tool Technical Note (page 1) states:

> "The COC of agricultural land use is the total amount of carbon lost from plants and soils on land occupied by agriculture relative to native vegetation."

Comment on LSRS Approach 4:

The LSRS has been established based on a misleading interpretation of the economic concept of opportunity cost. From an economic perspective, this concept refers to the income forgone by using a resource (e.g., land) in a way that differ from its most profitable alternative.

For instance, if corn production is the most profitable use of a land parcel, then there is no opportunity cost of using that land for producing corn, whether corn is used for food, feed, or ethanol. If that land is converted to forest, then the forgone income from this conversion needs to be considered in determining the full cost of this land conversion.

This concept is being misapplied in LSRS when it considers the carbon opportunity cost (COC) of land-based products as the carbon foregone relative to a hypothetical scenario of unharvested forest. Using the carbon sequestration potential of current cropland as if it were mature, unharvested forest is inappropriate, as it is not an economically viable scenario and would impose large economic opportunity costs.

The proposed LSRS, following a misleading approach that disregards economic opportunity costs, requires companies reporting significant land-sector activities must calculate and report land carbon leakage, specifically using the COC metric. The COC of land should not be included in LSRS. In this protocol, the COC is the carbon sequestration that could be achieved by allowing the same land to regrow its native vegetation.

In an imaginary scenario where land has no monetary opportunity cost, and the sole goal is to maximize carbon saving, one may consider COC as a relevant metric only if no other options exist. However, as shown by the existing literature, even under these hypothetical conditions, planting short-rotation crops for bioenergy conversion is often superior to allowing native vegetation to regrow for emission reductions.

In the real world, in the absence of policy interventions, the opportunity cost of cropland is determined by the next-best alternative land use, such as leasing or conversion to non-cultivated uses. If cultivating a piece of land is unprofitable, it is often left idle or converted to other purposes, rather than being returned to its original vegetation.

Of course, one may argue for a carbon sequestration policy paying subsidies to convert cropland to forest or avoid deforestation. However, as various publications have shown, such a sequestration policy causes huge food security implications. In addition, subsidies required to support such a carbon sequestration policy are immense and potentially unfeasible, even for high income countries. These subsidies generate major welfare losses everywhere.

The approach proposed by LSRS mainly relies on the Searchinger et al. (2018) study to support their use of the COC method. However, that paper relies on several assumptions that require critical examination regarding their validity and accuracy. Specifically, the assumptions concerning forest carbon storage capacity over time, natural disturbance-driven carbon stock losses, land productivity/management heterogeneity, data sources, and the amortization period deserve significant attention.

The idea of using the COC concept by LSRS relies on the arguments that the financial cost of using a hectare for reforestation or crop production is the same and that it is cheaper to plant a forest than to plant a crop, given crop subsidies. These are misleading arguments. Not all crops are subsidized and conversion of cropland to forest would require significant subsidies. Furthermore, land-use decisions are driven by potential revenue and profit, not just production and conversion costs. If forests are not commercially harvested, they generate no income, offering landowners no incentive to convert from crops. Finally, this proposal ignores the substantial food security implications of converting agricultural land to forest.

In summary we find that the carbon leakage and COC as assessed in the calculator tool suffers from serious scientific simplifications and a misunderstanding of opportunity costs in the economic literature and produces perverse incentives in the fuel, food, and feed markets. We believe that encouraging the implementation of conservation smart agricultural practices and maintaining soils for future generations provides a better alternative than discouraging food, fuel, and feed production with carbon leakage and COC concepts as written in the LSRS. Distinguishing between feedstocks grown for biofuels or food ignores the fact that all agricultural land, unlike land used for warehousing and solar installations, is immediately available for food production if demand necessitates it.

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