The Land Gap Report

Climate Resource

LAND GAP REPORT BRIEFING NOTE

November 23

2023 Update

Governments have proposed approximately 1 billion ha (hectares) of land for land-based carbon removal as part of their climate mitigation pledges.

A billion ha is more than the combined areas of South Africa, India, Turkey and the European Union.

Restoration accounts for about 50 percent of land-based pledges. This does not require land use change, and allows ecosystems to recover more of their carbon storage capacity.

Tree planting (afforestation and reforestation) accounts for the other 50 percent of land-based pledges. It usually involves land-use change, and can be in tension with the goals of food security, ecosystem resilience, and the rights of local communities.

A few high-income, high-emitting countries are responsible for almost 75 percent of total land use within climate pledges. This risks insufficient decarbonisation ambition in sectors like power generation and heavy industry in those countries.

These land-based pledges risk delaying climate ambition as many countries rely on sequestration after 2030 or even 2050, to compensate for the absence of near-term climate action.

Transparency of pledged climate action in the land sector is critical.

More credible plans for climate resilient, ecologically sustainable and socially responsible land sector strategies are needed in country mitigation pledges.

This brief gives an overview of the land required to implement country climate mitigation pledges. It is an update to the first Land Gap Report, published in 2022, which highlighted the risk that countries' pledges rely on unrealistic amounts of land-based carbon dioxide removal (CDR).

Over the past year, 21 countries have submitted updated Nationally Determined Contributions (NDCs), and a further 18 countries have submitted Long-term Low Emissions Development Strategies (LT-LEDS) to the United Nations Framework Convention on Climate Change (UNFCCC). NDCs and LT-LEDS represent the collective ambition of countries to reach net-zero emissions and meet the goals of the Paris Agreement. In addition, the Member States of the European Union clarified plans in the EU's 2023 NDC update by indicating each Member States' share of the EU's overall CDR goal.

In 2023 we updated our assessment of the land required to meet carbon dioxide removal as communicated in national pledges, taking into account new pledges submitted this year and clarifications about the intent and land required to meet some existing pledges. Figure 1 summarizes these pledges.

Some pledges over-rely on land-based carbon dioxide removals (CDR) to offset fossil fuel emissions. This raises serious concerns that these countries are shifting their mitigation burden away from reducing fossil fuel use. Reliance on planting new trees to offset emissions from fossil fuels or the destruction of primary forests ignores scientific principles.[1]

[1] Allen, M., Friedlingstein, P., Girardin, C., Jenkins, S., Malhi, Y., Mitchell-Larson, E., Peters, G., Rajamani, L. Net Zero: Science, Origins, and Implications. Annual Review of Environment and Resources, Vol. 47, pp. 849-887 (2022).

Land required for carbon dioxide removal in national climate pledges

Figure 1 shows our assessment of the total land required to meet biological carbon removal in national climate pledges. This total land area is equal to **910-1,060 million hectares[2],** if those pledges are met in full. Of this total, **470-490 million hectares requires the use of reforestation and afforestation**, and a further **440-570 million hectares requires the restoration of ecosystems and degraded lands**.

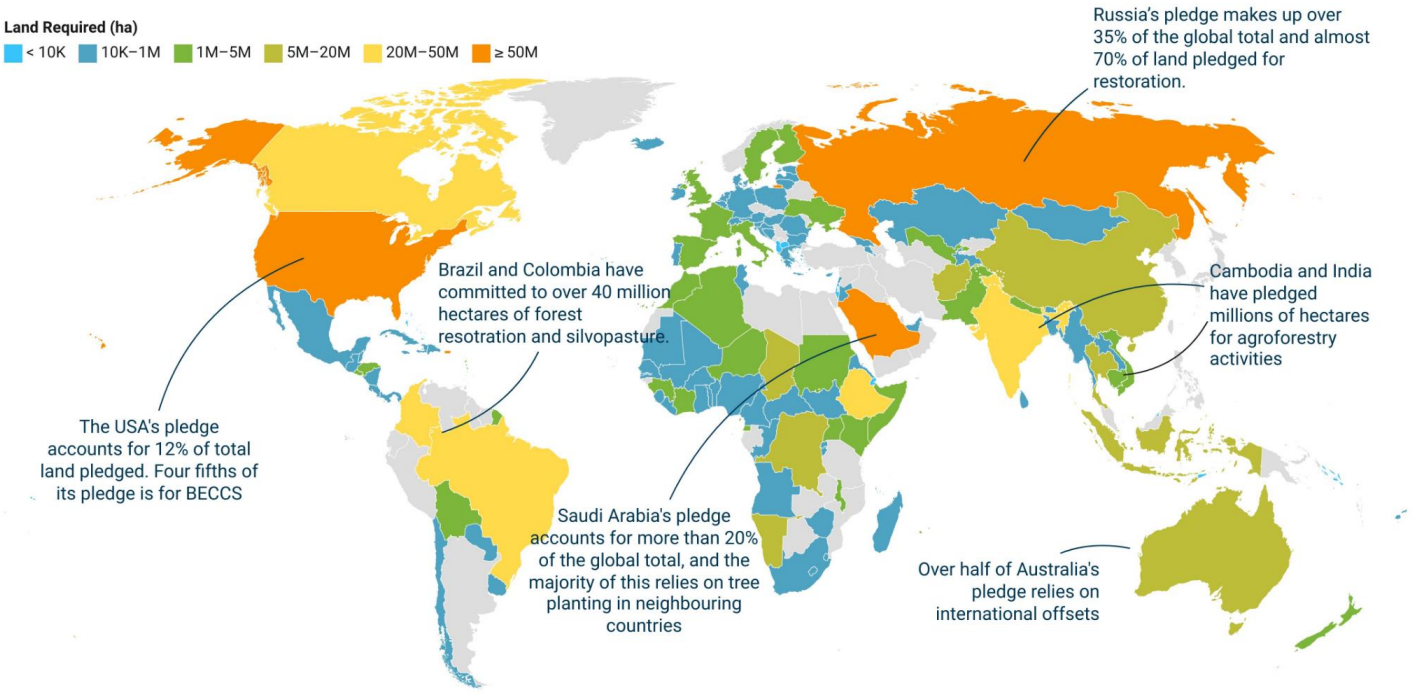


Figure 1: Land area required to deliver country climate pledge submitted to the UNFCCC. Note: Grey denotes countries that have not included land based CDR in their climate pledges

CDR through land use change or restoration activities

The extent to which pledges require conversion of land to new forests (land use change), or involve restoration of degraded land and forests (no land use change) affects the risks, benefits, and credibility of the pledges in providing additional emission reductions.

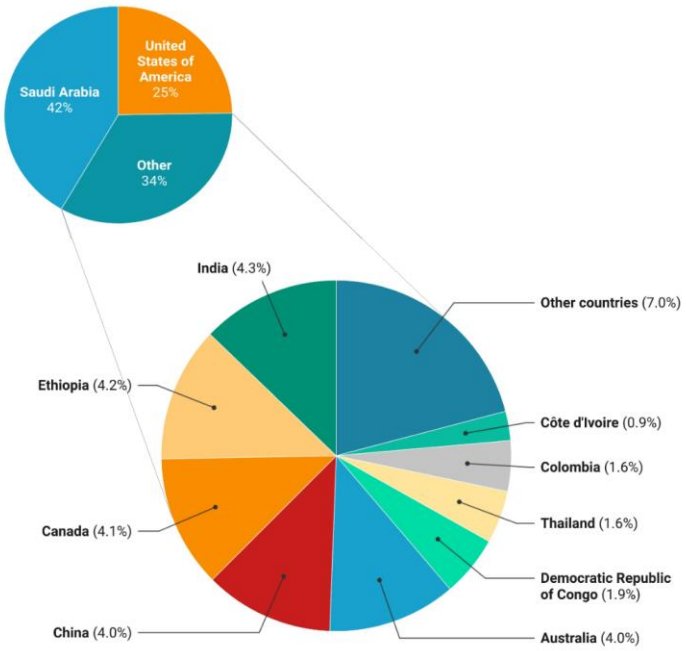
Land use change involving the conversion of forests to agricultural land is a leading driver of biodiversity loss, as well as a contributor to climate change. At the same time, many climate mitigation approaches that rely on large scale reforestation and afforestation efforts, threaten to exacerbate, rather than help to solve the biodiversity crisis. In some countries, reforestation and afforestation could exacerbate food insecurity and land conflict, given the multiple competing uses of land and its impact on the livelihoods of indigenous peoples and other vulnerable and land dependent communities (See Chapter 4 in the Land Gap Report 2022).

Protection and restoration of primary forests and other intact ecosystems is the most effective climate mitigation action in the land sector, providing co-benefits for adaptation, biodiversity conservation and other critical ecosystem services (see Chapter 3 and Table 3.1 in the Land Gap Report 2022). Conserving all carbon-dense primary ecosystems, and in particular all remaining primary forest – boreal, temperate, and tropical – is critical to climate mitigation efforts, as they store far more carbon compared with harvested forests or plantations. To contribute to climate mitigation efforts, land restoration activities must produce an increase in carbon stored that is both additional to what may have otherwise occurred, and resilient to external shocks and stressors, including climate change (Chapter 3, in the Land Gap Report 2022).

[2] An uncertainty value is included in this overall figure, as detailed in the Appendix.

Planned land use change and restoration of degraded forests is attributable to a small number of countries

Figure 2 shows CDR pledges that require land use change (reforestation and afforestation activities, and some plantings for bioenergy with carbon capture and storage (BECCS)), and **Figure 3** shows those that do not require land use change (restoration or regeneration of existing forests, mangroves, agroforestry, silvopasture).



Land use change

Within the calculator, CDR pledges that required land use change are dominated by two countries - Saudi Arabia and the United States, which account for 42% and 25% of total land-use change respectively. High-income countries account for over three quarters of land use change in pledges.

Figure 2 - Share of land-use change required for carbon dioxide removal as communicated in country pledges.

Restoration

Russia makes up a considerable portion of pledges that make use of restoration activities - almost 70% of the total. Aside from Russia, Brazil, the EU and Canada account for a further 14% of the total land pledged for restoration. The remaining restoration pledges are spread amongst non-Annex I countries.

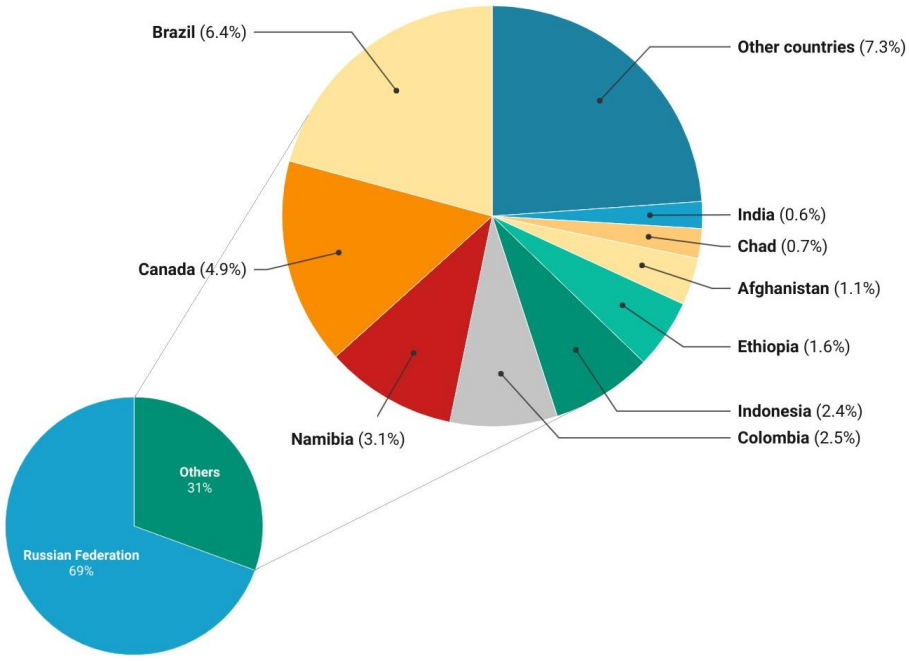


Figure 3 - Share of restoration activities required for carbon dioxide removal as communicated in country pledges.

Data in national climate pledges

The data page of the Land Gap Report website offers the opportunity to further explore the data that underpins this Brief. Here we discuss the key trends and country pledges of note.

Distribution of pledges in time

Figure 4a shows that currently, emissions abatement in the land sector is **largely pledged beyond 2030**. More countries' pledges include land-based removals in 2030 than in later decades (**Figure 4b**). More than 80 percent of countries in our results are based on pledges for 2030. It can be expected that the share of land-based removals after 2030 will likely grow as more countries submit long term targets and detail is added to existing long term pledges. Already close to 80 per cent of land area required falls within 2050 and 2060 pledges, in large part as these include the Russian Federation, Saudi Arabia and the United States. This is consistent with other assessments that countries are relying on rapid mitigation action in the decades beyond 2030 to reach net-zero targets.[3]

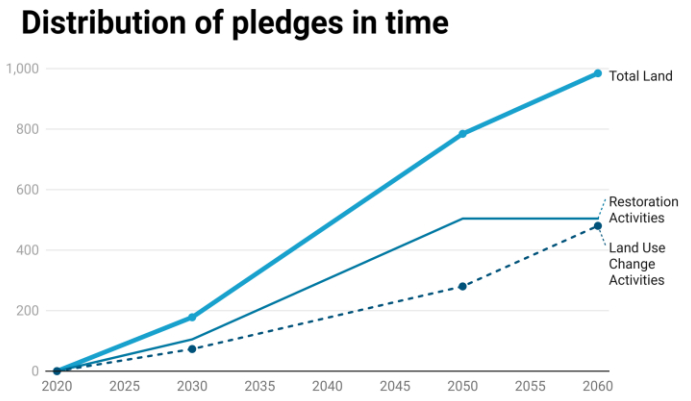


Figure 4a - Land required for CDR is heavily skewed towards 2050 and 2060

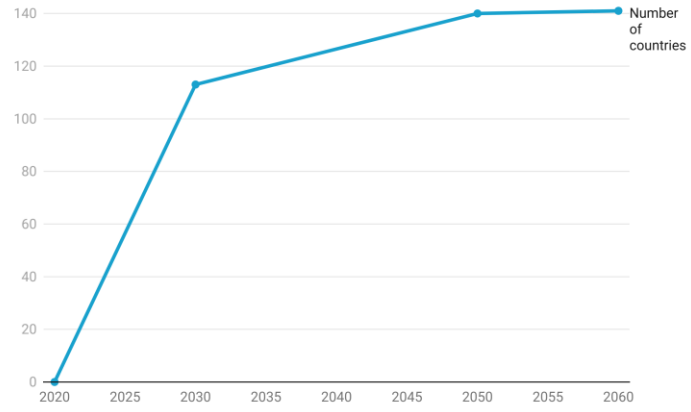


Figure 4b: Country pledges are heavily skewed towards this decade.

However, to pursue efforts to limit warming to 1.5 degrees as countries agreed in Paris, mitigation efforts need to be focussed on the current critical decade. This highlights the need for more ambitious, credible pathways across all sectors, and for countries to provide more detail on how they will develop more climate resilient, ecologically sustainable and socially responsible plans for any mitigation that relies on the land sector.

Greater transparency and detail about planned land-based CDR is required.

Transparency in NDCs and LT-LEDs remains a problem. Countries often provide insufficient detail meaning assumptions must be used to assess the land area required or the emissions reductions that will be delivered from land-based CDR. This leads to low and high estimates based for two different reasons - due to 1) uncertainty, and 2) due to country pledges including multiple scenarios.

Uncertainty

Uncertainty arises as it is often unclear how countries might apply emissions removal factors within their pledges. These are default estimates of how much land and biological growth is required to absorb a certain amount of carbon. As further detailed below in the Appendix, methodological changes to account for different emissions factors may increase the uncertainty of estimating the extent of land required for CDR when this is not directly stated. Our analysis indicates that the uncertainty associated with the calculation of land requirements through emissions reduction pledges is ±75 million hectares, if CDR pledges are met in full. The total land required to meet CDR pledges in full is estimated to be **between 910 and 1,060 million hectares** with a best estimate of **983 million hectares**.

Range

Ranges (lower and upper) arise because of conditional pledges, as well as scenarios included within NDCs or LT-LEDs. Conditional pledges are those indicated by developing countries that rely on assistance from the international community, such as financial resources, technology transfer, technical cooperation, capacity-building support, or the availability of market-based mechanisms. These conditional pledges may commit to a higher level of emissions reduction through land use (and greater area of land) if these assistance conditions are met. Scenarios are alternative pathways suggested within LT-LEDS. For example a country might suggest a low / medium / high pathway for total emissions reduction, or a set of scenarios where land use makes up a smaller or larger component of emissions reduction depending on the scenario followed.

The upper estimate of assessed pledges shows that 983 (±75) million hectares is required to deliver countries' conditional pledges and the highest land use from LT-LEDs scenarios. If only

[3] For example see Figure 9 of the UNFCCC LT-LEDS Synthesis Report (https://unfccc.int/documents/619179)

unconditional pledges are counted, the global total would be reduced by 50 million hectares. If the lowest possible pathways in LT-LEDs are counted, this total drops a further 115 million hectares. This means the lower estimate of assessed pledges is around **817 (±72) million hectares** if both unconditional pledges and low scenario pledges are assessed. **Figure 5** shows the upper and lower end of pledges for global land use change and restoration totals.

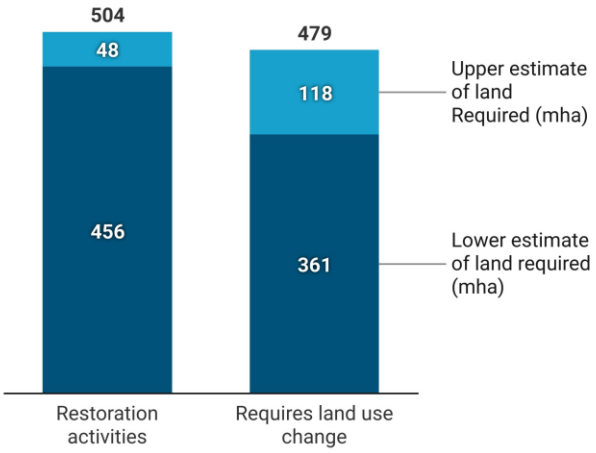


Figure 5 - Lower and upper range of assessed pledges. This figure shows the range in land areas required due to conditionality and scenarios in country pledges but does not show the impact of uncertainty in sequestration rates.

The range in country pledges mean the land area required to deliver land-based CDR could be as low as **745 million hectares**, if the lower estimate of assessed pledges is used, combined with the lower end of uncertainty.

An improvement of country reporting and transparency would provide a stronger basis for understanding land use requirements as part of country pledges, and measuring global progress towards the Paris goals.

Key high-income, high-emitting countries are most at risk of over-relying on land for net-zero emissions in 2050 and 2060.

By area, the largest pledges for land-based CDR are made by several high-income, high-emitting countries. These countries are major participants in international coal, gas and oil markets. The United States, Canada, Saudi Arabia, Russia, Australia, and the United Kingdom pledge significant land-based sequestration to reach net-zero and counteract the impacts of ongoing emissions from other sectors. This risks reducing the focus on short-term actions needed to reduce emissions from fossil fuels and industrial processes which are essential if the world is to limit warming to 1.5°C. **Table 1** shows the extent to which these countries are relying on land-based removals to achieve their net-zero 2050 pledges. Note that pledged emissions are upper scenario estimates.

Table 1: Countries most reliant on land for absolute emissions reductions.

Country	Removals from land-based CDR (MtCO2)	% of country 2021 emissions
Australia	200	38
Russia	665	30
Canada	166	24
United States	979	16
United Kingdom	58	14

Note this table focusses on countries that specifically indicate emissions reductions from land based CDR, and as such Saudi Arabia is not included.

In order to meet these goals, these countries plan to make use of methods that raise concerns regarding their feasibility and effectiveness, and may potentially impact food sovereignty, biodiversity or land rights. Key risks are briefly outlined below.

BECCS (bioenergy with carbon capture and storage)

BECCS frequently relies on the conversion of existing forests to cropland.[4] Further, its methods tend to underestimate the emissions generated in this conversion as well as the missed potential for carbon storage through natural regeneration.[5,6] In order to prevent undesirable impacts on biodiversity and livelihoods, one estimate surmises that land for bioenergy production should be capped at its current level, roughly 50 million ha.[7] Our assessment indicates that an additional 80 million hectares has already been pledged by only five countries to help meet their net-zero goals using BECCS technologies.

The United States' pledge accounts for over 80 per cent of this total. Its long term plan indicates that up to 65 million hectares of land for BECCS will be required in order to meet its net-zero target, and additionally up to 54 million hectares for reforestation. This land use would remove 1,000 $MtCO_2$ yearly - on top of the existing 820 $MtCO_2$ a year that is currently removed by forested lands. In alternative scenarios of its LT-LEDS, the United States indicates that only an additional 100 $MtCO_2$ of reductions would be achieved through land sequestration, which would require a far smaller fraction of land. Canada indicates BECCS emissions reductions of up to 73 $MtCO_2$ annually in 2050. This would require almost 7 million hectares of land, or 18% of Canada's arable land in 2021. At the low end, Canada indicates 1.5 million hectares for BECCS. The United Kingdom's pledge for BECCS removals of 58 $MtCO_2$ annually by 2050 would entail the use of a considerable portion of the United Kingdom's land – up to 1.4 million hectares, or almost 6% of its entire land area. The UK's land for BECCS may be limited to 230,000 hectares in a low scenario. Australia includes 38-84 $MtCO_2$ from BECCS removals in its plans, which requires 2.9-6.4 million hectares of land use. The only other nation that includes BECCS in its plans is Switzerland with 0.6 $MtCO_2$.

[4] Creutzig, F., Erb, K., Haberl, H., et al. 2021. Considering sustainability thresholds for BECCS in IPCC and biodiversity assessments. GCB Bioenergy, 13(4), 510-515.
[5] Harper, A.B., Powell, T., Cox, P.M., et al. 2018. Land-use emissions play a critical role in land-based mitigation for Paris climate targets. Nature Communications, 9(1), 1-14
[6] Searchinger, T.D., Wirsenius, S., Beringer, T., et al. 2018. Assessing the efficiency of changes in land use for mitigating climate change. Nature, 564(7735), 249–253.
[7] Creutzig, F., Erb, K., Haberl, H., et al. 2021. Considering sustainability thresholds for BECCS in IPCC and biodiversity assessments. GCB Bioenergy, 13(4), 510-515.

CDR and CO_2 fertilization

Russia relies heavily on land-based CDR to meet its 2050 target, which requires more than doubling its land sink through restoration. Russia includes the projected increase in carbon stored in both managed and unmanaged forests, which likely includes CO_2 fertilization, and the impact of changes in temperature and rainfall from the warming climate.[8,9] Much of this is already accounted for in climate models, and as such is not a source of additional CDR.[10] Similarly, Canada stands to benefit from increased CO_2 fertilization, which while contributing 93 $MtCO_2$ reductions to its 2050 net-zero emissions, is already accounted for within climate scenarios and so cannot not be used to offset continued fossil fuel emissions. In its LT-LEDS document, Canada models these reductions in all scenarios, which accounts for 36 million hectares of land-based CDR.

International Offsets and Tree Planting

Both Australia and Saudi Arabia state that they will make use of international offsets in their net-zero plans to offset continued domestic emissions. Australia relies on up to 200 $MtCO_2$ of land-based CDR in its net-zero commitment in 2050, of which 94 $MtCO_2$ is made up of international offsets. This would require 7 million hectares of reforestation.[11] Notably Australia's LT-LEDS plan was submitted under the former government. Australia has since submitted more ambitious 2030 targets, but as of 1 November 2023 not submitted a new LT-LEDS.

Saudi Arabia plans to make use of substantial international offsets in addition to domestic land-based CDR. In 2021, Saudi Arabia announced its plans to: *Plant 10 billion trees* within the Kingdom in the upcoming decades, equivalent to rehabilitating roughly 40 million hectares of degraded land, and, in coordination with neighboring countries *plant an additional 40 billion trees*, for a total area equivalent to 200 million hectares of restored degraded land.

Three risks evident in Saudi Arabia's planned contribution from land-based CDR are:

- The size of the increase in forested area in the Kingdom it implies. According to the FAO, the total forested area in Saudi Arabia in 2022 was 977,000 hectares. As such, the in-country commitment implies an increase of forested area by greater than 4000%.
- The proportion of planting required in later decades. The plan aims for 650 million trees by 2030, implying over 9 billion (or >93%) of these trees are to be planted between 2030 and 2060.
- The lack of detail regarding its planned activities in neighboring countries. Little information is available as to where in the Middle East a further 40 billion trees will be planted, however other countries within the Middle East are similarly sparsely forested. The longevity of new plantings in these arid environments in the context of a changing climate is questionable.

Given Saudi Arabia's weight of contribution to the calculated global land requirements for CDR, improved clarity on these points is important. Saudi Arabia alone accounts for almost 20 percent of the total land area pledged for CDR activities according to these announcements made in March of 2021. We note however that as of October 2023 these commitments have not yet been formalized within its NDC or LT-LEDS.

Collectively, the countries discussed here contribute to almost three quarters of the total land use required for CDR in climate pledges. As such, the unrealistic land demands for CDR could be significantly reduced if these high emitting and economically developed countries committed to low CDR pathways, or reformulated net-zero plans to more clearly separate out emission reduction targets from removal targets to ensure that ambition is not undermined.

2023 European Update

This update includes individual pledges from EU countries. In December 2020, the EU submitted a joint NDC for its 27 member states. This NDC included a commitment to remove 225 $MtCO_2$ yearly through land-based uptake by 2030, which was increased under the EU Climate Law to 310 $MtCO_2$.

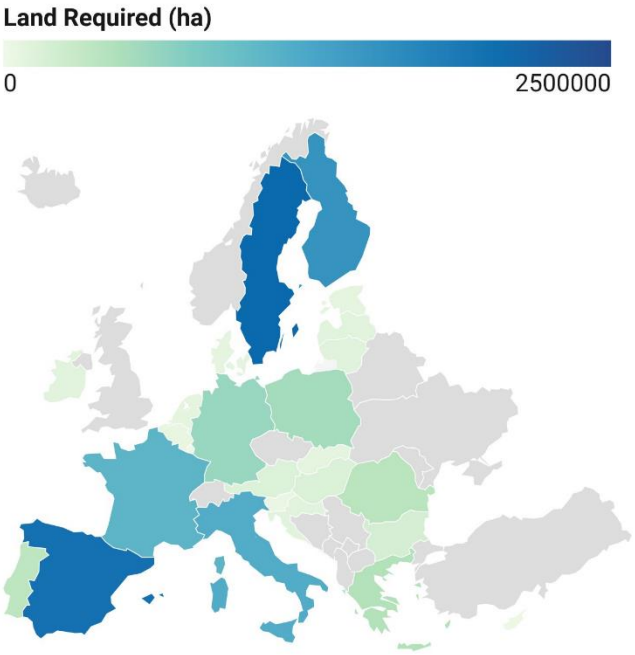


Figure 6 - Land Requirements for the Member States of the European Union, derived from its 2023 NDC update.

[8] Schepaschenko, D., Moltchanova, E., Fedorov, S. et al. Russian forest sequesters substantially more carbon than previously reported. Sci Rep 11, 12825 (2021)
[9] Nabuurs, GJ., Ciais, P., Grassi, G. et al. Reporting carbon fluxes from unmanaged forest. Commun Earth Environ 4, 337 (2023)
[10] Grassi, G., Stehfest, E., Rogelj, J. et al. Critical adjustment of land mitigation pathways for assessing countries' climate progress. Nat. Clim. Chang. 11, 425–434 (2021).
[11] This assumes plantings will take place in a tropical climate domain given the recent announcement of the Indo-Pacific Carbon Offsets scheme by the Australian government.

This entails a 42 $MtCO_2$ increase from the existing sink which is stated in EU legislation as 267 $MtCO_2$.[12] The EU target is to be achieved by a reversal of the degradation trend over the last decade, and as such the removal potential in the EU is considered to be undertaken through restoration of old secondary forests. Within the legislation, each country is allocated an individual emissions reduction target. Using these targets, we calculate the land required across the EU to meet its 2030 sink target at 12.3 million hectares.

The share of this total required by each EU Member state to meet individual pledges is shown in **Figure 6**, and this land use and CDR is placed in the context of each country's land and greenhouse gas emissions in **Table 2.**

Table 2: EU Pledges

Country	% of country land required to meet CDR pledge	% of 2021 emissions to be reduced by CDR pledge
Austria	1.7%	1.1%
Belgium	1.7%	0.3%
Bulgaria	1.7%	2.2%
Croatia	1.7%	2.5%
Cyprus	2.5%	0.7%
Czechia	1.7%	0.7%
Denmark	1.8%	1.1%
Estonia	1.6%	3.1%
Finland	5.0%	6.0%
France	2.0%	1.6%
Germany	1.7%	0.5%
Greece	3.3%	1.5%
Hungary	1.7%	1.5%
Ireland	1.5%	1.0%
Italy	4.0%	0.8%
Latvia	1.7%	6.4%
Lithuania	1.7%	3.4%
Luxembourg	1.7%	0.3%
Malta	2.3%	0.1%
Netherlands	2.1%	0.3%
Poland	1.7%	0.8%
Portugal	3.9%	1.8%
Romania	1.7%	1.9%
Slovakia	1.7%	1.2%
Slovenia	1.7%	1.4%
Spain	4.0%	1.8%
Sweden	5.1%	8.9%

Summary

Since the release of the Land Gap Report, 21 countries have submitted updated NDCs, and a further 18 countries have submitted LT-LEDS. These updates have done little to change the overall picture and messages emerging from the 2022 Land Gap Report: countries' climate pledges continue to rely on unrealistic amounts of land-based carbon removal. The estimated total area of land required has decreased relative to the 2022 assessment, largely due to changes in baseline or pledge year assumptions for large land-area pledges such as the EU and India. Many of these plans rely on CDR later in the century, however the level of reductions that take place this decade are critical in deciding whether warming will be limited to 1.5°C or 2°C.[13] Governments in some high income major emitters continued reliance on land-based carbon removal in their climate pledges risks shifting mitigation efforts away from the immediate reduction in fossil fuel emissions required to achieve the Paris Agreement goals. Furthermore, many countries' climate submissions lack the necessary detail and information to properly assess intended land requirements for mitigation. An improvement of country reporting and transparency would provide a stronger basis for understanding land use requirements in country pledges, and measuring global progress.

Key messages for decision makers

- **Climate pledges by a few high-income, major emitters account for over half of total land required to implement the land-based CDR included in the world's mitigation pledges.** The overreliance on land-based CDR that may not generate permanent additional mitigation risks the achievement of the Paris goals.
- **The 'net' in net zero must not distract from emissions reductions now.** Framing climate targets as 'net zero' risks undermining mitigation action by allowing a trade-off between emissions reductions and removals. Targets based on net accounting obscure the extent to which countries are relying on land removals for meeting climate mitigation commitments, and allow them to delay reductions in other sectors.
- **Ecosystem restoration as a removal could help get us closer to 1.5 °C if emissions reductions in all sectors happen now.** The scale of CDR that can be achieved sustainably via ecosystem restoration is sufficient to be compatible with a 1.5 °C temperature limit only when coupled with the most ambitious reductions in emissions from all sectors – such as fossil fuel use, industrial agriculture, deforestation and forest degradation related activities.
- **Transparency of land-based CDR pledges is an issue.** Many countries' climate submissions lack the necessary detail and information to properly measure intended land requirements for mitigation, and assess the feasibility of these actions. Improved transparency and reporting in the land sector would provide a stronger basis for measuring global aims and understanding progress.

[12] Regulation (EU) 2023/839 of the European Parliament, available at https://eur-lex.europa.eu/eli/reg/2023/839/oj
[13] IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Appendix - Methodological Notes

To maintain consistency, the updated calculations for the LGR used a methodology closely aligned with the 2022 Land Gap Report, as outlined in Chapter 2.

- For countries without long-term pledges, we reviewed near-term climate pledges in countries' NDCs.
- Our review focused on mitigation pledges. We did not review countries' National Adaptation Plans or land restoration commitments made outside of climate pledges.
- We identified both land-based CDR (reforestation, restoration and plantations) and technological CDR (BECCS and DACS).
- We did not assess bioenergy demand separate from CDR pledges, as bioenergy tends to be embedded within the energy sector of climate mitigation pledges. This means that our assessment of land demand for climate mitigation is likely to be conservative.

Climate pledges were reviewed for all countries defined according to UN Member status. For this year's update this includes 197 countries as well as the EU after the accession of the Holy See to the UNFCCC. The EU was assessed both as a bloc, and each of its member states were also assessed. We reviewed all climate pledges that were submitted until the beginning of November 2023, including new and updated NDCs. In some cases, other government documents or speeches by leaders were used to cross-check and appropriately estimate land use pledged within official climate pledges. In the case of Brazil, information from a previous NDC was used in quantification as the most recent NDC lacks detail on land use activities. Given Brazil's commitment to 'revise its National Climate Change Policy in light of the Paris Agreement'[14], our expectation is that Brazil will further commit to restoration activities on a scale similar to its first NDC.

From this review of pledges, It was possible to quantify the land area requirements for 141 pledges that relied on carbon dioxide removal, including land and forest restoration, reforestation, and for a very small number of countries, BECCS. A further 40 countries were assessed as including no CDR within their climate pledges. 16 countries included CDR commitments that were not quantifiable given the information in the NDC or LT-LEDs. For countries with both LT-LEDs and NDCs we included the longest-term pledge in the total figures. 40 countries had information relating to pledges that are to be met beyond 2030. Though the bulk of countries assessed have 2030 pledges, the bulk of land (close to 80%) falls within 2050 and 2060 pledges, as these include the Russian Federation, Saudi Arabia and the United States.

Country climate strategies and pledges express commitments in a range of different metrics and qualitative ambitions. Therefore, a number of assumptions were made to identify the scale of CDR commitments. The range of land-based actions for carbon removal were presented in climate pledges as:

- **Direct** references to land area (in hectares, acres or km2).
- **Indirect** references to land area, for example a proportion of forest cover to be maintained or extended as part of a pledge.
- In terms of **emissions reductions** required to achieve targets (for example presented as MtCO2 or percent of total emissions to be reduced through AFOLU activities)
- As a **number of trees** that would be planted in order to meet a pledge.

The breakdown of the contribution in hectares of each of these different forms of pledges to total global land required is shown in **Figure 7**. Where pledges did not include direct references, commitments were combined with data from publicly available datasets on land cover and land use to calculate the implied land area. such as from the Food and Agriculture Organization of the United Nations (FAO), national GHG emissions profiles from Climate Resource's datasets, and academic sources.[15]

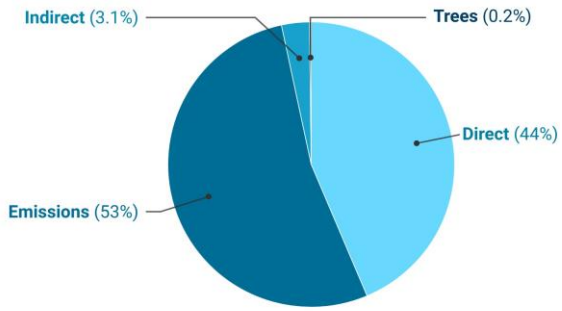


Figure 7: Share of total land area by pledge type

Amongst different pledge types, direct pledges are the most certain. 90 countries used direct pledges accounting for 430 million hectares of land. Indirect pledges are also of high certainty, and 14 countries made use of these accounting for 31 million hectares of land. Where countries pledged a certain amount of trees to be planted there is much greater uncertainty. Resources such as Crowther et al. (2015) give a measure of the natural density of forests within a country, however generally it is not stated where the trees are to be planted or whether this is to be aligned with pre-existing natural densities, or in plantations where spacing of trees may reach 1600 - 2500 trees per hectare. The effect of uncertainty around trees per hectare in contributing to estimates of the global total is limited, as only 14 countries made use of a tree planting number in their pledges and this only accounts for 1.9 million hectares of the total.

Greater uncertainty can be attributed to those countries that were assessed using emissions pledges due to the larger contribution of these to the global total - 52 countries accounting for 522 million hectares were assessed through emissions pledges. This includes several large parties - Russia, the United States, the member states of the European Union, Canada, India, and Australia. To calculate the land associated with pledges in these countries, the various approaches to land management in national climate strategies were categorised into seven activity types, based on their carbon sequestration potential. These activities were combined with the climatic domain of each country as defined by

[14] Brazil's First NDC adjustment, available at https://unfccc.int/sites/default/files/NDC/2023-11/Brazil%20First%20NDC%202023%20adjustment.pdf
[15] Crowther, T., Glick, H., Covey, K. et al. Mapping tree density at a global scale. Nature 525, 201–205 (2015).

the FAO. From this information, removal factors from the IPCC and Harris et al., 2021[16] were applied to calculate the land required to sequester pledged emissions reductions.

To calculate the uncertainty associated with calculating land requirements through applying emissions removal factors to pledges that were presented as emissions, a simple analysis was performed using standard deviation values provided by Harris et al., 2021. **Figure 8** shows the size of this uncertainty.

Further uncertainties associated with this method may be refined in future calculations to give a better estimate of the global range of CDR pledges. These uncertainties arise as:

- A single climatic domain is applied to countries, which dictates the removal factor for the forest type. However many countries have a variety of climatic types.
- NDCs are often unclear as to what type of forest is being restored/reforested/afforested (e.g. primary, secondary, plantation etc.) In reading NDCs it is often unclear what split exists between activity type and forest type (e.g. a country may pledge 200,00 ha of 'mixed activities').
- There is also uncertainty in the figures derived by Harris et al., 2021. For example other studies[17] define higher removal factors than Harris et al., 2021 which would lead to lower amounts of land required in order to meet climate pledges.

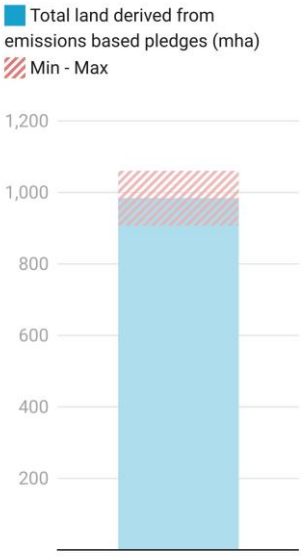


Figure 8: Uncertainty associated with calculating pledges

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[16] Harris, N.L., Gibbs, D.A., Baccini, A. *et al.* Global maps of twenty-first century forest carbon fluxes. *Nat. Clim. Chang.* 11, 234–240 (2021)
[17] Bernal, B., Murray, L.T. & Pearson, T.R.H. Global carbon dioxide removal rates from forest landscape restoration activities. *Carbon Balance Management* 13, 22 (2018)