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GHG inventory for the sector Land use, Land use change and Forestry of Vienna

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ZUSAMMENFASSUNG

Dieser Bericht beinhaltet die Ergebnisse eines Arbeitspaketes des Projekts „Vienna Urban Carbon Laboratory" (VUCL), das im Auftrag des Wiener Wissenschafts-, Forschungs- und Technologiefonds (WWTF) durchgeführt wurde. Das VUCL-Projekt untersucht den Beitrag von (biogenen) Senken und Emissionsquellen zur Wiener CO_2-Bilanz bottom-up mittels Treibhausgas(THG)-Inventur-Methoden und Gasmessungen. Zu diesem Zweck wurde auch eine THG-Bilanz für den Landnutzungssektor (LULUCF) erstellt, die auf den Methoden der Nationalen THG-Inventur basiert (Umweltbundesamt, 2024). Es wurde eine Zeitreihe von drei Jahren (2018–2020) auf der Grundlage der 2006 IPCC-Richtlinien für Nationale Emissionsinventuren erstellt.

Die notwendigen Inputdaten (Aktivitätsdaten und Emissionsfaktoren) für die THG-Bilanzierung wurden gesammelt, analysiert und berechnet, einschließlich Wien-spezifischer Aktivitätsdaten und Emissionsfaktoren für den Wald. Es wurde eine Zeitreihe der THG-Emissionen/-Senken des LULUCF-Sektors für die Jahre 2018, 2019 und 2020 erstellt. Dabei wurden auch die Ergebnisse eines früheren Projekts für die Stadt Wien aus dem Jahr 2014 verwendet, in dem bereits Berechnungen für den Wald in Wien und im Besitz der Stadt Wien (einschließlich Aufforstung und Entwaldung) durchgeführt wurden (Umweltbundesamt, 2016).

Um die Landnutzungsflächen und Landnutzungsänderungen zu quantifizieren, wurden die Daten der Realnutzungskartierung für die Jahre 2001, 2005, 2009, 2016 und 2020 ausgewertet und in die Kategorien Wald, Ackerland, Grünland, Feuchtgebiete und Siedlungsraum der LULUCF-Treibhausinventur übersetzt. Des Weiteren wurde der Datensatz des Bundesamts für Eich-und Vermessungswesen (BEV Landbedeckung – Lisa light) der Jahre 2015 und 2021 für den Siedlungsraum von Wien hinsichtlich Bedeckung von Bäumen, Sträuchern und Niedrigvegetation ausgewertet. Der Versiegelungs-Layer aus dem ÖROK-Bodenmonitoring wurde herangezogen, um den Anteil des versiegelten Bodens im Siedlungsraum zu bestimmen.

Die Flächen von Grünland und Ackerland nahmen in Wien in den vergangenen 20 Jahren am stärksten ab (-13 % bzw. -11 %), während der Siedlungsraum um 4 % und die Waldfläche um 0,6 % anstiegen. Die Kronenüberschirmung von Bäumen in der Kategorie Siedlungsraum betrug im Jahr 2015 22 %, jene von Sträuchern 4 % und 35 % des Siedlungsraums waren mit Niedrigvegetation (z. B. Wiesen) bedeckt. Die Kronenüberschirmung der Bäume wurde auch für 2021 ausgewertet, sie lag bei 19 % im Siedlungsraum und damit 3 %-Punkte unter dem Wert für 2015. Der Anteil an versiegelter Fläche in der Kategorie Siedlungsraum von Wien betrug 60 % im Jahr 2021.

Für die Berechnung der THG-Emissionen- bzw. -Senken wurden für die quantitativ bedeutendsten Kategorien Wien-spezifische Emissionsfaktoren verwendet. Basierend auf den Daten der Stichprobeninventuren der Waldgebiete (Wienerwald Ertragswald, Biosphärenwald Wienerwald, Nationalpark Lobau und Lobau Ertragswald) wurden Zuwachs und Nutzung der Waldbiomasse sowie der Vorrat

für Waldbiomasse und Totholz ausgewertet und Kohlenstoffvorratsänderungen für den Wald abgeleitet. Der durchschnittliche jährliche Kohlenstoffzuwachs der Biomasse des Waldes beträgt 3,1 Tonnen C/ha/Jahr, der durchschnittliche jährliche Kohlenstoffverlust (durch Nutzung und Mortalität) der Waldbiomasse in Wien beträgt -1,5 Tonnen C/ha/Jahr. Der Kohlenstoffvorrat der Waldbiomasse in Wien beträgt durchschnittlich 118,2 Tonnen C/ha. Der Totholzvorrat beträgt in etwa 3,2 Tonnen C/ha.

Für die restlichen Landnutzungskategorien und Kohlenstoffpools wurden hauptsächlich die Emissionsfaktoren aus der Nationalen THG-Inventur (Umweltbundesamt, 2024) verwendet. Für die Kategorie Siedlungsraum wurde zusätzlich auf Emissionsfaktoren für die Baum- und Strauchbiomasse (Umweltbundesamt, 2023a) zurückgegriffen, um die Veränderung der Biomasse in der Kategorie Siedlungsraum bezüglich Treibhausgasen zu quantifizieren. In diese Studie gingen auch die Daten aus dem Wiener Baumkataster ein.

Die LULUCF-Treibhausgasbilanz der Stadt Wien stellt für die Jahre 2018–2020 eine durchschnittliche Netto-Senke von etwa 11.000 Tonnen CO_2 Äq. pro Jahr dar. Diese Netto-Senke wird hauptsächlich von der Senkenleistung des Waldes bestimmt, der pro Jahr netto ca. 43.000 Tonnen CO_2 aufnimmt und somit die Emissionen aus den anderen Landnutzungskategorien kompensiert. Der Siedlungsraum ist die größte THG-Emissionsquelle im LULUCF Sektor und setzt im Schnitt jährlich 29.000 Tonnen CO_2 Äq. frei. Die Hauptursache für diese Emission ist der Verlust an Baumbiomasse in der Kategorie Siedlungsraum. Der Anteil von Vegetation, insbesondere von Bäumen, ist ein wichtiger Hebel, der ausschlaggebend sein kann, ob der LULUCF Sektor eine Netto-Quelle oder -Senke ist.

Generell ist der Anteil der THG-Senke des LULUCF Sektors an den Gesamtemissionen der Stadt Wien sehr gering, er kann ca. 1,3 % der THG-Emissionen der anderen Sektoren kompensieren. Jedoch kann sich dieses Verhältnis aufgrund von veränderter Bewirtschaftung oder Landnutzung auch ändern. Eine auch im Sinne der Klimawandel-Anpassung steigende Baumkronenüberschirmung bzw. Begrünung im Siedlungsgebiet zur Kühlung des Stadtgebiets könnte auch die Senke des LULUCF Sektors in Wien erhöhen.

SUMMARY

This report contains the results of a work package as part of the "Vienna Urban Carbon Laboratory" (VUCL) project, which was carried out on behalf of the Vienna Science and Technology Fund (WWTF). The VUCL project investigates the contribution of biogenic sinks and emission sources to Vienna's CO_2 balance by combining different approaches. For this purpose, a LULUCF greenhouse gas (GHG) inventory was also prepared based on the methods used in the National GHG Inventory (Umweltbundesamt, 2024). A time series of three years (2018-2020) was established based on the 2006 IPCC Guidelines for National GHG Inventories.

The necessary input data (activity data and emission factors) were collected, analysed and estimated, including Vienna-specific activity data and emission factors for Forest land. The results of an earlier project for the City of Vienna from 2014 were also used, in which estimates for Vienna's forests (including afforestation and deforestation) were already carried out (Umweltbundesamt, 2016).

In order to quantify land use and land-use change areas, the mapping data of Vienna (Realnutzungskartierung, 2023) were evaluated for the years 2001, 2005, 2009, 2016 and 2020 and translated into the categories forest land, cropland, grassland, wetlands and settlements of the LULUCF greenhouse inventory. Furthermore, the data set of the Federal Office of Metrology and Surveying (BEV Landbedeckung – Lisa light) was evaluated for the years 2015 and 2021 for the settlement area of Vienna with regard to the cover of trees, shrubs and low vegetation. The sealing layer from the ÖROK soil monitoring was used to determine the proportion of the sealed soil in the settlement area.

The areas of grassland and cropland in Vienna have decreased the most in the past 20 years (-13% and -11%), while the settlement area has increased by 4% and the forest area by 0.6%. The crown cover of trees in the settlement category was 22% in 2015, those of shrubs 4% and 35% of the settlement area was covered with low vegetation (e.g. lawn). The crown cover of the trees was also evaluated for the year 2021, in which it covered 19% of the settlement area. The proportion of sealed area in the category settlement of Vienna was 60%.

Vienna-specific emission factors were used for the calculation of CO_2 emissions and removals for the quantitatively most important categories. Based on the data of the sample inventories at the forest areas in Vienna (Wienerwald forest in yield, Biosphere Forest Wienerwald, National Park Lobau and Lobau forest in yield), the forest biomass increment and drain, as well as the carbon stocks of the forest biomass and dead wood were evaluated and carbon stock change rates were derived. The average annual increment of forest biomass is 3.1 tons C/ha/year, the average annual carbon loss (from harvest and mortality of biomass) is -1.5 tons C/ha/year. The carbon stock of forest biomass averages 118.2 tons C/ha. The deadwood stock is about 3.2 tons C/ha.

For the other land use categories and carbon pools, the emission factors from the National Greenhouse Gas Inventory (Umweltbundesamt, 2024) were mainly used. For the settlement category, the emission factors for tree and shrub biomass from the Austrian greenhouse gas inventory according to a new study by Umweltbundesamt (2023b) were also used to quantify the change in the crown cover of trees. The data from the Viennese tree cadaster were also included in this study.

The LULUCF greenhouse gas inventory of Vienna represents an average net sink of about 11,000 tons of CO_2eq. per year for the years 2018–2020. This net sink is mainly determined by the sink capacity of the forest land, which absorbs net approximately 43,000 tons of CO_2 per year and thus compensates for emissions from the other land use categories. The settlement category is the largest source of emissions in the LULUCF sector and amounts to an average of 29,000 tons of CO_2eq per year. The main cause of this emission is the loss of tree biomass in the settlements category. Here, the share of vegetation, especially trees, is an important lever, which can determine whether the LULUCF sector is a net source or sink.

In general, the LULUCF sector's share of total greenhouse gas emissions in Vienna is very low; it can offset around 1.3% of GHG emissions from other sectors. However, this ratio may also change due to changes in land use and management of land. An increasing canopy cover or greening in the settlement area for cooling the urban area (for the purpose of climate change adaptation) could also increase the sink of the LULUCF sector in Vienna.

1 INTRODUCTION

At present GHG inventories are only prepared for the national level, e.g. to meet reporting obligations under the United Nations Framework Convention on Climate Change (UNFCCC), to track progress against climate targets in the context of the Paris Agreement and the EU climate targets. In Austria, the Bundesländer Luftschadstoff-Inventur (BLI) is being prepared since many years on the level of the federal regions. The latter, however, only includes greenhouse gas inventories for the sectors Energy, Industrial Products and Product Use, Agriculture and Waste. For the land use, land use change and forestry (LULUCF) sector, only national estimates are available. In addition, there are currently no LULUCF inventories available for cities in Austria and the compilation of the Vienna LULUCF GHG inventory is the first time that a LULUCF inventory has been compiled for the regional and municipal level.

In the Vienna Urban Carbon Laboratory (VUCL) project, measurement-based emissions monitoring methods are tested and compared against the inventory-based estimates. The comparison between the greenhouse gas inventory on the one hand and net fluxes inferred from atmospheric measurements on the other, must consider and account for all sources and sinks, particularly with respect to carbon dioxide (CO_2). The two CO_2 inventories of Vienna, namely the Bundesländer Luftschadstoff-Inventur, BLI (Umweltbundesamt, 2023b) and the emission cadaster (EMIKAT) of the city of Vienna, do not include biogenic CO_2 emissions and removals of the land use, land use change and forestry (LULUCF) sector, but they are also required for an overall balance to compare with the emission measurements. As part of the VUCL project, a greenhouse gas inventory for the LULUCF sector for the city of Vienna was therefore prepared in a dedicated work package in order to estimate the biogenic contribution to the city's CO_2 balance.

The section 2 on the methodology is structured similar to a National GHG inventory report (NIR) and it provides information on the land use areas, as well as information on the methods applied for each land use category and carbon pool. In section 3 the results are presented separately for each land use category and for the total LULUCF sector, including an interpretation of the results and conclusions.

2 METHODOLOGY AND DATA SOURCES

2.1 Introduction to GHG inventories for the LULUCF sector

The LULUCF greenhouse gas inventory produces the annual increases and decreases in the carbon pools of a land use category as an indication for the related CO_2 emissions and removals. To calculate the emissions and sinks of an activity or land use on a given area, the net annual changes in the carbon pools are calculated. The following land use categories, carbon pools and greenhouse gases (GHG) are considered in the inventory:

Table 1: Elements of a LULUCF GHG inventory

Land use category	Carbon pool	Greenhouse gases
Forest land	Above ground biomass	CO_2 (emissions and removals)
Cropland	Below ground biomass	CH_4 (emissions)
Grassland	Dead wood	N_2O (emissions)
Wetlands[1]	Litter	
Settlements[2]	Soil (mineral and organic)	
Other land[3]	Harvested wood products[4]	

Emissions and sinks are essentially calculated according to this basic calculation, which must be prepared for each land use change, for managed land without land use change and for each pool (if any):

Annual emission or sink = area on which an activity or land use change takes place x Annual change in carbon stock (of the respective pools)

In the LULUCF sector, activity data refers to the area data of the main land use categories, as well as the annual land use changes between the categories and

1 According to the definition in the Austrian National GHG inventory this category includes rivers, lakes, storage reservoirs, bogs and peatland.

2 This category includes e.g. buildings and infrastructure, roads, transport areas, sports facilities, landfills and green areas in settlements that are neither cropland, grassland nor forest.

3 This category includes, among others, glaciers, rocks, alpine plant communities that are not agriculturally managed, and can be used to correct any discrepancies in the data set so that the area sum of all categories always corresponds to the total area of the country.

4 Harvested Wood Products is a special case and is included in the reporting like a separate category, although strictly speaking it is a carbon pool. The change in the carbon pools of sawn wood, panels and paper based on domestic harvesting and production is thus recorded.

the land without land use changes (remaining in the same category over time). These data are needed for a specific time series to map the long-term impacts of land use and land use changes in the carbon pools. For example, to calculate the carbon change for the year 2020, a land use change time series would be needed from 2001 (i.e. 20 years back).

Regarding the emission factors, where available Vienna-specific data was used or the national factors were modified, if applicable (e.g. forest land, settlements). In all other cases, the emission factors from the National GHG Inventory were applied (see Umweltbundesamt, 2024).

In this project, a time series of LULUCF emissions and removals were estimated for the years 2018, 2019 and 2020 due to the availability of area information data.

The following chapters describe in more detail the input data needed to calculate emissions/sinks in the land use sector.

2.2 Area information and land use change matrix

The City of Vienna has an extensive data set (Realnutzungskartierung, 2023) for the urban area based on the evaluation of aerial photographs since 1981, divided into use categories. The data is available on data.gv.at and includes the years 2001, 2003, 2005, 2008, 2009, 2012, 2016, 2018 and 2020. According to the city's homepage, there are evaluations since 1981, but they are not available online. The time series is continued approximately every two years, depending on the availability of orthophotos.

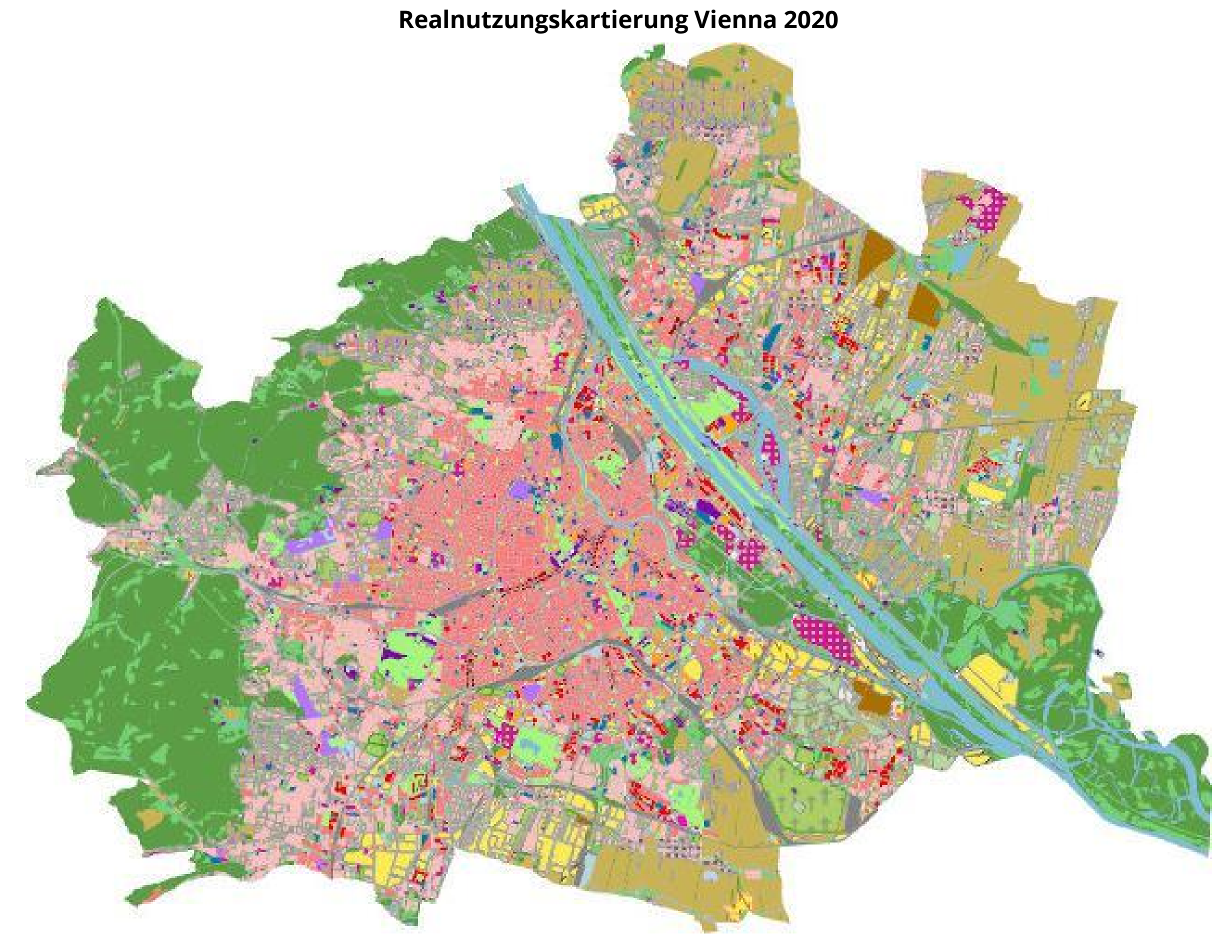
For this project, we used the datasets for the years 2001, 2005, 2009, 2016 and 2020, which means a time series from 1999 to 2020 is required for all land use categories covering the municipality of Vienna. The data source Realnutzungskartierung (RNK) distinguishes 43 land use classes until 2005 and 32 land use classes from 2009 onwards for which a cross-walk table was prepared to match them with the five LULUCF categories (it should be noted that the category Other land is not occurring in Vienna). Table 2 shows as an example the crosswalk for the land use classes applied from 2009 onwards.

Table 2: Crosswalk between the categories of Realnutzungskartierung and the LULUCF categories

Categories of the Realnutzungs-kartierung (NUTZUNG_LEVEL3)	code	LULUCF categories
Acker	27	Annual cropland
Wald	30	Forest land
Wiese	31	Grassland
Gärtnerei, Obstplantage	29	Perennial cropland
Weingarten	28	Perennial cropland
Bahnhöfe, Bahnanlagen	22	Settlements
Bildung	12	Settlements
Büro- und Verwaltungsstrukturen	5	Settlements
dichtes Wohn(misch)gebiet	3	Settlements
Energieversorgung, Rundfunkanlagen	16	Settlements
Friedhof	26	Settlements
Geschäfts-, Kern- u. Mischgebiet	7	Settlements
Gesundheit und Einsatzorganisationen	11	Settlements
großvolumiger, solitärer Wohn(misch)bau	4	Settlements
Industrie, prod. Gewerbe, Großhandel inkl. Lager	9	Settlements
Kläranlage, Deponie	15	Settlements
Kultur, Freizeit, Religion, Messe	10	Settlements
locker bebautes Wohn(misch)gebiet	1	Settlements
Militärische Anlagen	14	Settlements
Mischnutzung wenig dicht / alter Ortskern	8	Settlements
Park, Grünanlage	24	Settlements
Parkplätze, Parkhäuser	21	Settlements
solitäre Handelsstrukturen	6	Settlements
Sport und Bad (Indoor)	13	Settlements
Sport und Bad (Outdoor), Camping	25	Settlements
Straßenraum begrünt	19	Settlements
Straßenraum unbegrünt	20	Settlements
Transformationsfl., Baustelle, Materialgewinnung	18	Settlements
Transport und Logistik inkl. Lager	23	Settlements
Wasserversorgung	17	Settlements
Wohn(misch)gebiet mittlerer Dichte	2	Settlements
Gewässer inkl. Bachbett	32	Wetlands

The following figures show the map of Vienna based on the Realnutzungs-kartierung (Figure 1) and the map for the main LULUCF categories (Figure 2) for the year 2020.

Figure 1: Original map based on Realnutzungskartierung for the year 2020



Source: Stadt Wien, 2022

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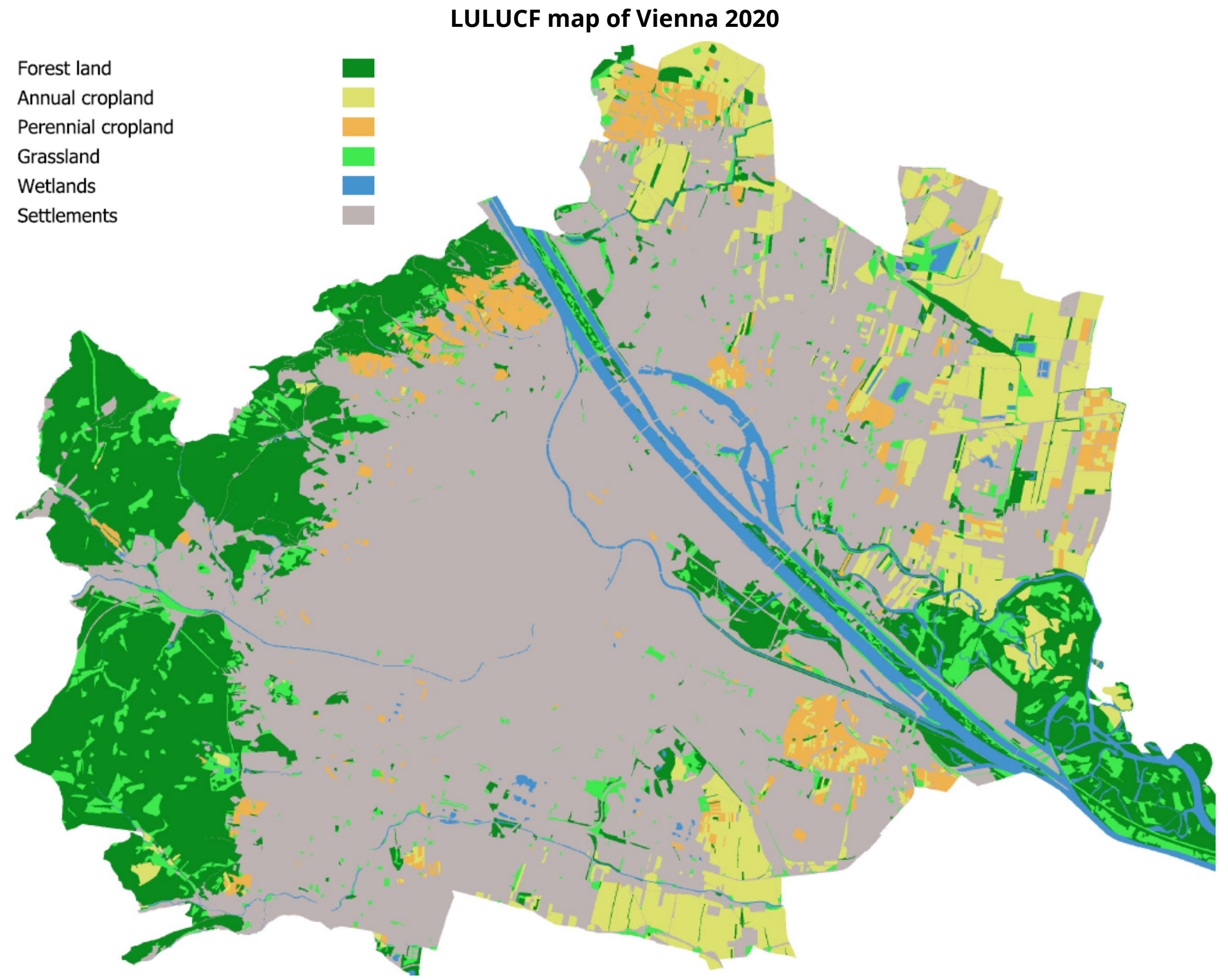
Figure 2: Result of the map with the LULUCF classification for the year 2020 (own compilation)



Source: Umweltbundesamt, based on Stadt Wien 2022

Using QGis in a second step the maps of different years where harmonized (the road network was not mapped in certain years) and vector information was rasterized using a 5m pixel size. At pixel level, changes in land classification between the following year-pairs were calculated and aggregated:

- 2001/2005
- 2009/2016
- 2016/2020

Before calculation of land-use changes, the changes between years at pixel-level were subject to the following correction procedures:

- Changes from one land use to another, which were then followed by a subsequent change back to the original land use were filtered by correcting the intermediate land use to the pre and prior land use classification.
- Implausible land use changes (changes from Settlements to the categories Forest land, Cropland and Grassland) were rejected. Working backwards from the 2016/2020 pair, such changes were cancelled by correcting the

initial land-use e.g. 2016 to that of the subsequent land use. Pixels changing between 2016 and 2020 from Settlement to Forest land, would be corrected by changing the 2016 land use to Forest land.

Following the above corrections, the gross total land-use changes between year-pairs were converted to annual change rates by dividing by the number of years between respective pairs. Note that changes between the pair 2005/2009 were not calculated from the pixel data due to a systematic change in the land-use classification system of the RNK. Therefore, annual land use changes between 2005 and 2009 were gap-filled by interpolating between respective values derived from the 2001/2005 and 2009/2016 pairs. The annual land use changes derived from the 2001/2005 pair were furthermore extrapolated to the years 2000 and 1999 to provide a time series of annual land use changes rates for all land-use change combinations for all years between 1999 and 2020.

In addition to the time series of annual land use changes, annual total areas for each land-use category were estimated. The (corrected) pixels of the 2020 layer were aggregated for each of the five land use categories. The difference between official area of the city (41,487 ha) and the sum of land-use pixels resulted in 22 ha of missing area, that was corrected for by adding this residual to the total Forest land area. Once fully corrected, total land use areas for the years 2019 back to 1999 were extrapolated based on the time series relevant land-use changes to and from the respective categories.

In addition, for the settlements category we analysed the crown cover of shrubs and trees, as well as the coverage with low vegetation, which was assessed for the year 2015, with an additional assessment for the year 2021 to estimate the tree cover change. For this purpose, we used the new data set “Lisa light” which is provided by the Bundesamt für Eich- und Vermessungswesen (BEV).

To estimate the soil carbon stock in the settlement category, we used the result of an analysis conducted for Austria, based on the National Sealing Layer (Versiegelungslayer) which is a new data product that was established in the context of the ÖROK – Soil monitoring (ÖROK, 2023) and is also based on Lisa light.

The Lisa light data set, with an original resolution of 20 x 20 cm, represents an automated evaluation of the Austrian orthophoto survey and differentiates between six land cover classes:

1. tall vegetation/trees (> 5m),
2. open ground/vegetation-free areas/sealed areas,
3. medium vegetation/shrubs (2–5 m),
4. buildings,
5. water bodies,
6. low vegetation (< 2 m).

Classes 1 and 3 are addressed as areas planted with trees and shrubs, which are used to calculate the canopy cover in the settlement category of Vienna.

The Soil Sealing Layer is based on the land cover class 2 of the LISA light data. However, the high resolution of LISA light means that buildings and traffic areas are partially covered by the canopy cover. On the one hand, this is useful for calculating the canopy cover in the settlement area, but on the other hand it is a hindrance when recording the sealed area, which cannot be fully represented with LISA light alone. For this reason, the raster-based sealing from LISA light was combined with vector data for buildings and traffic areas in the course of ÖROK Bodenmonitoring. The results of the further GIS based analysis for Vienna are summarized in Table 3.

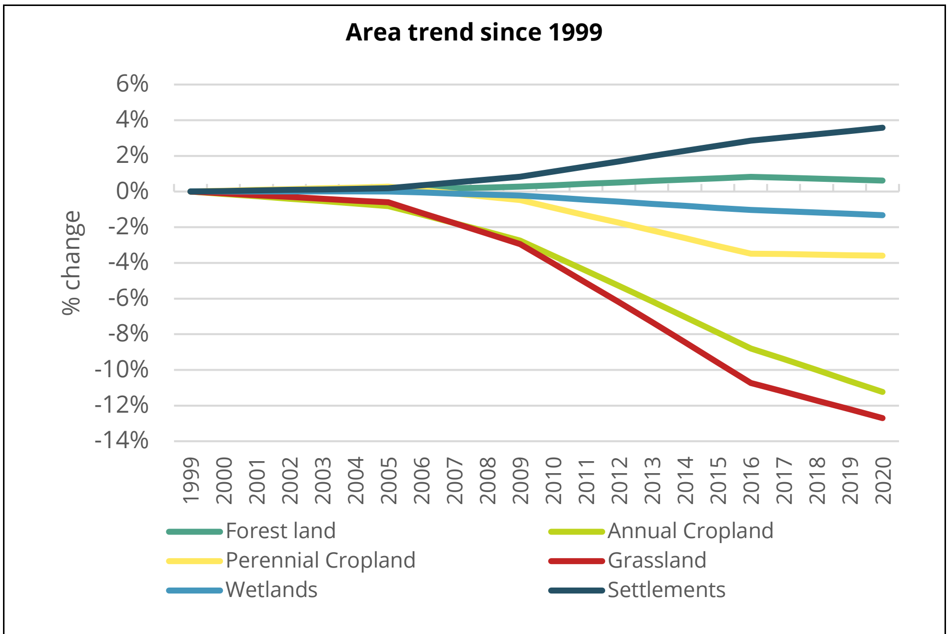
Table 3: Vegetation cover and sealed soil in the settlement category of Vienna

Category / Year	2015	2021
Crown cover of trees %	22	19
Crown cover of shrubs %	4	–
Cover of low vegetation %	35	–
Share of sealed soil in settlements (including sealed areas under the tree and shrub canopies) %	60	–

It should be noted that for the soil carbon stock estimates of the settlement category a sealing share of 63% consistent with the ÖROK Bodenmonitoring approach was used.

Based on this information we compiled the land-use change matrix, which includes the annual land use changes between the categories and the total area of each category for Vienna. The category cropland was further split into annual and perennial cropland, as this differentiation is needed for the estimation of the carbon stock changes.

Figure 3: Relative change in area trend of the main land use categories in Vienna since 1999



Source: Umweltbundesamt

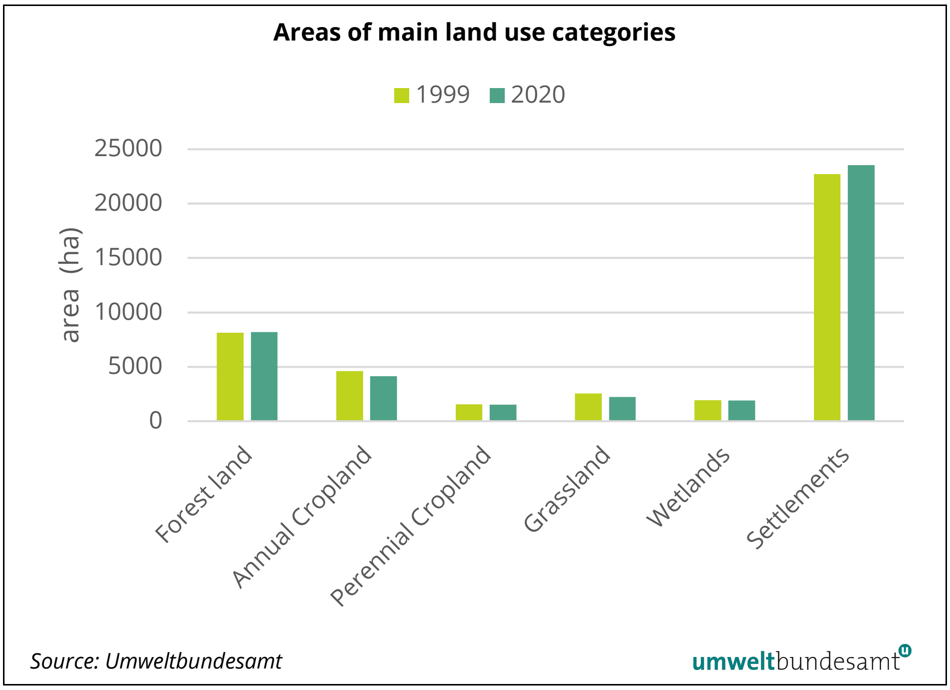


Figure 4: Comparison of areas in 1999 and 2020 per main land use category in Vienna

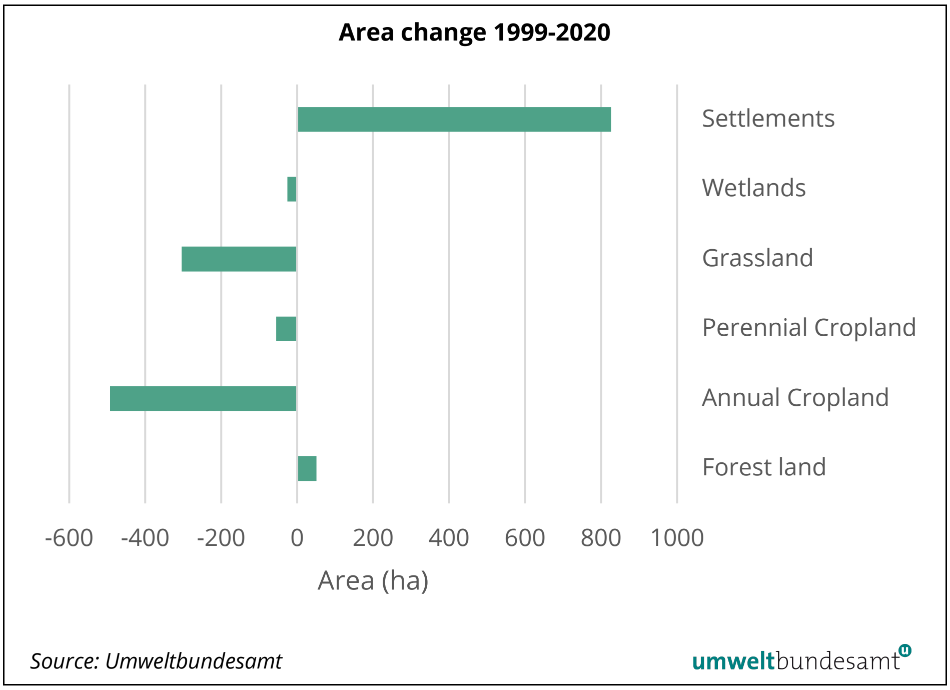
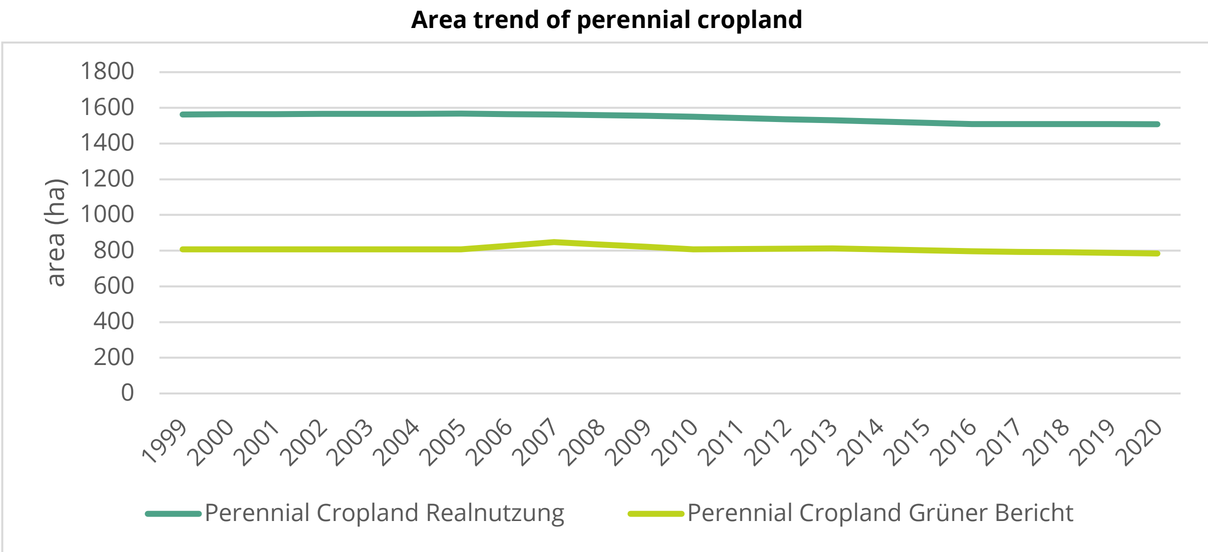


Figure 5: Area changes between 1999 and 2020 per main land use category in Vienna

For perennial cropland in addition, area information on the areas of different perennial crop types, such as vineyards, orchards, energy crops and tree nurseries, is required. This data were derived from the statistics of different editions of Grüner Bericht (2005, 2007, 2010, 2022, 2015, 2021 and 2022 edition). As the total area of perennial cropland in Grüner Bericht is substantially lower than the area according to the Realnutzungskartierung, we calculated the relative share of the perennial crops in total perennial cropland from Grüner Bericht and multiplied it with the total perennial cropland of Realnutzungskartierung to adjust the data (see Figure 6).

Figure 6: Comparison of perennial cropland area in Vienna from Realnutzungskartierung und Grüner Bericht



Sources: Grüner Bericht, Stadt Wien

2.3 Methodology per main land use category

The 2006 IPCC Guidelines for National Greenhouse Gas inventory (Vol. 4) provide the methodological rules to estimate the emissions and removals from the LULUCF sector. Whenever available, specific emission factors for Vienna were used (e.g. for biomass and dead wood for forest land). For the other categories we used the same emission factors as for the Austrian GHG inventory or we slightly modified them according to the circumstances of Vienna (e.g. the mineral soil carbon stock changes from and to forests).

For some categories and pools, no estimates were prepared for the LULUCF inventory of Vienna for following reasons:

- The category Harvested Wood Products is not occurring in Vienna, as according to the method applied in line with the 2006 IPCC Guidelines only semi-finished wood products derived from domestic harvest can be accounted. As there is no sawmill based in Vienna, no estimates are made for this category.
- Other land is also not occurring in Vienna according to the data from Realnutzungskartierung.
- As there are no organic soils occurring in Vienna, no emissions were calculated for these carbon stocks.

2.3.1 Forest land

Representative emission factor data for the Viennese forests were derived from the two largest forest owners, the City of Vienna (owning 74% of the forest area) and the Austrian Federal Forests (ÖBF, owning 12% of the forest area) (WEP, 2016). Therefore, the forest condition of the different regions (floodplain forests in the East and beech forests in the West) and different management types (nature restoration and timber production) are covered. In the city of Vienna, three subdivisions administer the forests, namely MA58, MA49 and MA42.

The necessary data from the sample inventories[5] of the forests of the City of Vienna based on angle counting sampling of MA49 and parameters for the GHG inventory calculation where submitted by DI Werner Fleck. The information included:

- living biomass stock separated by woody species in stemwood volume,
- increment separated by woody species in stemwood volume/ha/year,
- drain separated according to woody species in stemwood volume/ha/year,
- change in standing deadwood in stemwood volume/ha/year.

Dr. Alexandra Wieshaider from ÖBF delivered data on the biomass stock, increment and drain data as well as deadwood increment and stock based on the company's own forest inventory.

2.3.1.1 Biomass

To estimate the net emissions/removals from forest land (which is divided into the sub-categories forest land remaining forest land and land converted to forest land), the calculation consists of three steps:

1. Vienna-specific biomass increment and drain values for different regions and management regimes were derived from the above mentioned data providers and aggregated based on their share in the total forest land of Vienna. Increment and drain estimates of the forests administrated by the City of Vienna were based on two field recordings per region, which were conducted in an interval of 10 years. For the forest in yield in the National Park Lobau just one field inventory was recently completed (in 2021/23). The most recent field inventories are the "Wienerwald forest in yield inventory" carried out in 2017/20, "Biosphärenpark Kernzonen inventory" carried out in 2020 and the "Nationalpark Lobau inventory" carried out in 2021/23. Because only two points in time were available, the gains and losses were assumed constant over the time series. The ÖBF increment data is based on a 2018 field recording and the standing stock is based on a 2019 forest inventory. An average harvest value was calculated based on the provided annual harvest data for the last 13 years. The aggregated annual increment in stemwood volume for the forests in Vienna is estimated to be

[5] Wienerwald yield forest inventory 2017–2020, core zone inventory 2020–2021, NP natural area inventory 2018/19 and yield forest Lobau except NP 2021–2023

7.37 m^3/ha/year and the annual drain of stemwood volume amounts to 3.75 m^3/ha/year. Based on the methodology used in National GHG Inventory of Austria (Umweltbundesamt, 2024), these data were expanded and converted into carbon stocks of total trees to calculate the carbon stocks and changes in biomass in the total forest land (see Table 6). The same country specific conversion factors and biomass functions for tree branches, needles and below ground biomass as in the national inventory were used.

2. To obtain the biomass carbon stock changes for forest land remaining forest land, in line with the 2006 IPCC Guidelines, the carbon stock changes of land converted to forest land (step 3) need to be subtracted from the total result of step 1).

Table 4: Emission factors for biomass in forest land of Vienna. Note: the standing stock is not used in the calculation of forest land remaining forest land, but to account for the carbon losses in deforestation (forest land converted into other land uses)

Category	Stemwood volume m^3/ha/yr or m^3/ha	Carbon stock of total trees t C/ha/yr or t C/ha
Annual increment	7.37	3.1
Annual drain	3.75	1.5
Standing stock	289.82	118.36

3. The estimation of net emissions/removals for land use changes to forest land is based on the measured biomass increment and losses on afforestation areas “Donauinsel-Wohlfahrtsaufforstungen” and “Laaerberg-Mannswörth” for which a net gain in stemwood volume of 8.25 m^3/ha/year was recorded.

Table 5: Emission factors for biomass in afforestation

Category	Stemwood volume (m^3/ha/yr)	Carbon stock change of total trees (t C/ha/yr)
Annual net increment	8.25	3.5

2.3.1.2 Dead wood

The estimates for the carbon stock changes in dead wood in forest land include only standing dead wood, because any falling dead tree (part) is accounted for as a C flux to litter/soil. The annual carbon stock changes in deadwood are based on two field recordings, therefore the net change had to be assumed constant over the time series. The dead wood data was converted into carbon stocks in line with the country-specific factors used for deadwood in the National GHG Inventory (Umweltbundesamt, 2024).

To calculate the dead wood carbon stock changes in forest land remaining forest land, the same steps (1–3) as for biomass have to be carried out. First, the net carbon stock changes in dead wood based on the net increase from Table 6 is calculated for the total forest land. Second, the dead wood carbon stock changes of land converted to forest land have to be calculated (see next paragraph) and finally this result needs to be subtracted from the result of step 1.

For land converted to forest land, it is assumed that in the previous land use change category no dead wood is present and that the dead wood carbon stock of the new forest is built up over the 20 years transition period to reach the average standing stock. Therefore, the annual dead wood carbon stock change factor for land converted to forest land is the dead wood standing stock divided by 20 (Table 6, row 2 and 3).

Table 6: Emission factors for dead wood in forest land and land converted to forest land

Category	Standing dead stemwood volume (m^3/ha) and its annual change (m^3/ha/yr)	Standing dead wood carbon stock (t C/ha) and its annual change (t C/ha/yr)
Annual deadwood net increase remaining forest land	0.3	0.08
Standing deadwood stock total forest land	12.3	3.22
Annual deadwood increase in land converted to forest land	–	0.05

2.3.1.3 Litter

In forest land remaining forest land it is assumed that the carbon stock of litter is in equilibrium and therefore no emissions/removals are estimated.

The calculation of litter carbon stock changes for land converted to forest land is based on measured litter values from a study conducted in a Vienna beech forest which yielded 5.5 tC/ha in litter biomass (Leitner et al. 2016). It is assumed that this litter stock is built up over the 20 years transition period after land-use change to forest land.

Table 7: Emission factor for litter in forest land and land converted to forest land

Category	tC/ha or tC/ha/yr
Litter carbon stock	5.5
Annual increase of litter carbon stock	0.275

2.3.1.4 Mineral soil

In forest land remaining forest land it is assumed that the carbon stock of mineral soil is in equilibrium and therefore no emissions/removals are estimated.

The soil carbon stock changes in land use changes to and from forest land were based on the “land-use soil C stock look-up table” of the National GHG Inventory (Table 253, Umweltbundesamt, 2024). The table is stratified according to the specific soil carbon pools of different land use changes and additionally, according to five forest growth regions in Austria (Bohemian Massif, Inner Alps, Calcareous Alps, Foothills and Alpine ridge). Therefore, the carbon stocks of the stratum representative for Viennese conditions, namely the Foothills, was used to calculate the carbon stock changes. The slightly different mineral soil carbon stocks used for conversions to and from forest land are caused by different shares of the subcategories under the main land use categories composing the total area converted to forest land or from forest land, respectively. Zero values indicate that such a land-use change does not occur.

Table 8: Initial and final mineral soil carbon stocks (0–50 cm) for land use changes from and to forest land

Category	For conversions to forest land t C/ha	For conversions from forest land t C/ha
Forest land	77	77
Cropland	66	67
Grassland	93	109
Wetlands	0	0
Settlements	0	43

2.3.1.5 Direct and indirect N_2O emissions from managed soils

Increases in available N due to soil C losses from human induced land use changes enhance the mineralisation of soil organic N and therefore cause N_2O emissions. In addition to the direct N_2O emissions from mineralized soil nitrogen, indirect N_2O emissions occur due to the mineralized N, which is leached from the soil. We used the same methodology as for the National GHG inventory to calculate the direct and indirect N_2O emissions (see chapter 6.2.4.2.4 and 6.2.4.2.5 of Umweltbundesamt, 2024). For forest land, N_2O emissions occur from land use changes of Grassland to Forest land. It should be noted that these N_2O emissions are only a very small source in the GHG inventory of Vienna.

2.3.2 Cropland (annual and perennial crops)

For cropland, net emissions/removals are estimated for cropland remaining cropland, including perennial cropland remaining perennial cropland, and conversions between annual and perennial cropland. For annual cropland remaining annual cropland, it was assumed that there are no carbon stock changes (in line with the 2006 IPCC Guidelines). Regarding land use changes, only changes from forest land and grassland to cropland are occurring.

2.3.2.1 Biomass

For cropland remaining cropland in consistency with the National GHG inventory we only estimated emissions/removals for the sub-category perennial cropland remaining perennial cropland to capture the impacts of crop rotation. The areas of perennial crops were based on Grüner Bericht/Realnutzungskartierung and the biomass emission factors were taken from the National GHG inventory (see Table 9). For annual cropland remaining annual cropland no carbon stock changes are estimated, as it is assumed that the biomass is in equilibrium.

For conversions between annual and perennial cropland we also used the same emission factors as from the National GHG inventory (see Table 9, columns A and B) and the area data was derived from the Realnutzungskartierung.

Land use changes of forest land and grassland to cropland occur, for which emissions and removals are estimated. For forest land converted to cropland, the forest biomass loss is derived from data provided by the city of Vienna and the ÖBF (see Table 6, chapter 2.3.1. forest land). The biomass loss of grassland is provided in Table 11. The biomass gains data for cropland is presented in Table 9, column A.

Table 9: Emission factors of cropland biomass for land use changes from and to annual and perennial cropland as well as remaining perennial cropland

Category	A	B
Cropland sub-category	Cropland biomass gains (t C/ha/yr)	Cropland biomass losses (t C/ha/yr)
LUC to and from annual cropland, respectively	6.7 (in the year of land-use change)	-6.7 (in the year of land-use change)
LUC to and from perennial cropland, respectively	0.3 (over 20 years after land-use change)	-6.1 (in the year of land-use change)
Perennial cropland remaining perennial cropland	Vineyards: 0.096 (over 35 years)	Vineyards: -3.37 (at the end of the rotation period
	Orchards: 0.745 (over 18 years)	Orchards: -13.41 (at the end of the rotation period)

2.3.2.2 Dead wood

Dead wood losses are reported when forest land is converted into cropland. The emission factor for the carbon loss of dead wood is provided in Table 6.

2.3.2.3 Litter

Litter losses are reported when forest land is converted to cropland. The emission factor for the carbon loss of litter is provided in Table 7.

2.3.2.4 Mineral soil

For annual cropland remaining annual cropland and perennial cropland remaining perennial cropland it is assumed that the carbon stock of mineral soil is in equilibrium and therefore no emissions/removals are estimated.

For conversions between annual and perennial croplands, the mineral soil carbon stocks used in the National GHG inventory (Umweltbundesamt, 2024) were taken for cropland (Table 10). The difference between initial carbon stock minus the carbon stock of the final land use category is accounted for a transition period over 20 years. The same methodology is applied for the other land use changes to cropland. The carbon stocks for these land-use change categories can be found in Table 8 (land use changes from forest land to cropland) and Table 10 and Table 12 (land use changes from grassland to cropland) respectively.

Table 10: Carbon stocks of cropland mineral soils for changes from and to cropland (except forest land) and conversions between annual and perennial cropland

Cropland sub-category	Carbon stock of 0–30 cm mineral soil (t C / ha)
Annual cropland	50
Perennial cropland	57

2.3.2.5 Direct and indirect N_2O emissions from managed soils

N_2O emissions from managed soils occur from land use changes from forest land and grassland converted to cropland, as the soil carbon stocks of forest land and grassland are higher than in cropland and therefore carbon losses lead to related N_2O emissions (methodological references are provided in section 2.3.1).

2.3.3 Grassland

Net emissions/removals are estimated for land converted to grassland, namely forest land converted to grassland and cropland converted to grassland (including annual and perennial cropland).

2.3.3.1 Biomass

For grassland remaining grassland it is assumed that there are no carbon stock changes in the biomass (equilibrium assumption).

Land use changes of forest land and cropland to grassland occur, for which emissions and removals are estimated. For forest land converted to grassland, the forest biomass loss is derived from data provided by the city of Vienna and the ÖBF (see Table 6, chapter 2.3.1 forest land). The biomass loss of cropland is provided in Table 9, column B for perennial and annual cropland. The biomass gains data for grassland is presented in Table 11, column A.

Table 11: Emission factors of grassland biomass for land use changes from and to grassland

Category	**A**	**B**
Grassland sub-category	Biomass gains (t C/ha/yr)	Biomass losses (t C/ha/yr)
LUC to and from Grassland, respectively	5.7 (in the year of land-use change)	-5.7 (in the year of land-use change)

2.3.3.2 Dead wood

Dead wood losses are reported when forest land is converted to grassland. The emission factor for the carbon loss of dead wood is provided in Table 6.

2.3.3.3 Litter

Litter losses are reported when forest land is converted to grassland. The emission factor for the carbon loss of litter is provided in Table 7.

2.3.3.4 Mineral soil

For grassland remaining grassland, it is assumed that the carbon stock of mineral soil is in equilibrium and therefore no emissions/removals are estimated.

For land use changes from forest land and cropland to grassland, the soil carbon stocks used in the National GHG inventory (Umweltbundesamt, 2024) were taken for grassland (Table 12). The difference between initial carbon stock minus the carbon stock of the final land use category is accounted for a transition period over 20 years. The carbon stocks for these land-use change categories can be found in Table 8 (land use changes from forest land to grassland) and Table 10 and Table 12 (land use changes from cropland to grassland) respectively.

Table 12: Carbon stocks of grassland mineral soils for changes from and to grassland (except forest land)

Category	**Carbon stock in 0–30 cm mineral soil (t C / ha)**
Grassland	70

2.3.4 Wetlands

Forest land and settlements converted to wetlands were detected, for which emissions were estimated.

2.3.4.1 Biomass

It is assumed that the wetlands category (i.e. surface waters) does not include any living biomass, therefore no net emissions/removals are calculated for wetlands remaining wetlands.

For forest land converted to wetlands, the forest biomass loss is derived from data provided by the city of Vienna and the ÖBF (see Table 6, chapter 2.3.1. forest land). The biomass loss of settlements converted to wetlands is provided in Table 13. There are no gains calculated for wetlands, because it is assumed that there is no biomass in this category.

2.3.4.2 Dead wood

Dead wood losses are reported when forest land is converted to wetlands. The emission factor for the carbon loss of dead wood is provided in Table 6.

2.3.4.3 Litter

Litter losses are reported when forest land is converted to wetlands. The emission factor for the carbon loss of litter is provided in Table 7.

2.3.4.4 Mineral soil

There are no net emissions/removals reported for mineral soil in this category.

2.3.5 Settlements

For the settlement category, net emissions/removals are reported for settlements remaining settlements and land use changes to settlements (from forest land, cropland, grassland and wetlands). The settlement category includes the subcategories as listed in Table 2. It includes also green space in Vienna, which does not represent forest land, cropland and grassland, like urban lawns, parks, cemeteries etc.

2.3.5.1 Biomass

To include the effects of changes in the tree cover in settlements remaining settlements, the change of the shares of the crown cover of trees, between 2015 and 2021 were used to estimate dynamic emissions factors (see Table 3). Between 2015 and 2021, we linearly interpolated to obtain the relevant time series 2015–2020 for the Viennese GHG inventory. As the crown cover of trees in the settlement category decreased between 2015 and 2021, the respective annual biomass losses (column B, Table 13) were considered. The methodology follows the Tier 2a approach of the 2006 IPCC Guidelines. The emission factors presented in Table 13 are based on a recent study, which was compiled for the Austrian National GHG inventory (Umweltbundesamt, 2023b). For shrubs and low vegetation we assumed a constant coverage in settlements remaining settlements and therefore no carbon stock changes have been estimated for this sub-category. It should be noted that tree biomass gains across all the years of growth at the settlement areas are smaller than tree biomass losses in the year of loss due to the fact that trees of already a certain and known size are planted at the settlement areas.

Table 13: Emission factors for settlement biomass for settlements remaining settlements and land use changes from and to settlements

Category	**A**	**B**
Settlements sub-category	Biomass gains (t C/ha crown cover/yr)	Biomass losses (t C/ha crown cover/yr)
Trees	2.8 (calculated over 15 years)	65.2 (in the year of loss)
Shrubs	1.5 (calculated over 20 years)	30 (in the year of loss)
Low vegetation	6.7 (calculated in the year of land-use change)	6.7 (in the year of loss)

To account for the carbon stock gains when land is converted to settlements we used a similar approach with a dynamic emission factor for trees representing the change in the tree cover over time and the value presented for trees in column A is multiplied by the crown cover. For shrubs and low vegetation, we calculated the biomass gains by using the emission factors from column A, Table 13. In addition, the biomass of the previous land uses is lost. This concerns the biomass of forest land Table 6, cropland (Table 9, column B) and grassland (Table 11, column B).

2.3.5.2 Dead wood

Dead wood losses are reported when forest land is converted to settlements. The emission factor for the carbon loss of dead wood is provided in Table 6.

2.3.5.3 Litter

Litter losses are reported when forest land is converted to settlements. The emission factor for the carbon loss of litter is provided in Table 7.

2.3.5.4 Mineral soil

Regarding the carbon stock changes in mineral soils of settlements remaining settlements we assumed that the area of the sealed surface is constant over time (Table 3) and therefore no carbon stock changes are estimated.

For land converted to settlements, the difference between initial carbon stock minus the carbon stock of the final land use category is accounted for a transition period over 20 years. As there is no information on the average soil carbon stocks of mineral soils in settlements for Vienna, the same approach as for the National GHG inventory was used, by assuming that the mineral soil stock of the unsealed share of settlement is similar to a grassland soil (see Table 12). This stock is only considered for the unsealed area of the settlements. The mineral soil carbon stock of the sealed share of settlement is assumed to be zero. The average carbon stock in mineral soils of settlements is calculated by multiplying the grassland carbon stock with the most recent value for the share of unsealed areas settlements (see Table 3):

Table 14: Carbon stocks of settlement mineral soils for changes from and to settlement (except forest land)

category	Carbon stock in 0–30 cm mineral soil (t C / ha)
Settlements	25

The initial mineral soil carbon stocks of the cropland and grassland categories before conversion to settlement can be found in Table 10 and Table 12, respectively. Table 8 provides the initial and final soil carbon stocks, which are used for conversions from forest land to settlement.

2.3.5.5 Direct and indirect N_2O emissions from managed soils

N_2O emissions from managed soils occur from land use changes from forest land, cropland and grassland converted to settlements, as the soil carbon stocks of forest land, cropland and grassland are higher than in settlements and therefore carbon losses lead to related N_2O emissions (methodological references are provided in section 2.3.1).

3 RESULTS OF THE LULUCF GHG INVENTORY

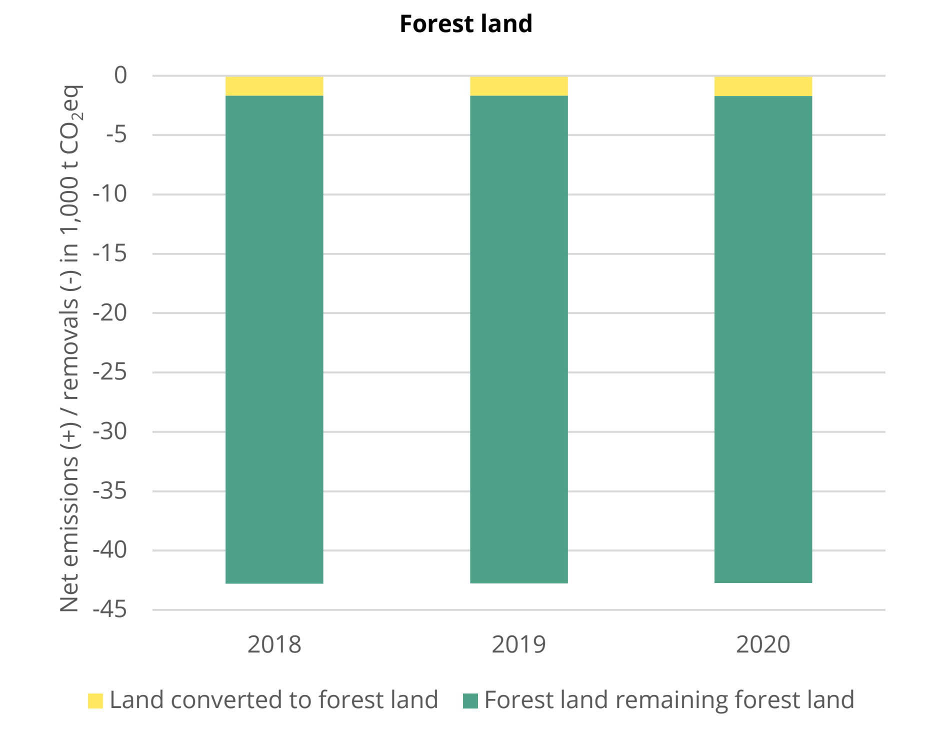
This chapter presents the results of the LULUCF Greenhouse Gas Inventory for the city of Vienna. First, the data is shown by land use category and later the total LULUCF emissions and removals are compared to Vienna's emissions in other sectors.

3.1 Results by land use category

3.1.1 Forest land

Forest land is a net sink of greenhouse gases in Vienna. In 2020 about 42,700 t CO_2eq per year have been removed by Viennese forests. The majority of removals took place in the category forest land remaining forest land (i.e. forests that have existed for at least 20 years). Approximately 1,700 t CO_2eq per year have been removed on land converted to forest land. The results for 2018 and 2019 differ only slightly from those of the latest year 2020 (see Figure 7).

Figure 7: Net emissions and removals from Forest land in 1,000 t CO_2eq

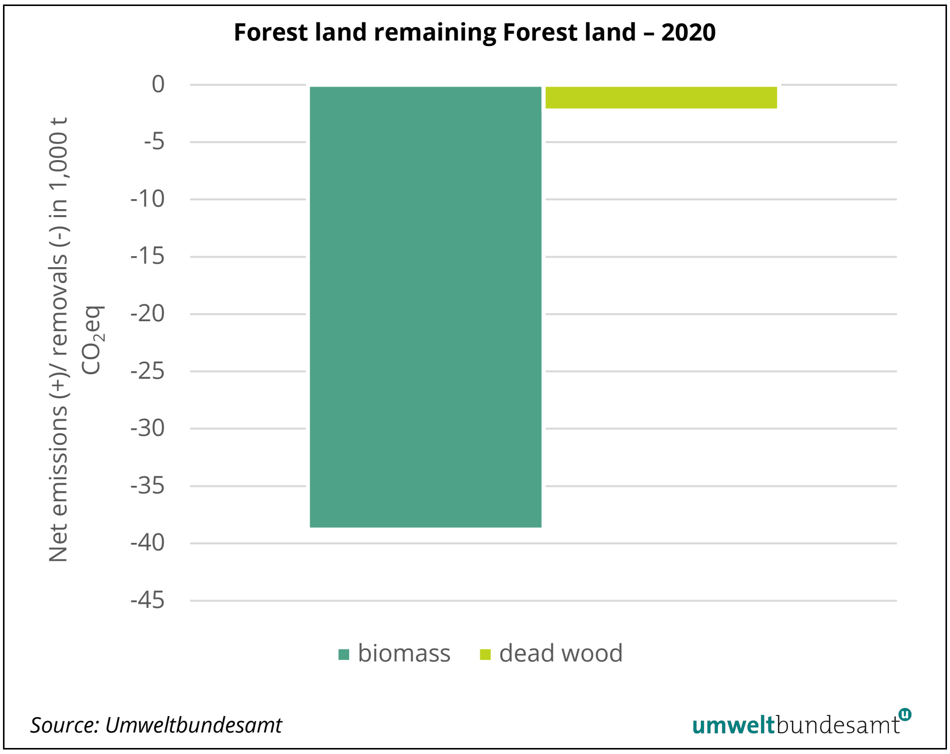


Source: Umweltbundesamt

The bar charts below show the contribution of each carbon pool to the emissions and removals in forest land in 2020. The results for 2018 and 2019 are very similar.

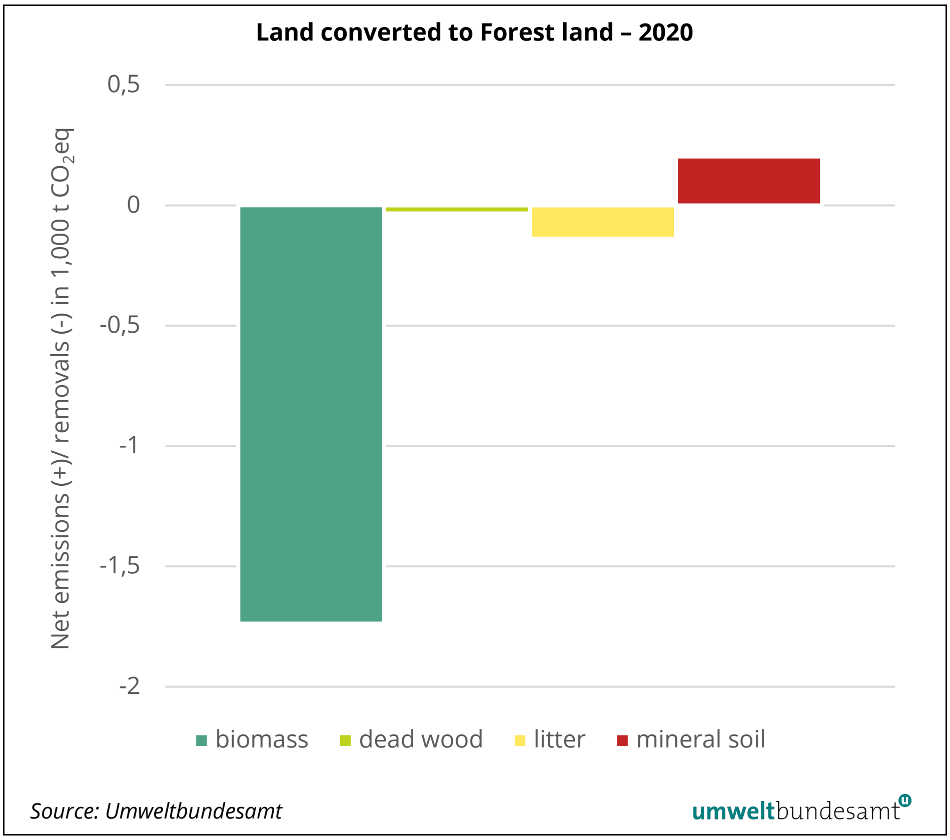
In forest land remaining forest land most of the removed carbon is sequestered in biomass. The deadwood carbon stock is also increasing, it is a small net GHG sink (see Figure 8). Mineral soil and litter are assumed to be in equilibrium in forests remaining forests, thus no net emissions or removals are estimated for those pools.

Figure 8: Contribution of carbon pools to the net emissions and removals in forest land remaining forest land



In land converted to forest land, biomass is also the most important contributor. The sinks of litter and deadwood are comparatively small while mineral soil is a net GHG source emitting 200 t CO_2eq in 2020 (see Figure 9). This is due to a lower average soil carbon stock in forest land than in grassland, where most conversions (deforestation) from forest land occurred.

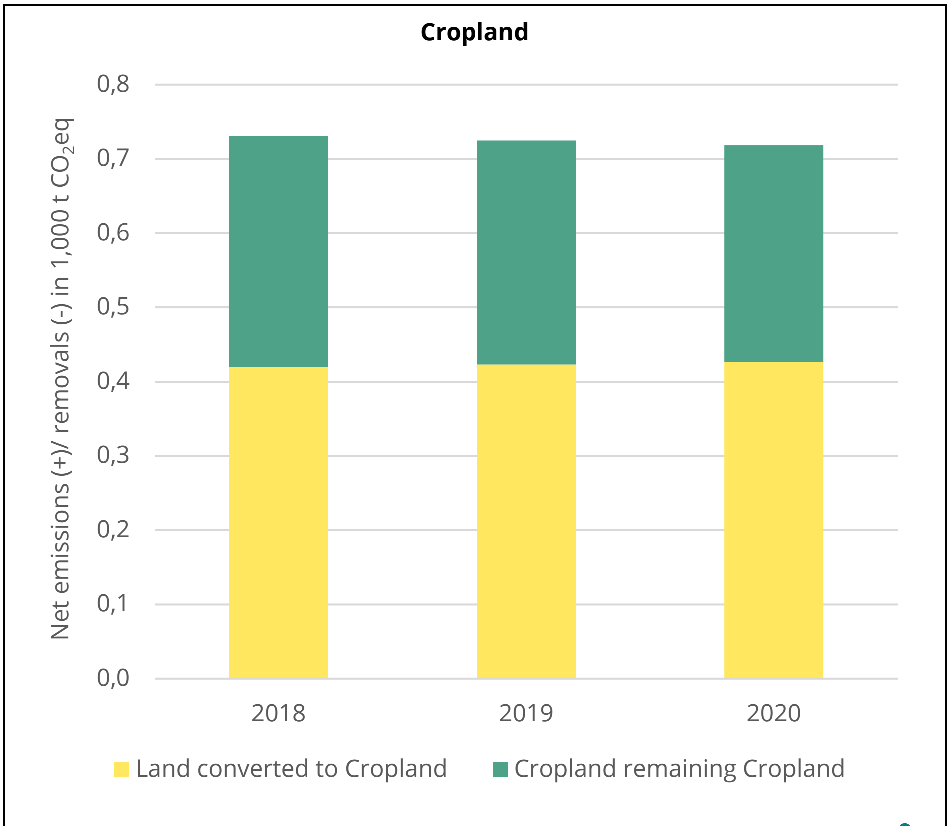
Figure 9: Contribution of carbon pools to the net emissions and removals in land converted to forest land



3.1.2 Cropland

Cropland is a net GHG source of 718 t CO_2eq in 2020, of which 427 t CO_2eq are attributed to land converted to cropland and 292 t CO_2eq to cropland remaining cropland. The trend from 2018 to 2020 is stable (see Figure 10). The main emission sources in the cropland category are from losses of carbon from mineral soil through the conversion of grassland to cropland and losses of biomass in perennial cropland due to a decrease of the orchard area.

Figure 10:
Net emissions and removals from cropland in 1,000 t CO_2eq

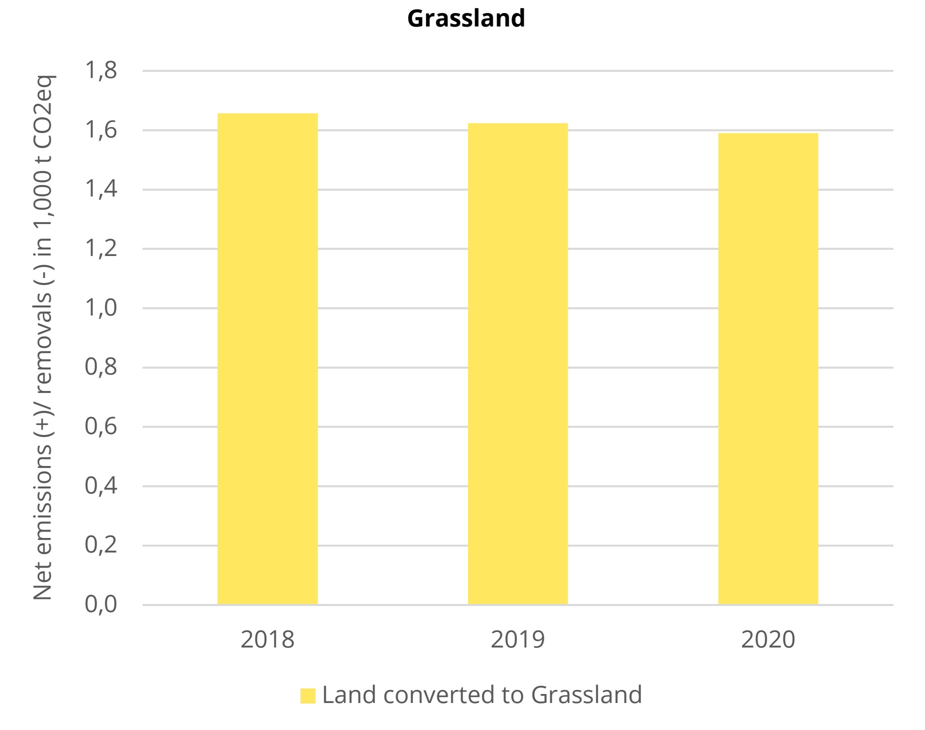


Source: Umweltbundesamt

3.1.3 Grassland

Grassland is a net emission source of 1,591 t CO_2eq in 2020. It has decreased slightly since 2018 when it was 1,657 t CO_2eq. All reported emissions are caused by land (especially forest land) being converted to grassland. The biomass and soil carbon stocks in grassland remaining grassland are assumed to be in equilibrium (see Figure 11).

Figure 11: Net emissions and removals from grassland in 1,000 t CO_2eq

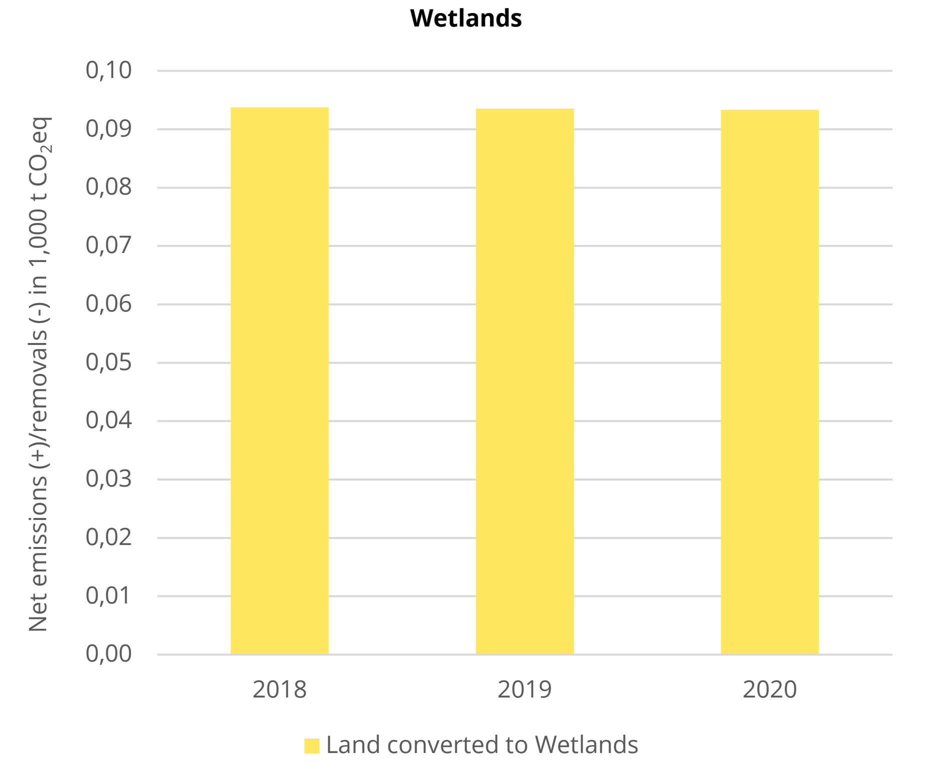


Source: Umweltbundesamt

3.1.4 Wetlands

The category wetlands constitutes a small source of emissions in Vienna. In 2020 it amounts to 93 t CO_2eq, and differences in the previous two years are less than one ton CO_2. All emissions are due to a loss of carbon on land converted to wetlands (see Figure 12). For wetlands remaining wetlands no carbon stock changes are estimated.

Figure 12: Net emissions and removals from wetlands in 1,000 t CO_2eq

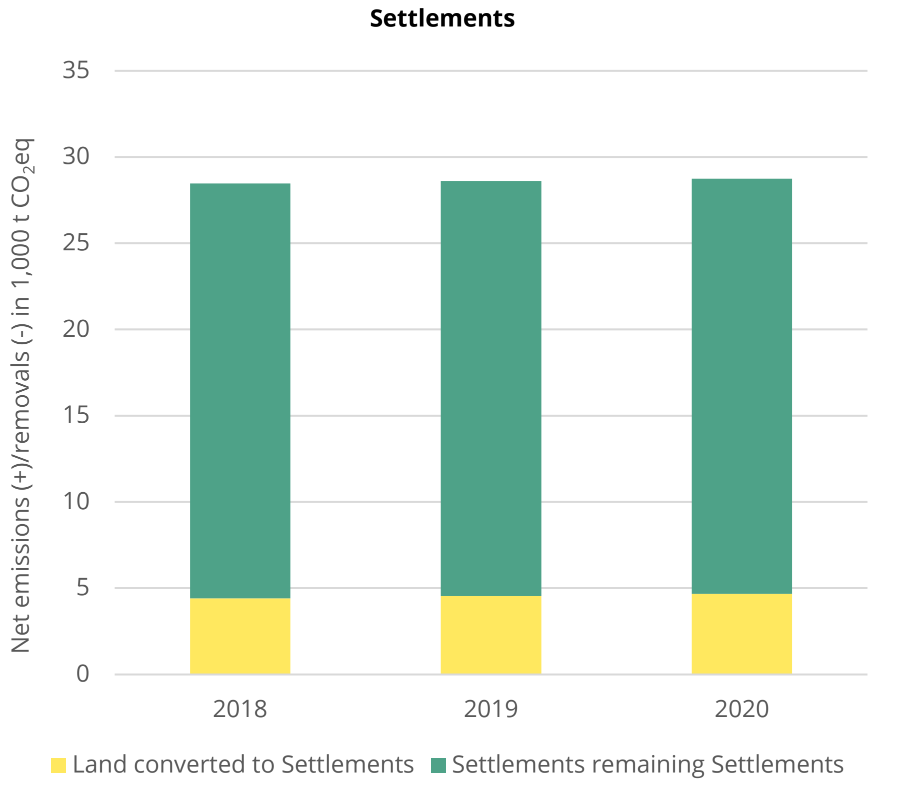


Source: Umweltbundesamt

3.1.5 Settlements

Settlements is the second most important category in the LULUCF inventory of Vienna. For the years 2018 to 2020, the trend in net emissions is rather constant and amounts to approx. 29,000 t CO_2eq per year. These emissions are mainly due to biomass losses in settlements remaining settlements caused by a reduction of the tree cover in settlements (approx. 25,000 t CO_2eq per year). A sensitivity analysis for the tree cover share showed that the area of green space is a critical factor in terms of the net result of the settlements category of Vienna. A constant tree cover share would result in a much smaller net emission for this category (of approx. 4,500 t CO_2eq per year) than under the current situation with a decreasing tree cover. Emissions from mineral soils due to conversions of cropland and grassland to settlements amount to 4,500 t CO_2eq per year.

Figure 13: Net emissions and removals from settlements in 1,000 t CO_2eq

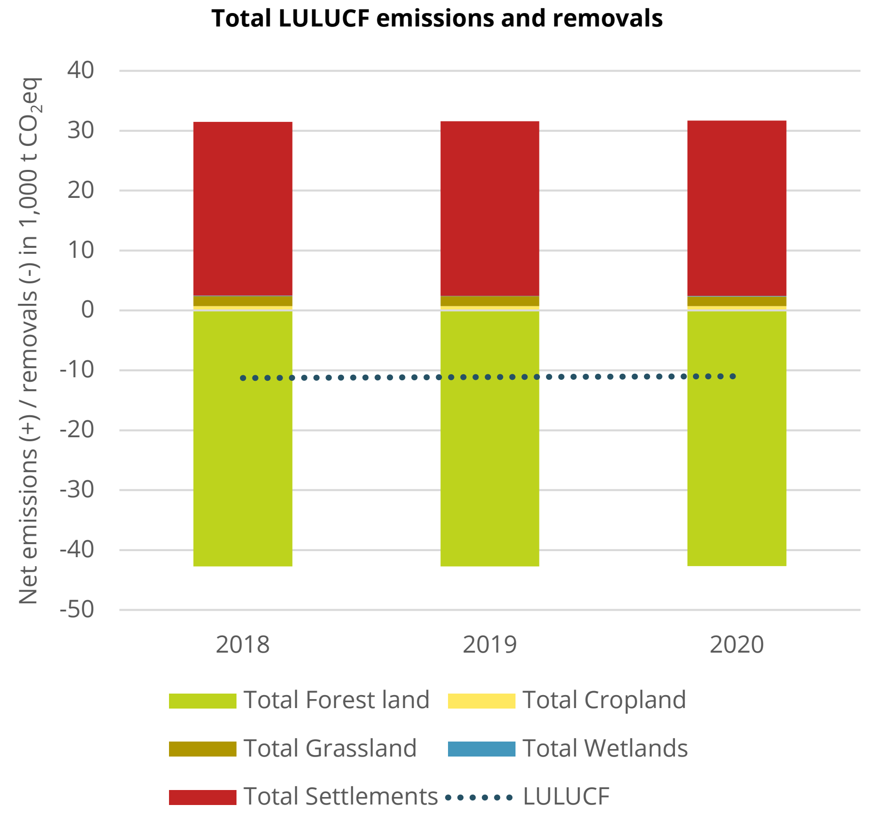


Source: Umweltbundesamt

3.2 Total emissions/removals of the LULUCF sector

In total, the LULUCF sector is a net source of GHG emissions in Vienna in the range of -11,000 t CO_2eq. The main impact of the overall result is from the categories settlements and forest land. Due to its large area, the forest land is a net sink of 43,000 t CO_2eq per year and is currently able to outweigh the emissions from settlements. However, the results are very sensitive to small changes. If e.g. the crown cover in settlements further decreases and assuming that the forest sink remains the same, it is likely that the LULUCF sector becomes a net source of emissions. Cropland, grassland and wetlands are all small net sources as well but play only a minor role in the overall GHG balance, contributing together less than 2,500 t CO_2 per year.

Figure 14: Total emissions and removals in the LULUCF sector in 1,000 t CO_2eq



Source: Umweltbundesamt

Table 15 shows emissions and removals from land use categories and the total LULUCF result for the years 2018, 2019 and 2020.

Table 15: Total emissions and removals in the LULUCF sector by land use category

	Net emissions/removals in t CO_2eq		
Category name/year	**2018**	**2019**	**2020**
Forest land	-42,785	-42,756	-42,732
Cropland	731	725	718
Grassland	1,657	1,624	1,591
Wetlands	94	94	93
Settlements	28,994	29,148	29,305
LULUCF	-11,282	-11,139	-10,996

3.3 Interpretation of the results and conclusions

Despite the LULUCF sector being a net sink of emissions, the contribution to the total GHG inventory of Vienna is small. From 2018 to 2020, the LULUCF sector accounts for less than 0.13% of the total GHG emissions from Vienna (Table 16).

This can be explained by the fact that emissions and removals from land use strongly depend on the size of the area of the managed land. Vienna only takes up 0.5% of the area of Austria, but houses 21% of its population (Statistik Austria 2023). Therefore, it cannot be expected from the LULUCF sector of a city to largely compensate emissions from other sectors. However, it is remarkable that 20% of the area is covered by forest land, which is a rather high share for a city. Without this sink, the sector would be a source of emissions. Furthermore, our results show that developments in the settlements category should be carefully monitored, especially the main parameters such as the vegetation cover and share of sealed soil, which can lead to substantially increased emissions.

Table 16: Results of the LULUCF GHG Inventory of Vienna compared to the city's total emissions in other sectors

	Net emissions/removals in t CO_2eq		
in	**2018**	**2019**	**2020**
LULUCF	-11.3	-11.1	-11.0
Total emissions in the city of Vienna[6]	8,479	8,750	8,162
LULUCF emissions in relation to total	0.13%	0.13%	0.13%

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This report contains the greenhouse gas results of the land use, land-use change and forestry sector (LULUCF) for Vienna. This balance was estimated as part of a work package of the "Vienna Urban Carbon Laboratory" (VUCL) project.

The LULUCF greenhouse gas balance of Vienna represents an average net sink of around 11,000 tons of CO_2eq. per year for the years 2018–2020. This net sink is mainly determined by the sink capacity of the forest in Vienna, which absorbs net approx. 43,000 tons of CO_2 per year. The settlement category in Vienna is the largest source of emissions in the LULUCF sector and releases an average of 29,000 tons of CO_2eq. per year. The other land use categories are minor sources.

The proportion of vegetation, especially trees, in Vienna is an important lever that can determine whether the LULUCF sector is a net source or sink.

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