LUH2-ISIMIP2b Harmonized Global Land Use for the Years 2015-2100

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Documentation Revision Date: 2020-06-30

Dataset Version: 1

Summary

This dataset provides 0.25-degree gridded, global, annual estimates of fractional land use and land cover patterns for the period 2015-2100, designed to support the ISIMIP2b effort to assess the impacts of 1.5 Deg Celcius global warming. Land use types, land use transitions, and cropland estimates of area fraction are provided and include detailed separation of primary and secondary natural vegetation into forest and non-forest sub-types, pasture into managed pasture and rangeland, and cropland into multiple crop functional types; all transitions between land use states per grid cell per year, including crop rotations, shifting cultivation, and wood harvest; and agriculture management including irrigation, synthetic nitrogen fertilizer, and biofuel management. The LUH2-ISIMIP2b datasets were derived using Land Use Harmonization 2 (LUH2) methodology and are based on land-use scenarios provided by the REMIND-MAgPIE Integrated Assessment Model using an SSP2 storyline along with RCP2.6 and RCP6.0 emissions scenarios. In contrast to the standard SSP scenarios, these land use changes additionally account for climate and atmospheric CO2 fertilization effects on the underlying patterns of potential crop yields, water availability, and terrestrial carbon content. This is achieved by using the LPJmL (Lund-Potsdam-Jena managed land) model forced with atmospheric CO2 concentrations and patterns of climate change generated from 4 different climate models (GFDL, HADGEM, IPSL, and MIROC) consistent with the 2 different RCP scenarios, resulting in a set of 8 different LUH2-ISIMIP2b datasets.

This LUH2-ISIMIP2b dataset was developed in support of the Inter-Sectoral Impact Model Intercomparison Project 2b (ISIMIP2b) effort. The aim of the ISIMIP2b is to provide robust information about the impacts of 1.5°C global warming and related low-emission pathways. The LUH2 methodology was developed as a contribution to CMIP6 and LUMIP and builds upon past work from CMIP5 (Hurtt et al. 2020, Hurtt et al. 2019a, Hurtt et al. 2019b, Hurtt et al. 2011, Frieler et al., 2017). The land use and emissions scenarios were provided by the REMIND-MAgPIE Integrated Assessment Model using an SSP2 storyline.

There are 24 data files in NetCDF version 4 (.nc4) format with this dataset, including three files for each of four models employing two emission scenarios.

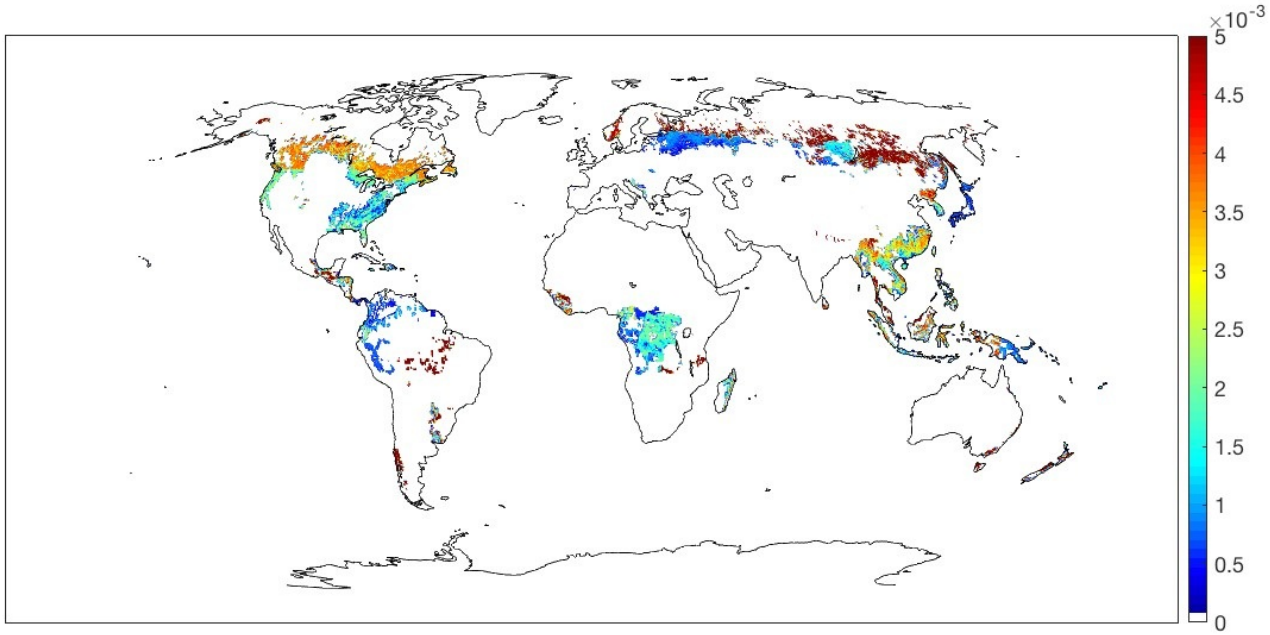

Figure 1. This figure shows the fraction of each grid cell being harvested for wood from primary forest (i.e. the primf_harv variable) for the year 2015.

Citation

Chini, L.P., G.C. Hurtt, R. Sahajpal, S. Frolking, K. Frieler, A. Popp, B. Bodirsky, F. Humpenoeder, M. Stevanovic, K. Calvin, S. Ostberg, L. Warszawski, and J. Volkholz. 2020. LUH2-ISIMIP2b Harmonized Global Land Use for the Years 2015-2100. ORNL DAAC, Oak Ridge,

Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1721

Table of Contents

1. Dataset Overview

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Related Publications:

Frieler, K., Lange, S., Piontek, F., Reyer, C.P., Schewe, J., Warszawski, L., Zhao, F., Chini, L., Denvil, S., Emanuel, K. and Geiger, T., 2017. Assessing the impacts of 1.5 C global warming–simulation protocol of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b). Geoscientific Model Development. 10: 4321–4345. https://doi.org/10.5194/gmd-10-4321-2017

Hurtt, G.C., Chini, L.P., Frolking, S., Betts, R.A., Feddema, J., Fischer, G., Fisk, J.P., Hibbard, K., Houghton, R.A., Janetos, A. and Jones, C.D., 2011. Harmonization of land-use scenarios for the period 1500–2100: 600 years of global gridded annual land-use transitions, wood harvest, and resulting secondary lands. Climatic change, 109(1-2), p.117. http://doi.org/10.1007/s10584-011-0153-2

Hurtt, G. C., Chini, L., Sahajpal, R., Frolking, S., Bodirsky, B. L., Calvin, K., Doelman, J. C., Fisk, J., Fujimori, S., Goldewijk, K. K., Hasegawa, T., Havlik, P., Heinimann, A., Humpenöder, F., Jungclaus, J., Kaplan, J., Kennedy, J., Kristzin, T., Lawrence, D., Lawrence, P., Ma, L., Mertz, O., Pongratz, J., Popp, A., Poulter, B., Riahi, K., Shevliakova, E., Stehfest, E., Thornton, P., Tubiello, F. N., van Vuuren, D. P., and Zhang, X.: Harmonization of Global Land-Use Change and Management for the Period 850–2100 (LUH2) for CMIP6, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2019-360, in review, 2020.

Related Dataset:

This current dataset (LUH2-ISIMIP2b) was specially created using the LUH2 technology (Hurtt et al. 2020, Hurtt et al. 2019a, Hurtt et al. 2019b, Hurtt et al. 2011, Frieler et al., 2017). LUH2 is the successor to the LUH1 dataset (below), also archived at the ORNL DAAC.

The 2014 LUH dataset provides fractional land use and land cover patterns annually for the period 1500-2100 for the globe at 0.5-degree (~50-km) spatial resolution. Land use categories of cropland, pasture, primary land, secondary (recovering) land, urban land, and underlying annual land-use transitions are included. Annual data on age and biomass density of secondary land, as well as annual wood harvest, are included for each grid cell.

Chini, L.P., G.C. Hurtt, and S. Frolking. 2014. Harmonized Global Land Use for Years 1500 -2100, V1. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1248

Hurtt, George; Chini, Louise; Sahajpal, Ritvik; Frolking, Steve; Bodirsky, Benjamin Leon; Calvin, Kate; Doelman, Jonathan; Fisk, Justin; Fujimori, Shinichiro; Goldewijk, Kees Klein; Hasegawa, Tomoko; Havlik, Petr; Heinimann, Andreas; Humpenöder, Florian; Jungclaus, Johann; Kaplan, Jed; Krisztin, Tamás; Lawrence, David; Lawrence, Peter; Mertz, Ole; Pongratz, Julia; Popp, Alexander; Riahi, Keywan; Shevliakova, Elena; Stehfest, Elke; Thornton, Peter; van Vuuren, Detlef; Zhang, Xin (2019a). Harmonization of Global Land Use Change and Management for the Period 850-2015. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/input4MIPs.10454

Hurtt, George; Chini, Louise; Sahajpal, Ritvik; Frolking, Steve; Bodirsky, Benjamin Leon; Calvin, Kate; Doelman, Jonathan; Fisk, Justin; Fujimori, Shinichiro; Goldewijk, Kees Klein; Hasegawa, Tomoko; Havlik, Petr; Heinimann, Andreas; Humpenöder, Florian; Jungclaus, Johann; Kaplan, Jed; Krisztin, Tamás; Lawrence, David; Lawrence, Peter; Mertz, Ole; Pongratz, Julia; Popp, Alexander; Riahi, Keywan; Shevliakova, Elena; Stehfest, Elke; Thornton, Peter; van Vuuren, Detlef; Zhang, Xin (2019b). Harmonization of Global Land Use Change and Management for the Period 2015-2300. Version YYYYMMDD[1].Earth System Grid Federation. https://doi.org/10.22033/ESGF/input4MIPs.10468

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2. Data Characteristics

Spatial Coverage: Global

Spatial Resolution: 0.25 x 0.25-degree

Temporal Coverage: 2015-01-01 to 2100-01-01

Temporal Resolution: Annual

Site boundaries: (All latitude and longitude given in degrees and fractions)

Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
-180	180	90	-90

Data File Information

There are 24 data files provided with this dataset in NetCDF version 4 (.nc4) format.

All files provide latitude, longitude, and time variables. Missing values are represented by 1.00E+20.

Outputs were based on
- two climate scenarios (RCP 2.6 and RCP 6.0)

That were driven by
- four climate models (GFDL, HADGEM, IPSL, or MIROC).

These outputs include
- three data types (states, transitions, and crop management).

Note that because the transitions files refer to the transitions between years (i.e., the changes that occur between year t and year t+1) there is one less time step (year) compared to the states and management files that refer to the state of the land surface during (or at some point during) year t+1.

Naming Convention

The files are named **RCP#_MODEL_Z** where

RCP# = RCP26 for RCP2.6 or RCP60 for RCP6.0 climate scenarios

MODEL = GFDL, HADGEM, IPSL, or MIROC climate models

Z = states, transitions, or management data types

Examples: **RCP26_GFDL_transitions.nc4**, **RCP60_IPSL_management.nc4**

Table 1. Data types and descriptions.

Data Type	Description	Naming Conventions
States	These files provide the area fraction of land use types, the secondary land use mean age, and the secondary mean biomass carbon density.	Variables in these files represent land use types (Table 2).
Transitions	These files provide area fraction of annual land use transitions from one land use type to another; that is, the change that occurs between year t and year t+1.	Variable names are a combination of two land use type variable names (Table 2) as type_to_type and in combination with wood harvesting variables (Table 3).
Management	These files provide land-use management data including the area fraction used as cropland, fertilization rates, the fraction of C3 and C4 perennial crops biomass carbon harvested annually, the flooded fraction of crop areas, irrigation fraction of crop areas, and the fuelwood fraction of wood harvest biomass carbon.	Variable names are land use type variables (Table 2) in combination with fertilization and crop variable names (Table 4).

Data File Details

States Variables

Land use type variables are used in **RCP#_MODEL_States.nc** files and in combination with other variables listed in Tables 3 and 4. Note that not all land use variables are included.

Table 2. Land use type variable names and descriptions.

Variable Name	Units	Description	Data Type
primf	fraction of grid cell	forested primary land	states, transitions
primn	fraction of grid cell	non-forested primary land	states, transitions
pastr	fraction of grid cell	managed pasture	states, transitions
range	fraction of grid cell	rangeland	states, transitions
urban	fraction of grid cell	urban land	states, transitions
c3ann	fraction of grid cell	C3 annual crops	states, transitions, management
c3per	fraction of grid cell	C3 perennial crops	states, transitions, management
c4ann	fraction of grid cell	C4 annual crops	states, transitions, management
c4per	fraction of grid cell	C4 perennial crops	states, transitions, management
c3nfx	fraction of grid cell	C3 nitrogen-fixing crops	states, transitions, management
secdf	fraction of grid cell	potentially forested secondary land	states, transitions
secdn	fraction of grid cell	potentially non-forested secondary land	states, transitions
secma	years	secondary mean age	states

secmb	kg C/m^2	secondary mean biomass density	states

Annual Transitions Variables

The variables are area fraction of annual transitions between land use types. There are 118 transitions variables in total.

Naming Convention and Syntax

1) **typeX_to_typeY** transitions

The variables refer to transitions between land use types. The variable names are a combination of the land use types, indicated here using land use **type X** and land use **type Y**

> **typeX** = secdf, secdn, urban, range, pastr, primf, and primn
>
> **typeY** = pastr, range, urban, secdn, secdf, c3ann, c3nfx, c3per, c4ann, or c4per (where ann = annual crops, per = perennial crops, and nfx = nitrogen-fixing crops)

There are seven **typeX** values paired with nine **typeY** values for a total of 63 transitions variables.

Example: variable names for **typeX_to_typeY** transition for **range_to_typeY**.

- range_to_c3per
- range_to_c4per
- range_to_c4ann
- range_to_c3ann
- range_to_c3nfx
- range_to_secdf
- range_to_secdn
- range_to_urban
- range_to_pastr

2) **“C”_to_typeY** or **“C_to_C”** transitions

> **“C” (crop types) =** c3ann, c3nfx, c3per, c4ann, or c4per
>
> **typeY =** secdf, secdn, urban, range, or pastr

There are 25 **“C”_to_typeY** transition variable combinations (where c3ann, c3nfx, c3per, c4ann, or c4per is combined with one of the five **typeY** land use type variables), and 20 **“C_to_C”** (4 x 5 combinations) variables. There are 45 transitions variables in total.

Example: variable names for these **“C”_to_typeY** and **“C_to_C”** transitions for **“C” = c3ann**.

- c3ann_to_range
- c3ann_to_c3nfx
- c3ann_to_c4ann
- c3ann_to_secdf
- c3ann_to_c4per
- c3ann_to_pastr
- c3ann_to_c3per
- c3ann_to_secdn
- c3ann_to_urban

3) Transitions wood harvest variables

The transitions data also include 10 variables for wood harvest area and wood harvest biomass carbon from wood harvest area and wood harvest biomass carbon from primary and secondary vegetation on LUH2 potential non-forest and forested land.

Table 3. Transition wood harvest variable names and descriptions.

Variable	**Description**
Annual Wood Harvest (fraction of grid cell)	
primf_harv	wood harvest area from primary forest
primn_harv	wood harvest area from primary non-forest
secmf_harv	wood harvest area from secondary mature forest
secyf_harv	wood harvest area from secondary young forest
secnf_harv	wood harvest area from secondary non-forest
Annual Wood Harvest (kg C per year)	
primf_bioh	wood harvest biomass from primary forest
primn_bioh	wood harvest biomass from primary non-forest
secmf_bioh	wood harvest biomass from secondary mature forest
secyf_bioh	wood harvest biomass from secondary young forest
secnf_bioh	wood harvest biomass from secondary non-forest

Management Variables

These files provide irrigation, fertilizer, and other land-use management information. There are 22 variables in total

Table 4. Management variable names and descriptions.

Variable	**Description**
Irrigation (in fraction of crop area)	

irrig_c3ann	irrigated fraction of C3 annual crop area
irrig_c3per	irrigated fraction of C3 perennial crop area
irrig_c4ann	irrigated fraction of C4 annual crop area
irrig_c4per	irrigated fraction of C4 perennial crop area
irrig_c3nfx	irrigated fraction of C3 N-fixing crop area
	Flood
flood	flooded fraction of C3 annual crop crop area
Fertilizer (kg N/ha/yr)	
fertl_c3ann	Crop season fertilizer rate for C3 annual crops
fertl_c4ann	Crop season fertilizer rate for C4 annual crops
fertl_c3per	Crop season fertilizer rate for C3 perennial crops
fertl_c4per	Crop season fertilizer rate for C4 perennial crops
fertl_c3nfx	Crop season fertilizer rate for C3 N-fixing crops
Biofuel Crops Variables (fraction of crop type area occupied by biofuel crops)	
crpbf_c3ann	C3 annual crops grown as biofuels
crpbf_c4ann	C4 annual crops grown as biofuels
crpbf_c3per	C3 perennial crops grown as biofuels
crpbf_c4per	C4 perennial crops grown as biofuels
crpbf_c3nfx	C3 N-fixing crops grown as biofuels
crpbf_total	fraction of total cropland area grown as 2nd
Biofuel Wood Harvest Variables (fraction of wood harvest biomass)	
rndwd	industrial roundwood fraction of wood harvest
fulwd	traditional fuelwood fraction of wood harvest
combf	commercial biofuels fraction of wood harvest
Harvest (fraction of biomass harvested annually)	
fharv_c3per	fraction of C3 perennial crops harvested annually
fharv_c4per	fraction of C4 perennial crops harvested annually

3. Application and Derivation

The diversity of approaches and requirements among Integrated Assessment Models (IAMs) and Earth System Models (ESMs) for tracking land use change, along with the dependence of model projections on land use history, presents a challenge for effectively passing data between these communities and for smoothly transitioning from the historical estimates to future projections. This harmonized set of land use scenarios smoothly connects historical reconstructions of land use with future projections, in the format required by ESMs, providing an important resource for studies of human impacts on the past, present, and future Earth system.

4. Quality Assessment

These results, particularly the future estimates, must be considered uncertain and highly dependent on the inputs and assumptions used.

5. Data Acquisition, Materials, and Methods

Frieler et al. (2017) describe in detail the simulation protocol and scientific rationale for ISIMIP2b. Following is a brief synopsis.

The ISIMIP was initiated by the PIK and the International Institute for Applied Systems Analysis (IIASA) and has since grown to involve over 100 modelling groups from around the world. The focus topic for ISIMIP2b is to provide robust information about the impacts of 1.5°C global warming and related low-emission pathways. In support of the ISIMIP2b effort these land-use datasets for the years 2015-2100 were developed using the LUH2 methodology. The data are "harmonized" with the LUH2 historical reconstructions and provided in a standard format for use in climate models. The LUH2 methodology was developed as a contribution to CMIP6 and LUMIP, it builds upon past work from CMIP5, and includes updated inputs, higher spatial resolution, more detailed land-use transitions, and the addition of important agricultural management layers.

The data are based on land-use scenarios provided by the REMIND-MAgPIE Integrated Assessment Model developed at PIK using an SSP2 storyline along with RCP2.6 and RCP6.0 emissions scenarios. In contrast to the standard SSP scenarios, the land use changes additionally account for climate and atmospheric CO2 fertilization effects on the underlying patterns of potential crop yields, water availability, and terrestrial carbon content. This is achieved by using the LPJmL model (jointly developed and maintained at PIK) forced with atmospheric CO2 concentrations and patterns of climate change generated from four climate models (GFDL, HADGEM, IPSL, and MIROC).

RCP Scenarios

RCP2.6 (also referred to as RCP3PD) represents a very low emission scenario and explores the feasibility of limiting climate change to less than 2°C by limiting radiative forcing to a peak of 3 W/m2 in mid-century, declining to 2.6 W/m2 in 2100.

RCP6.0 is a med-high emission pathway with mitigation actions taken late in the century to stabilize radiative forcing at 6 W/m2 after

2100 without ever exceeding that level.

Previous LUH Dataset

This LUH2-ISIMIP2b is a specially created dataset built upon the LUH2 technology. LUH2 is the successor dataset to LUH1.

The 2014 LUH1 dataset (Chini et al., 2014), also archived at the ORNL DAAC, provides fractional land use patterns annually for the years 1500 - 2100 for the globe at 0.5-degree (~50-km) spatial resolution. Land use categories of cropland, pasture, primary land, secondary (recovering) land, and urban land, and underlying annual land-use transitions, are included. Annual data on age and biomass density of secondary land, as well as annual wood harvest, are included for each grid cell.

Historical land use data for the years 1500–2005 are based on HYDE 3.1 and future land use projections for the period 2006–2100 came from four Integrated Assessment Model (IAM) scenarios which reach different levels of radiative forcing by the year 2100: MESSAGE (8.5 W/m2), AIM (6 W/m2), GCAM (4.5 W/m2), and IMAGE (2.6 W/m2) (Hurtt et al., 2011).

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

LUH2-ISIMIP2b Harmonized Global Land Use for the Years 2015-2100

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
- Telephone: +1 (865) 241-3952

7. References

Chini, L.P., G.C. Hurtt, and S. Frolking. 2014. Harmonized Global Land Use for Years 1500 – 2100, V1. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1248

Frieler, K., S. Lange, F. Piontek, C.P.O. Reyer, J. Schewe, L. Warszawski, F. Zhao, L. Chini, S. Denvil, K. Emanuel, T. Geiger, K. Halladay, G. Hurtt, M. Mengel, D. Murakami, S. Ostberg, A. Popp, R. Riva, M. Stevanovic, T. Suzuki, J. Volkholz, E. Burke, P. Ciais, K. Ebi, T.D. Eddy, J. Elliott, E. Galbraith, S.N. Gosling, F. Hattermann, T. Hickler, J. Hinkel, C. Hof, V. Huber, J. Jägermeyr, V. Krysanova, R. Marcé, H. Müller Schmied, I. Mouratiadou, D. Pierson, D.P. Tittensor, R. Vautard, M. van Vliet, M.F. Biber, R.A. Betts, B.L. Bodirsky, D. Deryng, S. Frolking, C.D. Jones, H.K. Lotze, H. Lotze-Campen, R. Sahajpal, K. Thonicke, H. Tian, and Y. Yamagata, 2017: Assessing the impacts of 1.5°C global warming — Simulation protocol of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b). Geosci. Model Dev., 10, 4321-4345, doi: https://doi.org/10.5194/gmd-10-4321-2017

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