Introduction to CLEWs

Hands-on lecture 7: Introducing land constraints and technoeconomic parameters

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Disclaimer: These worksheets have been adapted from work kindly provided by the United Nations Department of Economic and Social Affairs (UNDESA) and KTH Royal Institute of Technology.

Tags: CLEWs; Climate; Land; Energy; Water; Systems Modelling; Integrated; Policy Coherence; Installation; Hands-on; Climate Compatible Growth; Open Source; Teaching Kit.

Useful links:

1) Energy Modelling Community (EMC) Discourse Forum – please use this for any CLEWs-related discussions, especially troubleshooting queries!
2) EMC LinkedIn.
3) CCG YouTube.
4) Hands-on Solutions can be found here.

Pre-requisites:

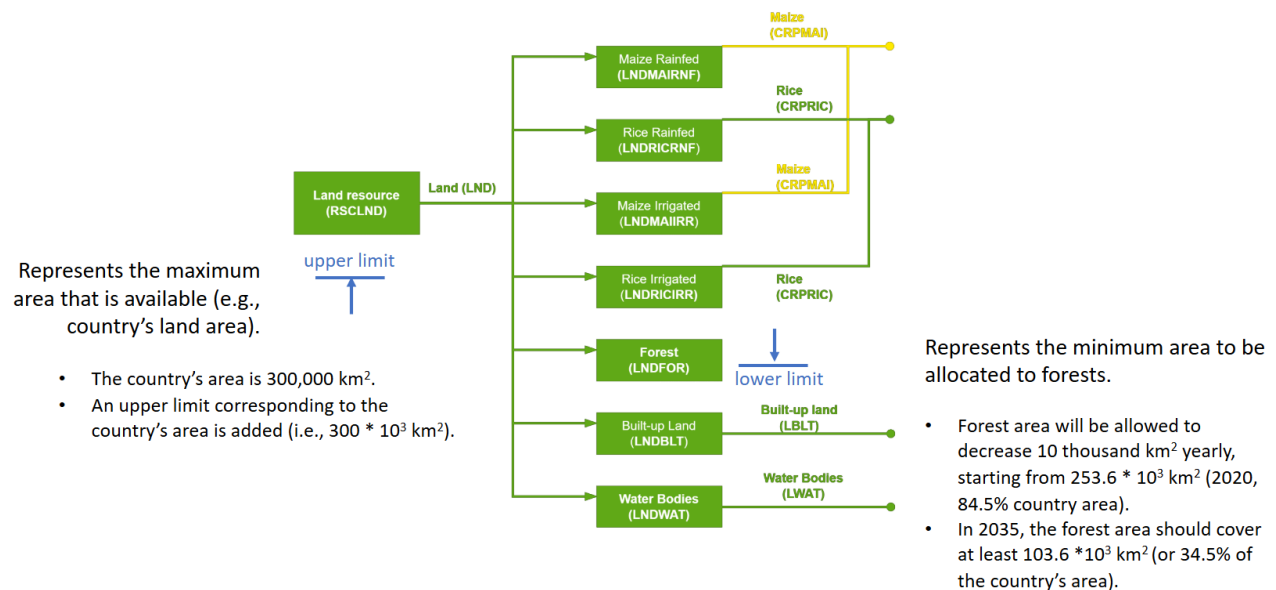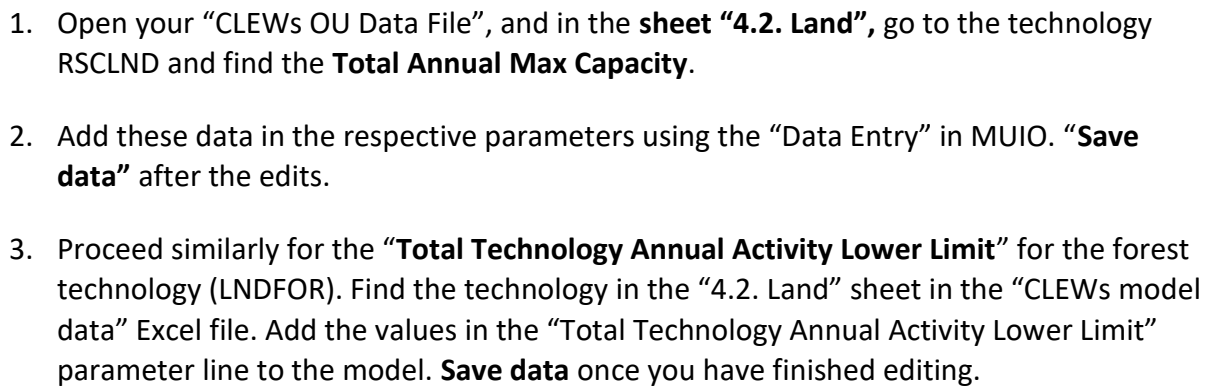1) Successful completion of all the activities under Hands-on Lecture 6.

Learning outcomes

In this exercise, you will apply various constraints and add cost parameters for different land technologies:

1) Limit the **activity and capacity** of technologies with OSeMOSYS parameters

2) Use different types of constraints for land uses and apply cost parameters to different land technologies.

3) Represent existing land use (practices) and impose activity expansion constraints.

Activity 1 – Introducing land constraints

Represents the maximum area that is available (e.g., country's land area).

- The country's area is 300,000 km².
- An upper limit corresponding to the country's area is added (i.e., 300 * 10³ km²).

Represents the minimum area to be allocated to forests.

- Forest area will be allowed to decrease 10 thousand km² yearly, starting from 253.6 * 10³ km² (2020, 84.5% country area).
- In 2035, the forest area should cover at least 103.6 *10³ km² (or 34.5% of the country's area).

1. Open your "CLEWs OU Data File", and in the **sheet "4.2. Land"**, go to the technology RSCLND and find the **Total Annual Max Capacity**.

2. Add these data in the respective parameters using the "Data Entry" in MUIO. "**Save data"** after the edits.

3. Proceed similarly for the "**Total Technology Annual Activity Lower Limit**" for the forest technology (LNDFOR). Find the technology in the "4.2. Land" sheet in the "CLEWs model data" Excel file. Add the values in the "Total Technology Annual Activity Lower Limit" parameter line to the model. **Save data** once you have finished editing.

Top toolbar: Total Technology Annual Activity Lower Limit ▾ | Save data | 0.0 ‹ 0.000 › | ↔ | ❓

Scenario	Technology	Y	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
SC_0	MINCOA		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	MINGAS		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	PWRCOA		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	PWRGAS		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	PWRTRN		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	RSCWND		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	RSCSOL		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	RSCHYD		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	PWRWND		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	PWRSOL		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	PWRHYD		PJ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	RSCLND		10^3km²	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	LNDMAIRNF		10^3km²	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	LNDRICRNF		10^3km²	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	LNDMAIIRR		10^3km²	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	LNDRICIRR		10^3km²	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	LNDFOR		10^3km²	253.600	243.600	233.600	223.600	213.600	203.600	193.600	183.600	173.600	163.600	153.600	143.600	133.600	123.600	113.600	103.600
SC_0	LNDBLT		10^3km²	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC_0	LNDWAT		10^3km²	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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4. **Now, RUN THE MODEL!** This is the first time running energy and land in a model together… **You should look at the following results:**

- **Use by Technology By Mode**: This shows the use of input commodities to a technology by mode of operation. The results inform on the amount of land (10^3km²) resource used by the different land covers.

a) Change the graph from default (Accumulated New Capacity) to **'Use by Technology by Mode'.**
b) Filter case (right click and go to field settings) to only the case run for HO7_A1.
c) Add Technology Description and untick Tech from **Columns** (or leave as tech if you want the naming conventions on your graph).
d) Add Commodity to **Filters** and filter out for only **LND**.
e) You should now see a result for how much land is being used by each technology. **Create a view** and give it a nice title, then you can save that view and download the graph if you wish!

You set the Max Capacity of Land to 300 (10^3km²), but is all of that land area being used up in your model?

Activity 2– Introducing technoeconomic parameters for land

1. Enter data for the listed parameters by searching for and selecting the respective parameter in "**Data Entry**" in the left-hand side menu. Click on **"Save Data"** after editing each parameter. The data will be entered for all years of the modelling period, i.e., 2020-2035, except for the "Operational Life" and "Capacity To Activity Unit", which have one value for the entire time domain. **You can also use the data file to copy & paste this data!**

	Parameter	Capital Cost	Fixed Cost	Variable Cost	Operational Life	Capacity to Activity Unit
	Units	M$/10³ km²	M$/10³ km²	M$/10³ km²	Years	10³ km²/10³ km²
Technology	RSCLND	0.001*	0.001*	0.001*	100	1*
	LNDMAIRNF	44	70	42	15	1*
	LNDRICRNF	60	110	57	15	1*
	LNDMAIIRR	51	76	53	15	1*
	LNDRICIRR	78	141	77	15	1*
	LNDFOR	233	0.001*	-29.4	50	1*
	LNDBLT	2904	0.001*	0.001*	20	1*
	LNDWAT	0.001*	0.001*	0.001*	100	1*

* Default value

Note: A filter is applied to the column "Technology" to show technologies with "LND" in their name.

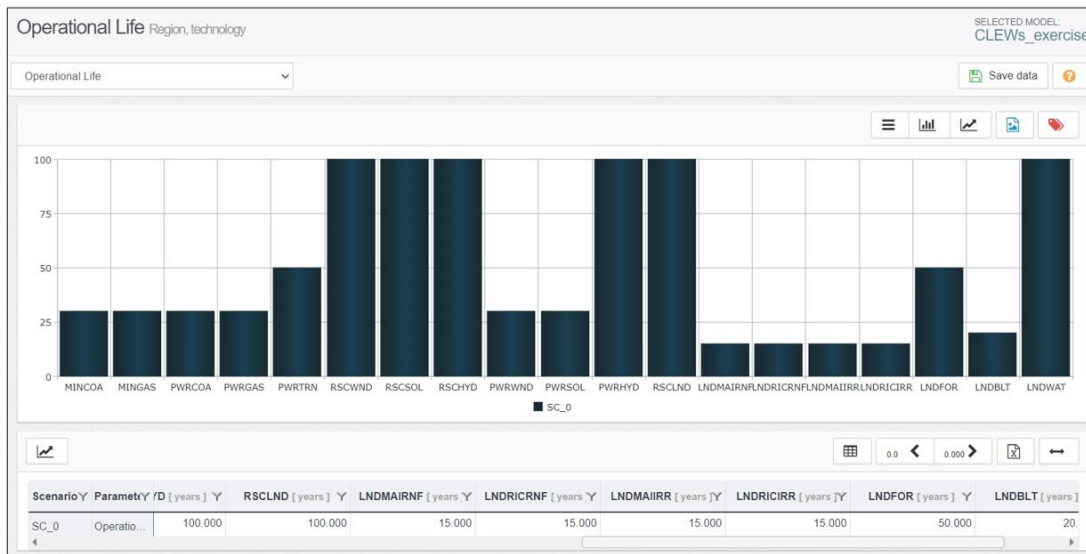## Fixed Cost — Region, year, technology

SELECTED MODEL: CLEWs exercise

Fixed Cost | 💾 Save data | 0.0 ‹ 0.000 › | 🔲 | ↔ | ❓

Scenario	Technology	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
SC_0	RSCLND	10^6US…	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
SC_0	LNDMAIRNF	10^6US…	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.00
SC_0	LNDRICRNF	10^6US…	110.000	110.000	110.000	110.000	110.000	110.000	110.000	110.000	110.000	110.000	110.000	110.000	110.000	110.000	110.000	110.00
SC_0	LNDMAIIRR	10^6US…	76.000	76.000	76.000	76.000	76.000	76.000	76.000	76.000	76.000	76.000	76.000	76.000	76.000	76.000	76.000	76.00
SC_0	LNDRICIRR	10^6US…	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.000	141.00
SC_0	LNDFOR	10^6US…	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
SC_0	LNDBLT	10^6US…	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
SC_0	LNDWAT	10^6US…	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00

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Note: A filter is applied to the column "Technology" to show technologies with "LND" in their name.

Variable Cost — Region, year, technology, mode of operation

SELECTED MODEL: CLEWs exercise

Variable Cost | 💾 Save data | 0.0 ‹ 0.000 › | 🔲 | ↔ | ❓

Scenario	Technology	MoO	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	203
SC_0	RSCLND	1	10^6USD/1…	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0
SC_0	LNDMAIRNF	1	10^6USD/1…	42.0000	42.0000	42.0000	42.0000	42.0000	42.0000	42.0000	42.0000	42.0000	42.0000	42.0000	42.0000	42.0000	42.0000	42.0
SC_0	LNDRICRNF	1	10^6USD/1…	57.0000	57.0000	57.0000	57.0000	57.0000	57.0000	57.0000	57.0000	57.0000	57.0000	57.0000	57.0000	57.0000	57.0000	57.0
SC_0	LNDMAIIRR	1	10^6USD/1…	53.0000	53.0000	53.0000	53.0000	53.0000	53.0000	53.0000	53.0000	53.0000	53.0000	53.0000	53.0000	53.0000	53.0000	53.0
SC_0	LNDRICIRR	1	10^6USD/1…	77.0000	77.0000	77.0000	77.0000	77.0000	77.0000	77.0000	77.0000	77.0000	77.0000	77.0000	77.0000	77.0000	77.0000	77.0
SC_0	LNDFOR	1	10^6USD/1…	-29.4000	-29.4000	-29.4000	-29.4000	-29.4000	-29.4000	-29.4000	-29.4000	-29.4000	-29.4000	-29.4000	-29.4000	-29.4000	-29.4000	-29.4
SC_0	LNDBLT	1	10^6USD/1…	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0
SC_0	LNDWAT	1	10^6USD/1…	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0

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Note: A filter is applied to the column "Technology" to show technologies with "LND" in their name.

Operational Life — Region, technology

SELECTED MODEL: CLEWs_exercise

Operational Life | 💾 Save data | ❓

Scenario	Parameter	…D [years]	RSCLND [years]	LNDMAIRNF [years]	LNDRICRNF [years]	LNDMAIIRR [years]	LNDRICIRR [years]	LNDFOR [years]	LNDBLT [years]
SC_0	Operatio…	100.000	100.000	15.000	15.000	15.000	15.000	50.000	20.

2. Enter data for the parameter "**Residual Capacity**" for land technologies using the data in the CLEWs data Excel file in the sheet "4.2. Land". Click on "**Save data**" after adding the values.

Overview of Residual Capacity assumptions

Technology	Residual Capacity (10^3 km^2)	
	2020	**Trend (2020-2035)**
LNDMAIRNF	0.955	Decreases to 0 by 2035
LNDRICRNF	1.423	Decreases to 0 by 2035
LNDMAIIRR	0.079	Decreases to 0 by 2035
LNDRICIRR	0.531	Decreases to 0 by 2035
LNDFOR	253.6	Constant and equal to 2020
LNDBLT	15.0	Constant and equal to 2020
LNDWAT	25.0	Constant

Land technologies with "Residual Capacity"
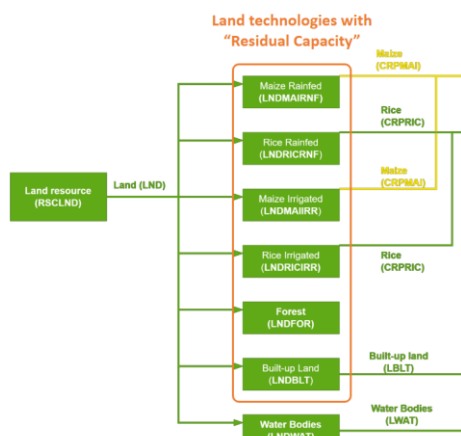
Residual Capacity _Region, year, technology_

SELECTED MODEL: **CLEWs exercise**

Scenario	Technology	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
SC_0	RSCLND	10³km²	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
SC_0	LNDMAIRNF	10³km²	0.955	0.892	0.828	0.764	0.701	0.637	0.573	0.510	0.446	0.382	0.318	0.255	0.191	0.127	0.064	0.06
SC_0	LNDRICRNF	10³km²	1.423	1.328	1.233	1.138	1.044	0.949	0.854	0.759	0.664	0.569	0.474	0.379	0.285	0.190	0.095	0.09
SC_0	LNDMAIIRR	10³km²	0.079	0.074	0.068	0.063	0.058	0.053	0.047	0.042	0.037	0.032	0.026	0.021	0.016	0.011	0.005	0.00
SC_0	LNDRICIRR	10³km²	0.531	0.496	0.460	0.425	0.389	0.354	0.319	0.283	0.248	0.212	0.177	0.142	0.106	0.071	0.035	0.03
SC_0	LNDFOR	10³km²	253.600	253.600	253.600	253.600	253.600	253.600	253.600	253.600	253.600	253.600	253.600	253.600	253.600	253.600	253.600	253.60
SC_0	LNDBLT	10³km²	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.00
SC_0	LNDWAT	10³km²	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.00

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Note: A filter is applied to the column "Technology" to show technologies with "LND" in their name.

3. It is assumed that irrigated land cannot expand more than 5% yearly. This assumption is introduced in the parameter "**Technology Activity Increase By Mode Limit**" as a fraction of 1, i.e., a 5% limit corresponds to 0.05.

   To add the parameter data, go to "**Data Entry**" and search for "**Technology Activity Increase By Mode Limit**", and the irrigated cropland technologies LNDMAIIRR and LNDRICIRR. **Add the number for all years!**

Technology	Technology Activity Increase By Mode Limit (2020 – 2035)
LNDMAIIRR	0.05
LNDRICIRR	0.05

4. "**Save data**" to save your edits.

Note: A filter is applied to the column "Technology" to show technologies with "IRR" in their name.

5. The investments in the first year (2020) should be restricted so that there is no investment in that year. To do so, go to "**Data entry**" and search for the parameter "**Total Annual Max Capacity Investment**". In the irrigated cropland technologies, set the investments to "0" in the first year (2020). Do not change values for the other years.

6. **DO NOT FORGET TO SAVE YOUR MODEL!**

Activity 3 – Running the Model

This is the first time running the model containing both the energy system and the full representation of the land system (before interlinkages) of the CLEWs model.

NOTE: Refer back to the previous hands-on if you have forgotten how to view results.

In this activity, you should explore the results for **these variables**:

1. **Use by Technology By Mode:** This shows the use of input commodities to a technology by mode of operation. The results inform on the amount of land resource used by the different land covers – you can also view **'Total Capacity by Technology'.**

2. **Production By Technology By Mode**: Shows the number of outputs produced by technology. This exercise provides information on the volume of crops (MTon) produced by cropland technologies (rainfed and/or irrigated).

3. **Capital Investment:** The total investment in every single year – you can also view **'Annualised Investment Costs'.**

a) Add *Tech Desc* to columns and remove *Tech* – this is not necessary; it just makes your graphs look better.
b) Filter (using field settings) **case**, to view **only HO7_A3**.