Introduction to CLEWs
Hands-on lecture 6: Introduction to the land system

Abhishek Shivakumar[a,b,c], Vignesh Sridharan[d], Francesco Gardumi[e], Taco Niet[f], Thomas Alfstad[a]

[a]*United Nations Department of Economic and Social Affairs, New York*

[b]*University College London, United Kingdom*

[c]*Loughborough University, United Kingdom*

[d]*Imperial College London, United Kingdom*

[e]*KTH Royal Institute of Technology, Sweden*

[f]*Simon Fraser University, Canada*

V1.2.0

Revised by: Shravan Kumar Pinayur Kannan[e], Roberto Heredia[e], Francesco Gardumi[e], Leigh Martindale[c], Abhishek Shivakumar[a,b,c], Thomas Alfstad[a]

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

Useful links:
   1) [Discussion forum](#) for CLEWs
   2) [Results from this Hands-on](#)

Pre-requisites:
   1) Successful completion of all the activities under Hands-on lecture 5

Learning outcomes

By the end of this exercise, you will be able to:

1) Explain basic concepts of land systems
2) Create an engineering and simplified representation of land systems on a CLEWs model
3) Understand implications of land use planning on other CLEW systems

Overview

Until now, you have been building the aspects of an energy system into the model. From this hands-on exercise, you will create commodities and technologies to represent land-cover and land-use in the CLEWs model. Additionally, you will learn how to differentiate between the rainfed and irrigated land representations in the model. Before you dive into the land representations, it is essential to recollect the concepts of modes-of-operation and how to use them. Kindly refer to the fourth section of lecture 6 (6.4) for detailed information on why and how modes of operation are used.

Before starting the work on land use representation, you will have to copy the model you created in the previous hands-on section.

1. Go to the left panel and click on the 'Home' button.

2. Click on 'Copy Model' to copy/clone your last model.

3. Go to left panel and click on 'Configure model'.

4. Update the model name and description, and Save the changes by clicking in 'Update model data'.

Activity 1 – Introducing rainfed landcover types

This activity will introduce the following structure to the existing model that includes only the power system.
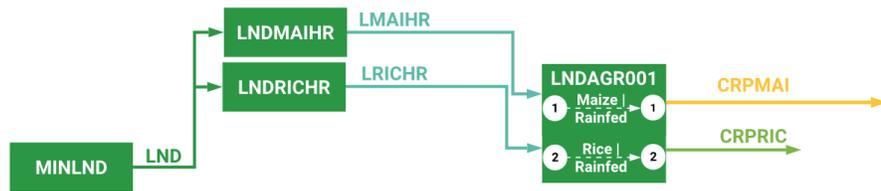
You will be adding the following new **Technologies** to the model.

MINLND	The land resource technology (used to account for the total available land).
LNDMAIHR	An accounting technology that keeps a tab on the land used for rainfed Maize cultivation.
LNDRICHR	An accounting technology that keeps a tab on the land used for rainfed Rice cultivation.
LNDAGR001	The technology where we specify the difference between the various land-cover types.

You will also add the following **Commodities**

CRPMAI	Commodity that represents the Maize crop
CRPRIC	Commodity that represents the Rice (Paddy) crop
LMAIHR	Land representing rainfed maize cultivation
LRICHR	Land representing rainfed rice cultivation
LND	Central land resource

You will introduce two types of rainfed crops: Maize and Rice. This is the first step in introducing land cover. Similar to the energy systems, you will have to add the technologies and commodities for the land system using the **"Define model configuration"** in the newly cloned model.

After you have added the new technologies and commodities, the modes of operation need to be created. For this, you again will have to refer to the **"Modes of operation'** and create two new modes that will represent the land allocated for rainfed maize and rice cultivation.
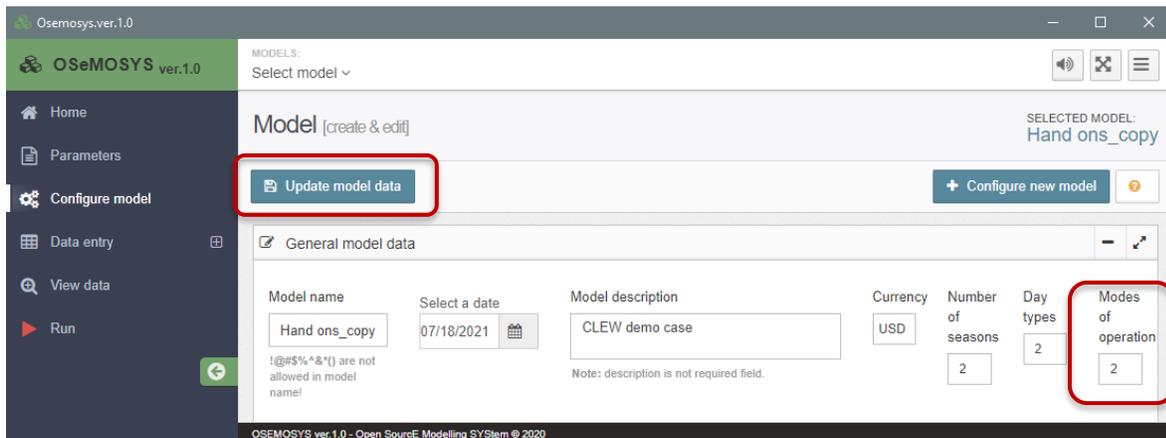
Modes to be used:

- Mode 1: represents land allocated to rain-fed Maize cultivation (the mode is already defined from previous activities, no need to re-define it)

- Mode 2: represents land allocated to rain-fed Rice cultivation (new, to be added)

The following figures can be used to guide on how to add the modes of operation.

Save the changes by clicking in 'Update model data'

After adding the new technologies, commodities and modes, the next step is to start including the data for the newly added entities. You will start from the demand side by adding demands for the two crops Maize and Rice.

Commodity	Value	Parameter used
CRPMAI (Maize)	40 Million tonnes (Mt)	AccumulatedAnnualDemand
CRPRIC (Rice)	30 Million tonnes (Mt)	AccumulatedAnnualDemand

The **"AccumulatedAnnualDemand"** parameter is used for those commodities with no requirement for the demand to be met in a particular **"TimeSlice",** unlike electricity demand in the energy system. It is important to note that the crop demand, in this exercise, is expected to remain the same for all the years. The parameter AccumulatedAnnualDemand can be found in the same place where you found the other parameters like Input and output activity ratios.

In the next step, you will have to enter the input and output activity ratios for the technologies detailed below. Most of them will be in the unit of **1000 sq. km** land

per 1000 sq. km activity. That is, the intended unit for the activity of land technologies is 1000 sq. km.
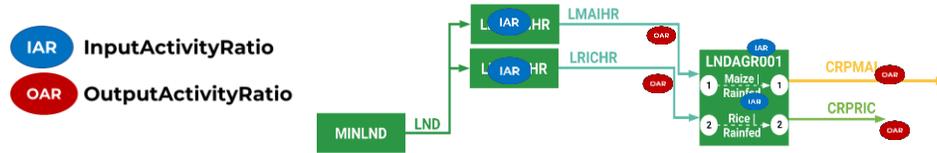
Technology	Commodity	Mode Of Operation	Value	Parameter
MINLND	LND	1	1 1000sq.km/1000sq.km	OutputActivityRatio
LNDMAIHR	LND	1	1 1000sq.km/1000sq.km	InputActivityRatio
LNDRICHR	LND	1	1 1000sq.km/1000sq.km	InputActivityRatio
LNDMAIHR	LMAIHR	1	1 1000sq.km/1000sq.km	OutputActivityRatio
LNDRICHR	LRICHR	1	1 1000sq.km/1000sq.km	OutputActivityRatio
LNDAGR001	LMAIHR	1	1 1000sq.km/1000sq.km	InputActivityRatio
LNDAGR001	LRICHR	2	1 1000sq.km/1000sq.km	InputActivityRatio
LNDAGR001	CRPMAI	1	0.8 Mt/1000sq. km	OutputActivityRatio
LNDAGR001	CRPRIC	2	0.2 Mt/1000sq.km	OutputActivityRatio

It must be noted that the default mode of operation is "1". Unless specified, all the parameters will be defined for the first mode. In the table above, we can notice that the modes are different only for the technology **"LNDAGR001",** where modes are essential. **Every unit of land in this model is equal to 1000sq.km.** This arrangement is made to minimize the number of digits used to represent the value. Effectively, in this setup, the technology LNDAGR001 takes 1 unit of land allocated

for rainfed maize (as input) and produces 0.8 million tonnes of CRPMAI (Maize) in mode 1.

Now, generate a Case for this model, download the data file and run it (if you do not recall how, kindly go back to Activity 3 of Hands-on lecture 3).

Own reflection

Optional (no deliverable needed)

- Reflect on the potential and limitations of such representation of land uses and whether there are other possible approaches.

- What demands are driving the land uses? Which input parameters you gave represented the link between land use and crop production?

Activity 2– Introducing irrigated land cover types

Before you start with the Activity, copy the model from the previous Activity. Make sure you do this every time you start a new Activity.

In this activity, you will add two more modes of operation to include irrigated land cover types. In addition to the 1st and 2nd, you will add modes 3 and 4 to include the irrigated alternatives for Maize and Rice crop, as shown in the following figure.
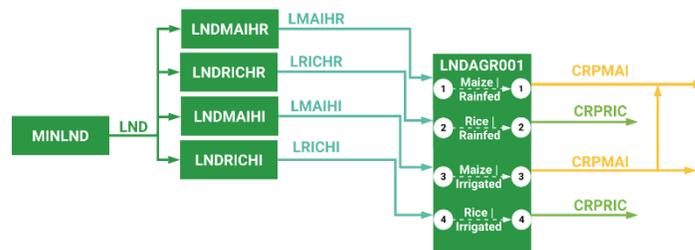
You will first need to add two new modes by following the same process described in **Activity 1**. Additionally, you will add two technologies and two commodities to account for the land allocated to the irrigated land cover types.

Technologies to be added:

LNDMAIHI:	An accounting technology that keeps a tab on the land used for irrigated Maize cultivation.
LNDRICHI:	An accounting technology that keeps a tab on the land used for irrigated Rice cultivation.

You will also add the following commodities

LMAIHI:	Land representing irrigated maize cultivation
LRICHI:	Land representing irrigated rice cultivation

It is important to note that for each of the modes in the LNDAGR001 technology, a pair of technology and commodity will need to be created to account for the land allocated to that mode. These **accounting** technologies are introduced to allow the user to specify capital and fixed costs for each land use type. It is not possible to do that only using the technology LNDAGR001.

Please note that the outputs for Maize crop in modes 1 and 3 are the same commodity. As you might have guessed by now, the only difference between the rainfed and irrigated modes will be the improvement in crop yield, which will be represented by using the output activity ratios. The table below details the necessary inputs.

Technology	Commodity	Mode Of Operation	Value	Parameter
LNDMAIHI	LND	1	1 1000sq.km/1000sq.km	InputActivityRatio
LNDRICHI	LND	1	1 1000sq.km/1000sq.km	InputActivityRatio
LNDMAIHI	LMAIHI	1	1 1000sq.km/1000sq.km	OutputActivityRatio
LNDRICHI	LRICHI	1	1 1000sq.km/1000sq.km	OutputActivityRatio
LNDAGR001	LMAIHI	3	1 1000sq.km/1000sq.km	InputActivityRatio

LNDAGR001	LRICHI	4	1 1000sq.km/1000sq.km	InputActivityRatio
LNDAGR001	CRPMAI	3	1 Mt/1000 sq.km	OutputActivityRatio
LNDAGR001	CRPRIC	4	0.4 Mt/1000 sq.km	OutputActivityRatio

Now, generate a Case for this model, download the data file and run it (if you do not recall how, kindly go back to Activity 3 of Hands-on lecture 3).

Own reflection

Optional (no deliverable needed)

- Elaborate on the differences between irrigated and rainfed crops, regarding water use and yield.

- Elaborate more on the structure of the land model you are creating: why do you think the intermediate land technologies (e.g. LNDMAIHR) are added to the model? Do you think anything is missing in the inputs you gave so far? Is there a way you are accounting for potential limits in available land for different uses?

Activity 3– Introducing non-agricultural land cover types

In this exercise, you will add three more modes of operation to include other non-agricultural land cover types like forests, built-up land and water bodies. The three new types will be in modes 5, 6 and 7, respectively.
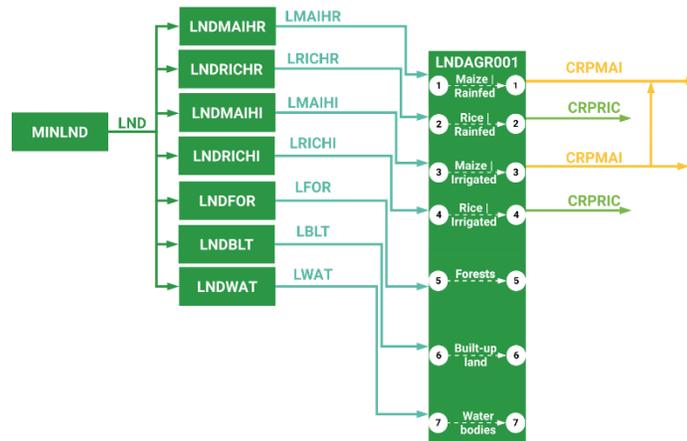
Similar to **Activity 1 and 2,** you will have to add three new modes of operation using the **"Configure model",** on the left panel of the UI. After the modes are defined, the next step is to introduce the necessary connections, as illustrated in the figure above. In this setup, there are no expected outputs from the forests, built-up lands and water bodies. Therefore, only the technologies and commodities used for accounting have to be created and connected.

Technologies to be added:

LNDFOR:	An accounting technology that keeps a tab on the forest land cover.
LNDBLT:	An accounting technology that keeps a tab on the built-up land.
LNDWAT:	An accounting technology that keeps a tab on the area covered by water bodies.

Commodities to be added:

LFOR:	Land representing forests
LBLT:	Land representing built-up areas
LWAT:	Land representing areas of water bodies

Additionally, introduce a cost (**variable cost**) for the Forest mode (mode 5) in the LNDAGR001 technology. This value will be equal to USD **-2** Million per unit of land. A **negative value** is provided to tell the model that it is beneficial to have land allocated to the forest category. Additionally, you will also include a value to signify the total

land available for allocation. This value is set to 300 units each year and is added to the technology representing the total land available, that is, MINLND. You will have to use the **"TotalTechnologyAnnualActivityUpperLimit"** parameter to specify the limit for the total land available. All the inputs you need to give are summarised in the below table.

Technology	Commodity	Mode Of Operation	Value	Parameter
LNDFOR	LND	1	1	InputActivityRatio
LNDBLT	LND	1	1	InputActivityRatio
LNDWAT	LND	1	1	InputActivityRatio
LNDFOR	LFOR	1	1	OutputActivityRatio
LNDBLT	LBLT	1	1	OutputActivityRatio
LNDWAT	LWAT	1	1	OutputActivityRatio
LNDAGR001	LFOR	5	1	InputActivityRatio
LNDAGR001	LBLT	6	1	InputActivityRatio
LNDAGR001	LWAT	7	1	InputActivityRatio
LNDAGR001	-	5	-2 Million USD/1000 sq.km	VariableCost
MINLND	-	-	300 (1000 sq.km)	TotalTechnologyAnnual ActivityUpperLimit

Now, generate a Case for this model, download the data file and run it (if you do not recall how, kindly go back to Activity 3 of Hands-on lecture 3).

Own reflection

Optional (no deliverable needed)

- What types of dynamics in land uses (e.g. changes in land uses, conflicts in land uses, or anything else) is one able to see with this model structure?

- You may reflect on the benefits and drawbacks of this type of simplified representation.