How far energy price and diets drive global land use?

First lessons from a global model driven by biophysical and economic dynamics

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❶ Introduction

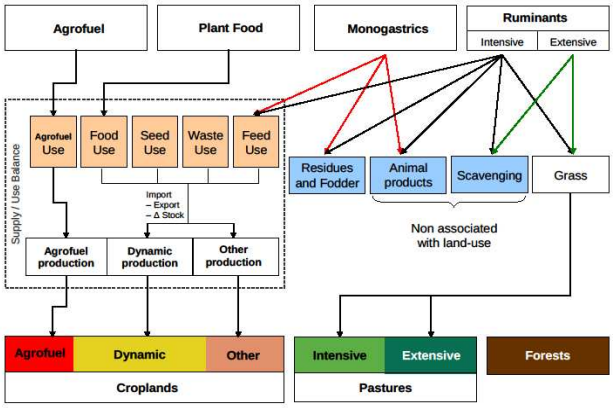
Soaring demography and growing per-capita incomes imply an increase in food demand, with a particular emphasis on the consumption of animal calories. At the same time, rising fossil energy prices are expected to spur the production of bioenergy and to increase fertlisers and pesticides prices. To study the combined impact of energy price and diets on agriculture in the most consistent manner, this poster presents a new world land-use model, called Nexus Land-Use, articulating biophysical potentials and economic dynamics into a single numerical framework.

❷ Nexus Land-Use modelling principles

The Nexus Land-Use modelling principles are the following:

- An external yearly demand of agrofuel, plant food and animal calories must be met by adequate supply given exogenous evolutions of agricultural areas;
- The model calculates the intensification levels that minimise production costs under supply/demand equilibrium of biomass
- Intensification processes are modelled both for crop and livestock production following two methodologies detailed in ❸ and ❹.

The Nexus Land-Use combines various data sources. Three are especially important: the LPJmL vegetation model that is used to parameterise crop yields; the Bouwman et al. (2005)'s representation of livestock production systems and the global database Agribiom (Dorin et al., 2011) which provides biomass balance in kilocalories.

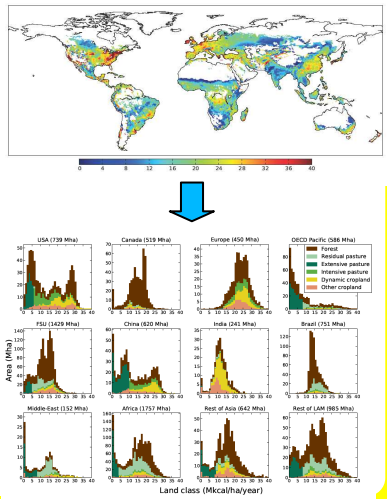


Each type of land-use modeled in the Nexus Land-Use are derived from the feedstocks used to produce agrofuel, plant food or animal calories (see above figure). The « dynamic crop » category refers to crop that are endogenously modeled, contrary to the « other crop » category on which LPJmL does not provide data. The intensive and extensive category corresponds to distinction made by Bouwman et al. between the different livestock production systems.

❸ Crop production

The modelling of crop production is done in several steps:

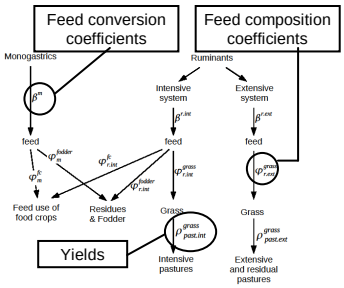
1. A representative potential yield is computed on a 0.5x0.5 grid from the potential yields given by LPJmL for 11 crop functional type
2. Land classes grouping together grid points with the same potential yield are set up
3. Actual yield in each land class is determined by a function of fertilisers and pesticides
4. This function is then optimised so as to minimise production costs with fixed labor and capital inputs.



❹ Livestock production

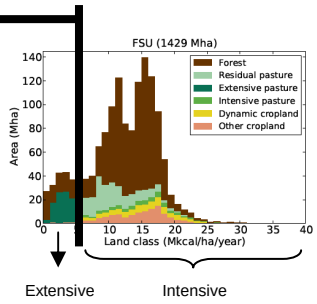
Following Bouwman et al. (2005), two farming systems for ruminant production are considered:

- The extensive system where animals are fed mainly by grazing on extensive pastures and to some extent by scavenging
- The intensive system or mixed-landless for which animals are fed not only with grass but also with residues and fodder, food crops, animal products and by scavenging.



Inspired by the Ricardian principles, the Nexus Land-Use models a production frontier between the two systems according to a cost minisation criterion.

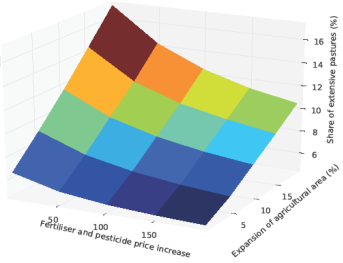
In this theoretical framework, the intensive system is supposed to be located on the most productive lands, along with croplands.

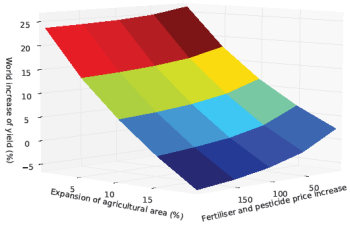


❺ Results

Scenario:

- Food consumption increases following a scenario inspired by the Millennium Ecosystem Assessment scenario « Global Orchestration »
  - Population grows according to the median scenario of the United Nations
- The selected expansion of agricultural surfaces between 2001 and 2050 ranges from 0 to 20%
- Variations of the fertiliser and pesticides price index range from 0% to + 200% to 2050





Key findings:

- Rise of fertilisers and pesticides prices disadvantages the use of chemical inputs over land and generate a yield reduction ceteris paribus
- Land scarcity tends to reduce the elasticity of yield with respect to fertilisers and pesticides price, showing that as land pressure grows, the flexibility to choose yields considering chemical and energy prices diminishes

- When the fertilisers and pesticides price increases, livestock production must be intensified by converting extensive pastures into crop or intensive pastures, in order to compensate the loss of production due to the fall of yield resulting from the rise of chemical inputs price

❻ References

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