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CO	Confidential, only for members of the Consortium (including the Commission Services)	

Land-use adjustments induced by climate change

This report shows the land-use modifications occurring as a consequence of climate change in the period 2001-2050. Results come from a simulation conducted by means of a dynamic-recursive computable general equilibrium model by FEEM known as ICES (Intertemporal Computable Equilibrium System, see Roson et al. (2008)).

Land use allocation

In this model, land is a primary factor together with capital, labour and natural resources. These factors are connected via a CES function, allowing some degree of substitutability among them. The bundle of primary factors is then grouped, to be combined in the upper nest of the production tree with the bundle of intermediates via a Leontief relation. This implies that there is no substitution between intermediates and primary factors.

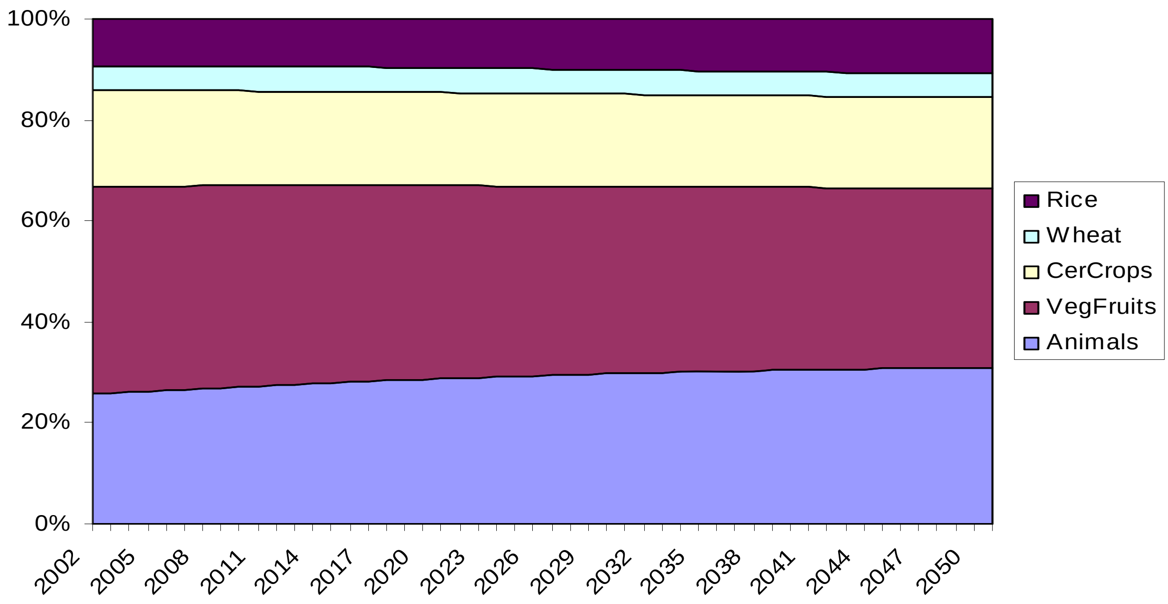
Even though land, intended as physical space, is necessary in almost all economic sectors (plants, houses, roads and so on), in ICES it regards only to agricultural land. This is because, in line with the standard input-output tables depicting an economic system at a certain point in time, all variables are measured in value rather than in physical terms. Therefore, its use in agriculture represents the only rent for land-owners which contributes together with the other components (wages and profits) to the creation of value added. Only one homogeneous land type exists in the basic structure of ICES, which is allocated among different types of crops. In the present aggregation the model groups agricultural commodities in five sectors which compete for the available land: rice, wheat, other cereal crops, vegetable/fruits and animals.

Being ICES a dynamic recursive model, it is possible to track agricultural land use over time since its allocation can move across competing crops according to several factors. Generally, the higher the remuneration from the production of a crop, the higher the incentive to allocate more land to it. The change in remuneration depends on crop prices, productivities of primary factors and its demand. However, land shifting from one crop to another is not an immediate process. This happens because, differently from capital and labour that are considered as perfectly mobile across sectors, land is assumed as a sluggish endowment and therefore imperfectly mobile across different uses. This means that it is possible to change the crop grown in a specific area, but with some restrictions making land an imperfectly mobile factor. From the modelling viewpoint, this aspect is introduced by the concept of elasticity of transformation in the production function. In fact, with a higher absolute value of the elasticity of transformation, it will be easier to move towards the most remunerative crops. The model captures this feature by setting a value for the elasticity of transformation equal to -1; meaning that changing from one agricultural production to another requires some time and effort and also that differential equilibrium rental rates can coexist.

Land use allocation in the baseline scenario

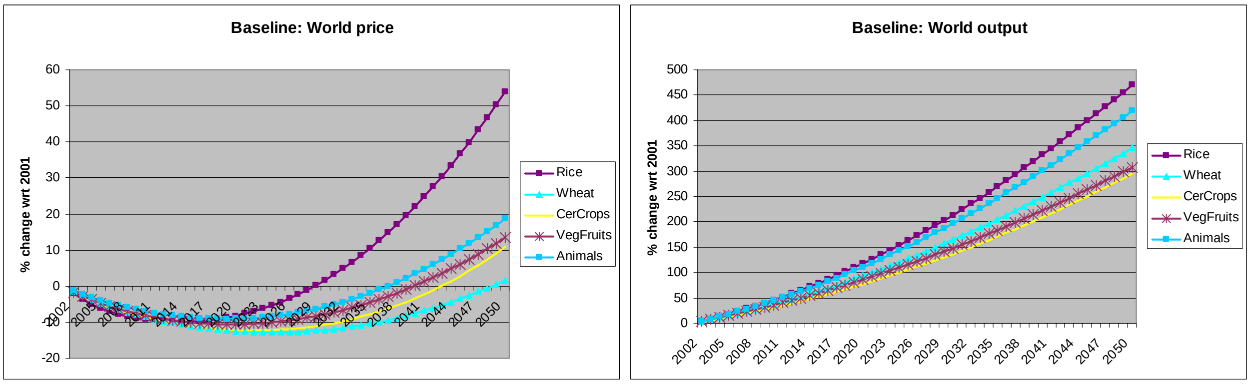
Having a baseline scenario that gives a reference of what could happen in the future in the absence of climate change, it is possible to plot the distribution of the total land in order to have an idea of the land use for agricultural purposes. Figure 1 shows the change in land use allocation as percentage of the total land available for the baseline scenario. The share of land allocated to wheat and cereal crops does not change substantially over time, while the share of land devoted to rice and animals increases at the expense of vegetables and fruits. However, despite its share diminishes over time, the vegetable and fruits sector keep on being the one with the main requirement of land in the period under consideration, with no change in the use of land in absolute terms, since there is a small increase in the quantity of land available for crops.

Figure 1: Land Use Allocation in the Baseline Scenario (2001-2050)



Behind the changes in the shares dedicated to the different crops are the changes in prices and output as shown in figure 2. The increase in the shares of rice and animals is explained because both activities register the greater increases at the end of the period for both price and output. Moreover, vegetables and fruits also show a sustained increase in price, which explains that in spite of a declining share it still uses a constant amount of land in absolute terms.

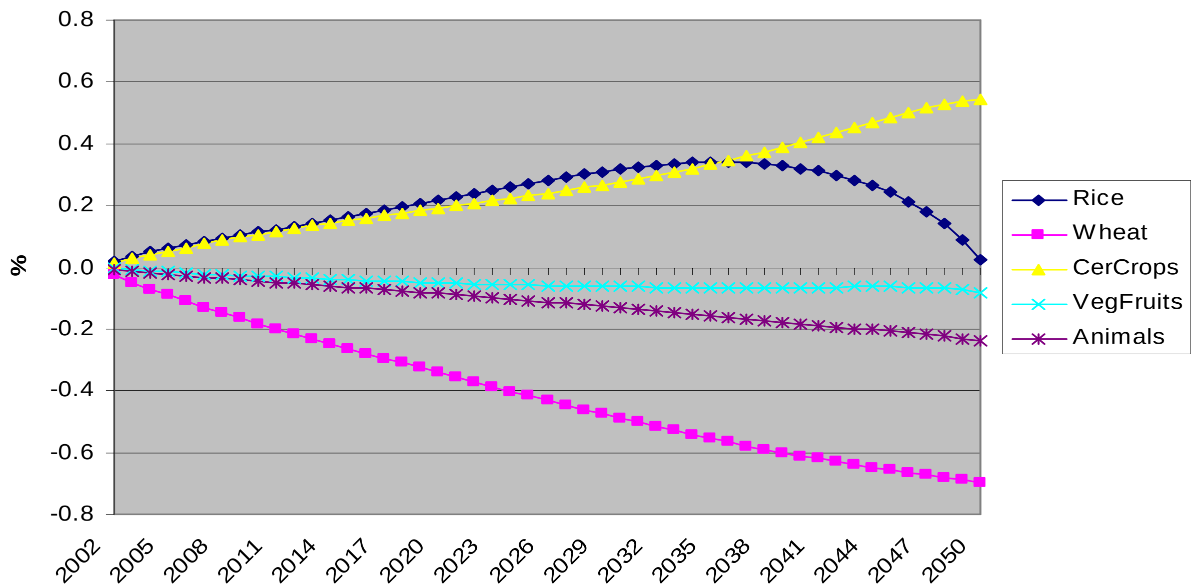
Figure 2: World output and price for agricultural commodities



Climate change effects on land use

The baseline scenario gives us a reference picture of what really will presumably happen in the future, since it neglects the effects of climate change. This affects land-use allocation between crops through different channels. From the five climate change impacts modelled: agriculture, sea level rise, residential energy demand, health and tourism; the first two affect directly the supply side of agricultural commodities while the remaining ones have an indirect influence through the demand side.

Figure 3: Changes in land use due to climate change impacts (2001-2050)



Looking at the overall effect of climate change, in the period 2001-2050 land use declines steadily for three crops; and for the year 2050 vegetables and fruits decreases by 0.08%, animals by 0.24% and wheat by 0.70%. On the contrary, land allocated to other cereal crops increases sharply reaching in 2050 an increase of 0.54%. Finally, rice, after achieving a peak in 2035 (+ 0.34%), in 2050 maintains practically the initial amount of productive land with respect to the case where climate change impacts are not considered.

Figure 4: Changes in agricultural world output due to climate change impacts (2001-2050)

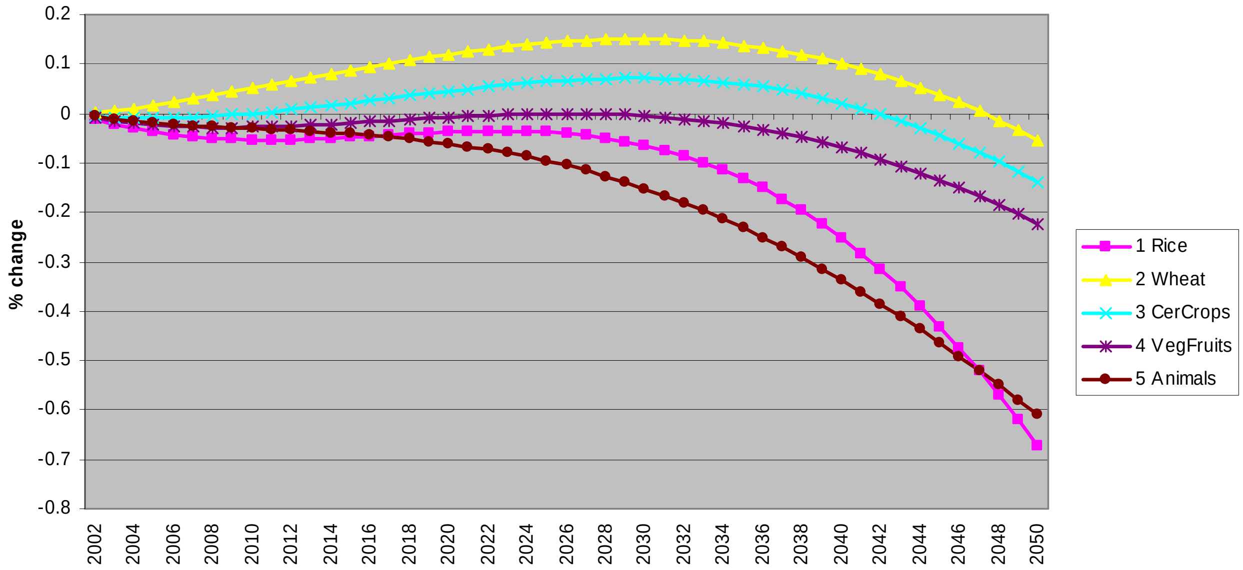
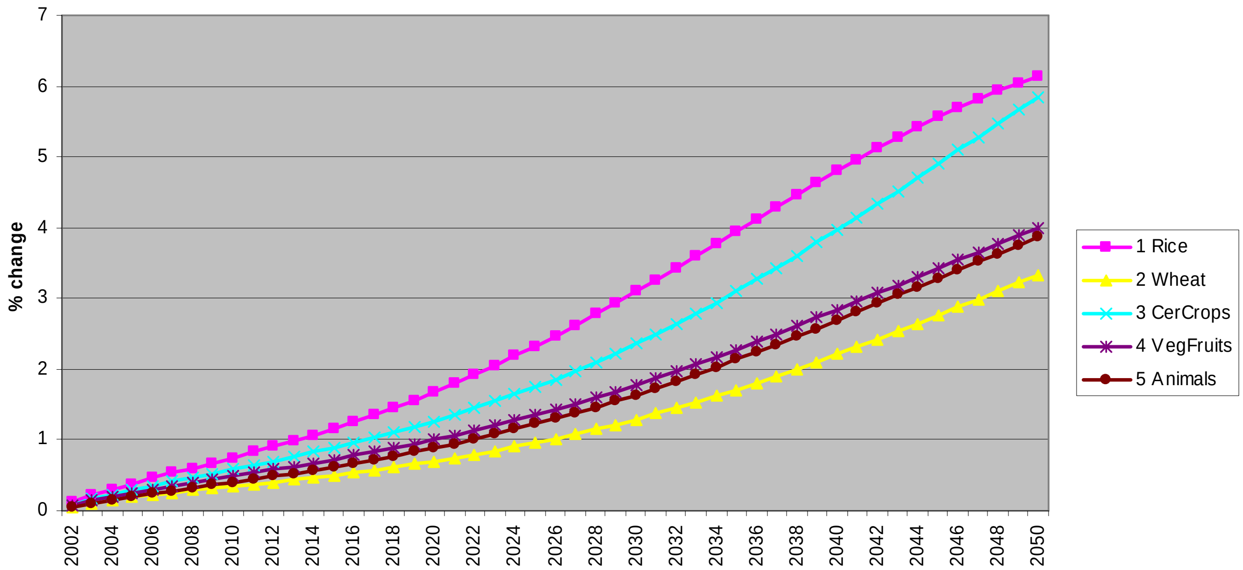


Figure 5: Changes in agricultural world prices due to climate change impacts (2001-2050)



Considering the effects of climate change, the agricultural sectors that experience a much higher increase in price are the same that increases land use: rice and cereal crops. However, the augmenting agricultural prices are in contrasts with a declining tendency in production particularly at the end of the period. This behaviour explains also the decline of land use in the case of rice, which is almost neutralized in 2050.

Since climate change influences economic activities both from the supply and demand side, it is useful to mention these kinds of effects on land use. Firstly, reduction in land supply due to sea level rise, increasing the price of land, penalises the most land-intensive production, being rice the most intensive, while other cereal crops the least intensive. Secondly, climate change affects land productivity in a differentiated way for each crop and in each region (other cereal crops mostly affected, wheat the least affected). Finally, change in demand in non-agricultural sectors and in non-land primary factors, induced by other categories of climate change impacts (human health impacts and modification in demand of energy and touristic services), may indirectly lead to a substantial change on return from competitive crops' production.

Recent developments in land use modelling

In recent years, in order to improve the issue of the change in land allocation in computable general equilibrium models, different approaches have been proposed. A first strategy relies upon different land types rather than one. Lee et al. (2005) and Golub et al. (2008) developed an extended database to incorporate a more realistic land-use mechanism into the GTAP model (Hertel, 1997). Here, land is divided in Agro-ecological Zones (AEZ) according to length in growing period, moisture regime and climate. In each AEZ only certain crops can be grown. Therefore, land is imperfectly substitutable among different uses within, but not substitutable across AEZ. Gurgel et al. (2008) modify the MIT-EPPA model differentiating among five land types (cropland, pasture land, harvested forest land, natural grass land and natural forest land), allowing also for land conversion over time.

An alternative methodology consists of economic models linked with land use models. These predict how land is allocated among competing uses (not only agricultural but also forestry or urban). Then, the resulting land allocation is implemented into general economic equilibrium models to assess economic impacts. This route is computationally and modelling demanding. Usually it is pursued by large integrated assessment exercises like in the IMAGE model (IMAGE, 2001), the IGSM-MIT model (Prinn et al., 1999) the AIM model (Kainuma et al. 2002) and the GTAP-KLUM model (Ronneberger et al., 2006). The last one has been developed by FEEM together with other European research centres for a static CGE; at the moment, a dynamic version is not yet available.

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