Comparative Analysis of Factor Markets for Agriculture across the Member States

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RED vs. REDD: Biofuel Policy vs. Forest Conservation

ABSTRACT

This paper assesses the complex interplay between global Renewable Energy Directives (RED) and the United Nations programme to Reduce Emissions from Deforestation and forest Degradation (REDD). We examine the interaction of the two policies using a scenario approach with a recursive-dynamic global Computable General Equilibrium model. The consequences of a global biofuel directive on worldwide land use, agricultural production, international trade flows, food prices and food security out to 2030 are evaluated with and without a strict global REDD policy. We address a key methodological challenge of how to model the supply of land in the face of restrictions over its availability, as arises under the REDD policy. The paper introduces a flexible land supply function, which allows for large changes in the total potential land availability for agriculture. Our results show that whilst both RED and REDD are designed to reduce emissions, they have opposing impacts on land use. RED policies are found to extend land use whereas the REDD policy leads to an overall reduction in land use and intensification of agriculture. Strict REDD policies to protect forest and woodland lead to higher land prices in all regions. World food prices are slightly higher overall with some significant regional increases, notably in Southern Africa and Indonesia, leading to reductions in food security in these countries. This said, real food prices in 2030 are still lower than the 2010 level, even with the RED and REDD policies in place. Overall this suggests that RED and REDD are feasible from a worldwide perspective, although the results show that there are some regional problems that need to be resolved. The results show that countries directly affected by forest and woodland protection would be the most economically vulnerable when the REDD policy is implemented. The introduction of REDD policies reduces global trade in agricultural products and moves some developing countries to a net importing position for agricultural products. This suggests that the protection of forests and woodlands in these regions reverses their comparative advantage as they move from being land-abundant to land-scarce regions. The full REDD policy setting, however, foresees providing compensation to these countries to cover their economic losses.

Keywords: RED, REDD, flexible land supply function, land, land use changes, food security.

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RED vs. REDD: Biofuel Policy vs. Forest Conservation

Peter Dixon, Hans van Meijl, Maureen Rimmer, Lindsay Shutes and Andrzej Tabeau*

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1. Introduction

A rapid growth in worldwide biofuel production has been observed since 2001, driven by Renewable Energy Directives (RED) and high crude oil prices, as well as a growing interest in reducing greenhouse gas (GHG) emissions. There are increasing concerns, however, that the demand for land for biofuel production may be leading to increased deforestation (Banse et al. 2008, Banse et al. 2011, Hertel et al. 2010), resulting in biodiversity losses and higher GHG emissions. Deforestation and forest degradation, together with peatland emissions, have been shown to account for between 15% (Werf et al. 2009) and 20-25% of greenhouse gas emissions, a total that is higher than the entire contribution of the transportation sector (Myers 2007).

The United Nations REDD programme seeks to Reduce Emissions from Deforestation and forest Degradation by protecting and managing forests and woodlands (UN-REDD 2011). Any effort to limit deforestation is also likely to limit the land available for increasing agricultural production, including biofuel production stemming from RED policies. The restriction of available land by REDD policies is therefore likely to change the pattern of comparative advantage in agricultural production between countries, leading to changes in agricultural prices, trade and food security. However, these effects, together with the land use impacts of REDD policies across the world, are not well understood and, to date, there have been no studies of the interaction between RED and REDD and little discussion in the policy arena.

This paper assesses the complex interplay between global renewable energy directives (RED) and the REDD programme to limit deforestation and forest degradation. We examine the interaction of the two policies using a scenario approach with a global Computable General Equilibrium (CGE) model and address a key methodological challenge of how to model the supply of land in the face of restrictions over its availability, as arises under the REDD policy. The consequences of a global biofuel directive on worldwide land use, agricultural production, international trade flows, food prices and food security, are evaluated with and without a strict global REDD policy. The advantage of such a modelling approach is that the feedback effects between agricultural, biofuel, energy and other markets are captured (Rajagopal & Zilberman 2007). In addition, the transmission of the impact of RED and REDD policies to other regions of the world through endogenous impacts on agricultural prices and land returns are captured. The economy-wide coverage of the CGE model also enables the impact on food security and the balance of trade to be evaluated.

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2. Modelling land use, RED and REDD

Capturing the interaction of RED and REDD policies requires a global multi-sector approach that accounts for both the changes in restrictions on land availability arising from the REDD agreements and changes in energy and agricultural markets arising from biofuel directives.

2.1 Modelling framework

The policy scenarios are implemented in the MAGNET model,[1] a multi-regional, recursive-dynamic, applied general equilibrium model based on neo-classical microeconomic theory (Nowicki et al. 2009, van Meijl et al. 2006). MAGNET is based on the standard GTAP model (Hertel 1997) and has at its core, an input–output model that links industries in a value-added chain from primary goods, over continuously higher stages of intermediate processing, to the final assembling of goods and services for consumption. Goods at any stage of production can be traded between regions. The MAGNET model goes beyond the standard GTAP model with an improved representation of five policy-relevant dimensions: i) the agricultural sector by including imperfectly substitutable types of land, a land use allocation structure, land supply function and substitution between various animal feed components; ii) agricultural policy by including production quotas and different land-related payments; iii) biofuel policy by including capital-energy substitution, substitution between fossil and biofuels; iv) shifting consumption patterns as incomes rise through the addition of a dynamic CDE expenditure function to allow for changes in income elasticities as purchasing power parity corrected real GDP per capita changes; and v) the observed differential in agricultural and non-agricultural wages and returns by introducing imperfect mobility between agricultural and non-agricultural labour and capital markets.

The model is calibrated to version 6 of the GTAP database (Dimaranan 2006), which contains detailed bilateral trade, transport and protection data characterising economic linkages among regions and detailed country input-output databases that account for domestic inter-sectoral linkages. All monetary values of the data are in millions of US dollars and the base year for version 6 is 2001, which is updated to 2010 using macroeconomic and yield data. The 88 regions in the GTAP database are aggregated to 45 regions for simulation purposes. The regional results are then aggregated to 12 larger regions for presentation purposes which are chosen as important from an agricultural production and demand point of view. The definition of the twelve presentation regions is given in Table 1.

Similarly the 57 sectors identified in the database are aggregated to 26 sectors that produce 28 products. The sectoral aggregation includes: land-using agricultural sectors such as rice, grains, wheat, oilseed, sugar, horticulture, other crops, cattle, pork and poultry, and milk; the petrol sector that demands fossil (crude oil, gas and coal) and bioenergy inputs (ethanol and biodiesel); and by-products of biofuels production.

2.2 Modelling the response of agricultural land to REDD

Most CGE models assume that the total amount of land available for agriculture is fixed and unaffected by changes in the land price and therefore, the total amount used is always equal to the amount of land available. Consequently, no land can move outside of agricultural production. However, converting land from forestry to agricultural use or vice versa may occur as a consequence of policy changes or changes in demand for agricultural products.

[1] Modular Applied GeNeral Equilibrium Tool. The Modular Applied GeNeral Equilibrium Tool (MAGNET) model is the new name for LEITAP.

Table 1. Membership of aggregated regions

Region	Members
Europe	Belgium, Luxembourg, Denmark, Germany, Greece, Spain, France, Ireland, Italy, The Netherlands, Austria, Portugal, Finland, Sweden, United Kingdom, Cyprus, Malta, Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Slovenia, Slovakia, Bulgaria, Romania, Switzerland, Albania, Croatia, Rest of EFTA, Rest of Europe
Central & South America	Mexico, Central America, Brazil, Colombia, Peru, Venezuela, Argentina, Chile, Uruguay, Rest of FTAA, Rest of the Caribbean, Rest of the Andean Pact, Rest of North America and Rest of South America
US	United States
Canada	Canada
Southern Africa	South Africa, Botswana, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe, Rest of Southern African Customs Union and Development Community
Rest of Africa	Morocco, Tunisia, Uganda, Madagascar, Rest of North Africa, Rest of Sub-Saharan Africa
Former Soviet Union	Post-Soviet states, excluding the Baltic states
China	China, Hong Kong, Taiwan and Rest of East Asia
Southeast Asia	Malaysia, Philippines, Singapore, Thailand, Vietnam, Rest of Southeast Asia
Indonesia	Indonesia
Oceania	Australia, New Zealand, Rest of Oceania
Rest of Asia	India, Bangladesh, Sri Lanka, Japan, Korea, Turkey, Rest of Middle East, Rest of South Asia

In specifying the land supply for each country, we started with simple functions of the form

$$P = F(L, \Gamma) \tag{1}$$

where

P is the real rental price of agricultural land;

L is the supply of land to agricultural activities;

Γ is an upper bound on the supply of agricultural land, that is, the total potential land that could be available for agriculture; and

F is a function defined for $L < \Gamma$ with the properties that

$$\frac{\partial F}{\partial L} > 0 \text{ and } P \to \infty \text{ as } L \to \Gamma \ . \tag{2}$$

An example of a function with these properties[2] is

$$P = \frac{A}{\exp\{B * (\Gamma - L)\} - 1} \tag{3}$$

where A and B are parameters with the same sign (either both positive or both negative).

[2] Another example is $P=(A/(\Gamma-\Lambda))^B$, again with A and B as parameters. This form was used in LEITAP, a forerunner of the MAGNET model (Meijl et al. 2006; Eickhout et al. 2009; and Nowicki et al. 2009). However, the choice between these forms is not important. The fundamental change made in this paper is to treat A and B as variables, thereby facilitating simulations of the effects of changes in total available land.

It became apparent, however, that a simple function such as (3) with A and B specified as parameters is unsuitable for simulating the effects of REDD, which involves large reductions for some countries in potential land availability (Γ). Large changes in Γ with A and B treated as parameters can introduce unrealistic shifts in the supply curve in the neighbourhood of actual land use (L). This is illustrated in Figure 1 for the case of Canada in which REDD requires an 82% reduction in potential agricultural land from 7.9 times land in use to 1.422 times land in use. In drawing Figure 1, we assumed that units are chosen so that the initial quantity of land in use is one, implying that the initial value for Γ (denoted as Γ_I) is 7.9. Similarly we chose monetary units so that the initial real rental rate on land is one. Then we set A and B to satisfy the equations

$$1 = \frac{A}{\exp\left\{B * \left(\Gamma_I - 1\right)\right\} - 1} \tag{4}$$

$$0.95 = \frac{A}{\exp\left\{B * \left(\Gamma_I - [1 - 0.05 * E]\right)\right\} - 1} \tag{5}$$

where E is the elasticity of land supply in the vicinity of the initial equilibrium.[3] Equations (4) and (5) imply that a 5% reduction in price (from 1 to 0.95) corresponds to a percentage reduction in land supply of 5 times E per cent (from 1 to 1-0.05*E).[4]

For Canada, E is 1.38, giving A = 162.8277 and B = 0.73896. With A and B treated as parameters, the movement in Γ from 7.9 to 1.422 shifts the Canadian land-supply curve in Figure 1 from S1 to S2. Under any plausible specification of demand for agricultural land, this supply shift causes an enormous and unrealistic price increase (from 1 to about 280 in Figure 1) and a corresponding large quantity decrease.

Our analysis of Figure 1 suggested that A and B should be treated as variables that respond to changes in Γ. In particular, A and B should be allowed to change so that a reduction in Γ does not significantly influence the position of the land-supply function for values of L well below the initial value. In addition, we decided to control the movements in A and B so that a reduction in Γ causes only a small leftward shift in the supply curve in the neighbourhood of the initial solution if the percentage of available agricultural land in use is low. Thus an 82% reduction in Γ when L/Γ is equal to 1/7.9 should have little effect on the relevant part of the supply curve. By contrast, a small reduction in Γ should have a large effect on the relevant part of the supply curve if a high fraction of potential agricultural land is in use.

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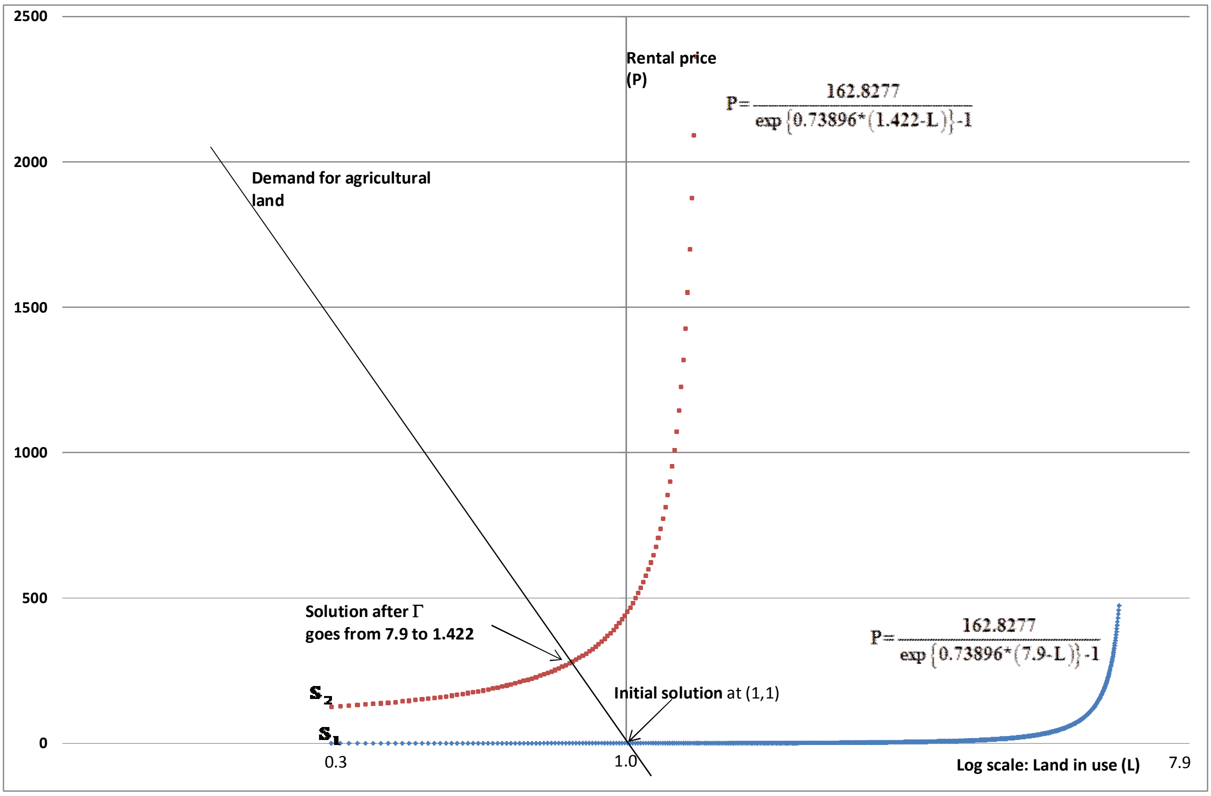
3 The elasticity values used in (5) were provided by Cixous (2006) for EU countries or derived from biophysical data from the IMAGE modelling framework (see Alcamo et al. 1998).

4 Thus E is an arc elasticity (rather than a point elasticity) calculated from the effects of a 5% price reduction. The choice of 5% is a matter of convenience. Other small percentage values could have been used with little effect on the calibrated values for A and B.

Figure 1. Demand and supply for land: Canada with A and B in (3) treated as parameters



Because REDD operates mainly by removing current forest/wilderness land from potential use in a country's agricultural sector, not actual use, it could be argued that there should be no effect on land-supply curves in the neighbourhood of the current rental/land-supply equilibrium. Against this, consider a situation in which owners of potential agricultural land make supply decisions stochastically each period. In a country in which there are n blocks of potential agricultural land, the number of blocks that will be supplied when P= 1 is given by

$$L = \sum_{i=1}^{n} Pr_i\left(P = 1\right) \tag{6}$$

where $Pr_i(P=1)$ is the probability that the owner of block i will supply this block to agriculture when the rental price is 1.

The imposition of REDD can be thought of as changing some of these probabilities from positive values to zero, thus reducing L even if no land currently used in agriculture is directly affected by REDD. For a land-abundant country such as Canada, we would expect REDD to withdraw from potential supply mainly blocks with low probabilities of supply at the current rental rate. Thus, we would expect REDD to cause only a small leftward movement of the supply curve in the neighbourhood of the initial equilibrium. For land-scarce countries such as the Netherlands, we would expect REDD to withdraw from potential supply blocks with relatively high probabilities of supply at the current rental rate. Thus for these countries we would expect REDD to cause a significant leftward movement of the supply curve in the neighbourhood of the initial equilibrium.

To achieve these desired properties for land-supply curves, we computed initial values for A and B according to (4) and (5). Then we computed $P_I(0.5)$, the rental price on the initial supply curve with land supply at half its initial value, according to:

$$P_I\left(0.5\right) = \frac{A_I}{\exp\left\{B_I * \left(\Gamma_I - 0.5\right)\right\} - 1} \tag{7}$$

where A_I, B_I and Γ_I are the initial values of A, B and Γ. Finally, we introduced two new equations to determine movements in A and B away from their initial values in response to changes in Γ:

$$P_I(0.5) = \frac{A}{\exp\left\{B*\left(\Gamma-0.5\right)\right\}-1} \tag{8}$$

and

$$1 = \frac{A}{\exp\left\{B*\left(\Gamma-\left(\frac{\Gamma}{\Gamma_I}\right)^{\frac{1}{(\Gamma_I)^{1.25}}}\right)\right\}-1} \tag{9}$$

Equation (8) anchors the supply curve: irrespective of the value of Γ, the land-supply curve passes through (L,P) = (0.5, $P_I(0.5)$). This ensures that reductions in Γ do not influence very much the position of the land-supply function for values of L well below its initial value. Via equation (9) we control the extent to which the supply curve shifts to the left at the initial rental price. At P = 1, equation (9) forces L to the adopt the value

$$L(P=1) = \left(\Gamma/\Gamma_I\right)^{\left(1/\Gamma_I^{1.25}\right)} \tag{10}$$

Under (10), for a given value of Γ_I, the smaller is Γ/Γ_I the larger is the leftward shift in the land-supply curve [that is, the smaller is L(P=1)]. And for any given value of Γ/Γ_I, the leftward shift is smaller for larger values of Γ_I. This second property can be accentuated or dampened through different choices for the 1.25 exponent. We arrived at 1.25 after initially judging that leftward supply shifts were too great without the exponent (an implicit value of 1).

In the Canadian case in which Γ is reduced from an initial value of 7.9 to 1.422, the leftward movement in the supply curve at P = 1 is 0.12; that is, the quantity supplied at the initial price falls by 12%. This is illustrated in Figure 2. For countries with less abundant land in comparison with their land use, $1/(\Gamma_I^{1.25})$ is larger. This means that these countries experience a larger leftward shift in their supply curve (percentage reduction in land use at the initial rental rate) for any given percentage reduction in the asymptote (Γ). This is illustrated in Figure 3 where an 82% reduction in the asymptote from 6 to 1.08 causes a leftward shift of 17% (compared with 12% in Figure 2).[5] Figure 4 is a further illustration of the effect on the supply curve of a reduction in Γ. Here Γ is reduced by only 40%, from 2 to 1.2. Reflecting the relative initial scarcity of land, the reduction in Γ causes a leftward shift in the supply curve of about 19%, greater than in the previous two cases in which the reduction in Γ was 82%.

[5] In drawing Figures 3 and 4 we continue to assume that E = 1.38.

Figure 2. Land supply function for Canada as Γ declines by 82% from 7.9 to 1.422

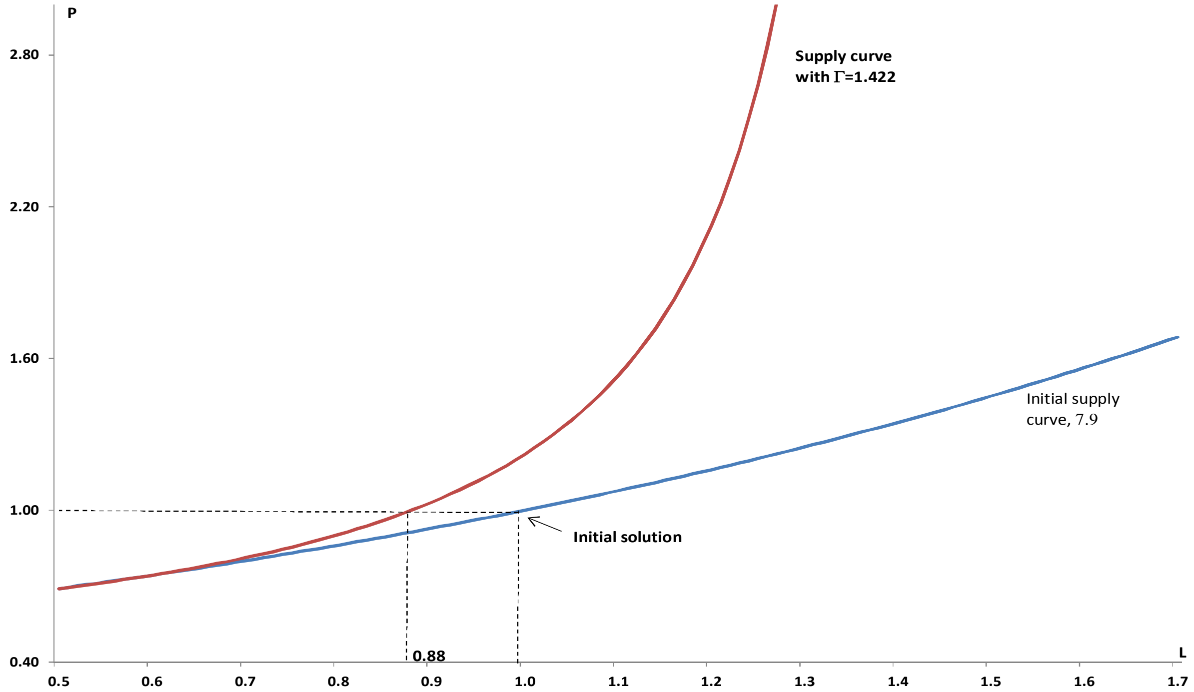


Figure 3. Land supply function as Γ declines by 82% from 6 to 1.08

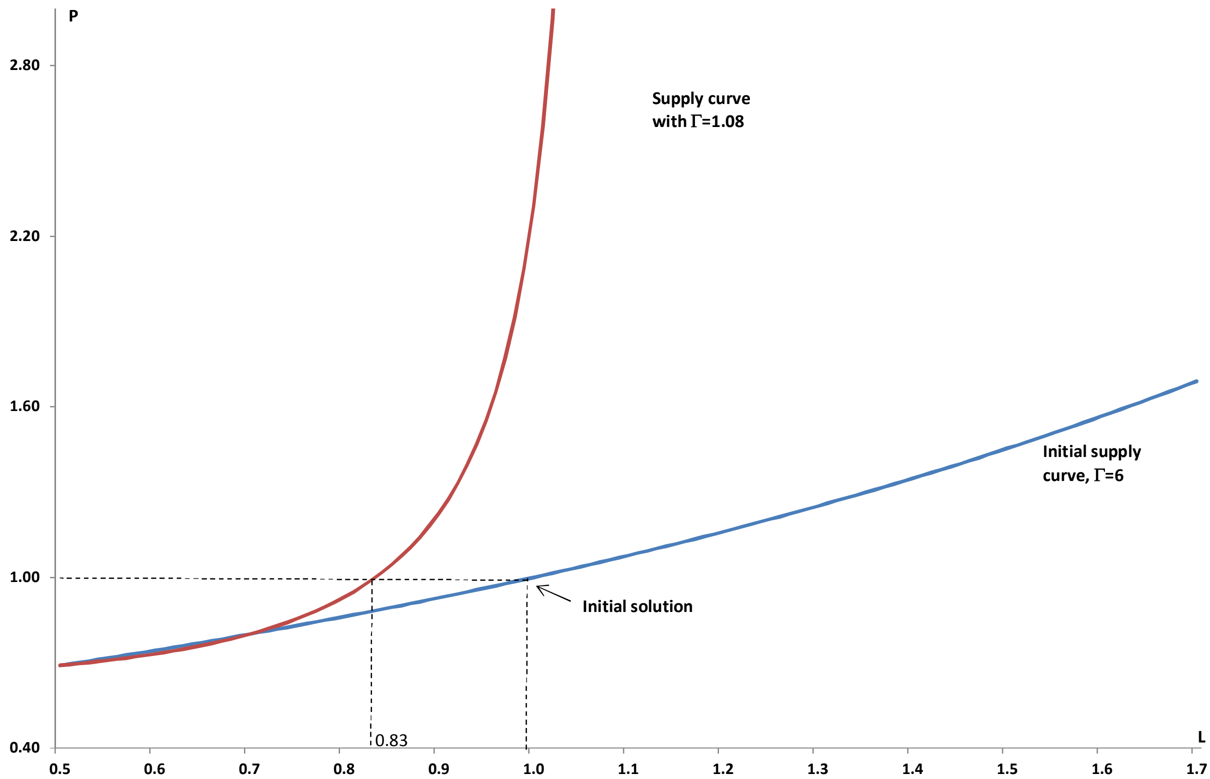
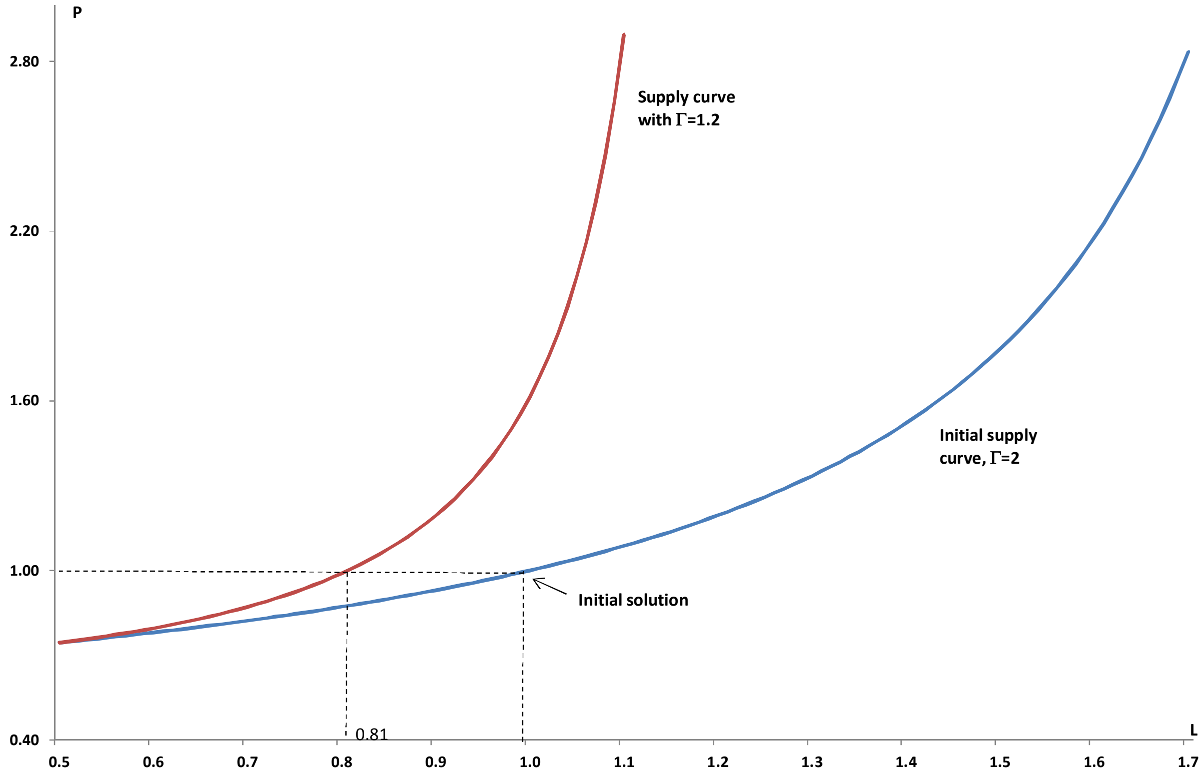


Figure 4. Land supply function as Γ declines by 40% from 2 to 1.2



We implemented specification (3), (8) and (9) in the GEMPACK[6] representation of MAGNET via linear change forms with P, L A, B and Γ treated as variables.

2.3 Including biofuels in energy markets

Two new energy sectors, ethanol and biodiesel, are introduced to improve the representation of biofuels in the model. The ethanol sector produces ethanol and a by-product of dried distillers grains with solubles (DDGS). Similarly, the biodiesel sector produces the primary product and a by-product of oilseed meals (BDBP). Both biofuels are introduced as direct competitors to crude oil in the model through their inclusion in the production structure of the petrol sector that produces motor-fuel. A subsidy on biofuels is introduced to ensure that the ratio of biofuel to crude-oil inputs in the motor-fuel sector meets the blending targets. This subsidy stimulates biofuel production to a level consistent with the blending requirement. The biofuel/crude-oil blend is then combined with other fuel inputs, capital, labour and other inputs to produce motor-fuels. RED policies are assumed to be budget-neutral from a government point of view, which is achieved by counter-financing the biofuel subsidy by an end-user tax on motor-fuels, implying that the motor-fuel user pays for the extra cost involved for using fuel with higher biofuel blending rates.

The byproducts of biofuel production (DDGS and BDBP) are demanded by the livestock sectors where they compete with wheat, other grains, oilseeds and other compound feeds to make the concentrated feed that is an alternative to grassland (roughage) feeding. The market price for the feed byproducts ensures that the demand for the products equals their supply.

[6] See Horridge et al. (2013) and Harrison et al. (2012).

3. Macroeconomic assumptions and RED and REDD scenarios

The evolution of the economy with RED and REDD policies in place is projected for the period 2010-30 and compared with the evolution of the economy without these policies (the business-as-usual scenario). The business-as-usual scenario shows a future that follows the GDP and population projections of the US Department of Agriculture (USDA) (see the first two rows of Table 2). A pre-simulation is run to derive the overall country-wide technological change consistent with the GDP projections (Hertel et al. 2004). The country-wide average rate of technological change is then distributed at the sectoral level using trends for relative sectoral total factor productivity growth. Technological change is assumed to be 3 times the average rate in agriculture, 1-2 times the average in manufacturing, and 0.5 times the average in services (CPB 2003). All factors except capital are assumed to experience technological change. Capital is exempt as the capital/output ratio has been shown to be roughly constant over long periods of time. Land productivity is assumed to improve following yield projections by the Food and Agriculture Organisation (FAO), as shown in row three of Table 2. The projected increases in GDP and population suggest a strong increase in demand for agricultural products and therefore agricultural land use. The MAGNET simulations suggest that the average worldwide real land price will increase by 47.3% between 2010 and 2030. The demand side pressure on land therefore outweighs any improvements in yields.

Table 2. Scenario assumptions

		World	Europe	C&S America	US	Canada	Southern Africa	Rest of Africa	Former Soviet Union	China	Southeast Asia	Indonesia	Oceania	Rest of Asia
All scenarios	GDP[1]	100	50	118	76	72	169	143	138	305	150	154	83	90
	Population[1]	21	-1	22	18	14	28	50	-4	8	24	19	24	28
	Yields[2]	39	20	32	19	21	44	64	17	55	30	31	28	44
RED	Biofuel share 2010[3]	-	1.7	[4]20.6 2.1	3.0	1.4	0	0	0.1	1.1	1.2	0.1	0.8	0.3
	Biofuel share 2020	-	10	[5]25 10	15	3	-	-	-	15	5	12	3	[6]20 5
REDD	Land availability[7]	-35	-4	-53	-32	-82	-30	-9	-56	-10	-71	-55	-22	-2

[1] Growth over the period 2010-2030 (USDA 2010).

[2] Average growth over the period 2010-2030, weighted by land area (Bruinsma 2003).

[3] Percentage of first-generation biofuels in transport fuel (Europe = EU27), simple average over countries in each region. (Calculations based on Sorda et al. 2010).

[4] 20.6% in Brazil, 2.1% in Rest of South America.

[5] 25% in Brazil, 10% in the Rest of South America.

[6] 20% in India, 5% in Japan.

[7] Percentage change in potential land availability due to forest and woodland conversion restrictions (IMAGE model calculations, Stehfest et al. 2010).

In addition to the macroeconomic and technological trends, crude oil prices are included in the business-as-usual scenario as they are a key determinant of biofuel production. These prices are assumed to be largely driven by projected future crude oil production as derived from IEA (2008, 2009). Country-specific values for the efficiency of natural resources utilisation in crude oil sectors are also derived from crude oil production figures. The figures show a decreasing productivity of natural resources in crude oil sector for almost all regions, which is generally consistent with the observed and expected decline of output from oilfields (IEA 2008).

The Renewable Energy Directive scenario is implemented as a global mandatory blending requirement. All major economies except Russia currently impose mandatory or voluntary requirements for liquid biofuels. Mandatory requirements for both ethanol and biodiesel are in place in the EU, US, Canada, Brazil, Argentina, Colombia, India, Thailand, Indonesia and the Philippines. Paraguay and Ecuador employ an mandatory ethanol mandate, whereas Uruguay has a mandatory biodiesel mandate. China, Japan and Australia set voluntary targets for biofuel production.

The targets are set at different levels and formulated differently in each country or region. The US mandate is volume-based, requiring 36 billion gallons of fuel from renewable sources to be used in US transportation by 2022, whereas the EU and Canadian mandates are share-based. The EU mandate requires a 10% share of biofuels in transport fuel by 2020 and the Canadian mandate required 5% renewable content in gasoline-based motor-fuels by 2010 and 2% renewable content in diesel fuel and heating oil by 2012. Other countries implement their renewable energy targets through the biofuel-gasoline blend available at the pump. For instance, the Brazilian target for 2013 is E25, reflecting a 25% ethanol to 75% gasoline mix, and in Indonesia the mandatory level of biofuels consumption is planned to increase to E15 and B20 by 2025 to reflect a 15% and 20% share of ethanol and biodiesel, respectively.

The shares of biofuels in transport fuel implied by these targets are given in Table 2. The starting shares in 2010 are small for all regions except the US (3%) and Brazil (21%). Moving from these starting shares to the RED scenario targets requires, in most cases, a large increase in the share of biofuels in transport fuel. To achieve the RED target, the biofuel share in Indonesia must increase 120-fold, due to the small initial share. This compares with a smaller increase in Brazil from 20.6% to 25%. These targets for using biofuels in the transportation sector are assumed to be achieved by 2020 and maintained up to the end of the simulation period in 2030.

The REDD scenario is introduced as reductions in the maximum amount of land available for agricultural production as presented in Table 2. This reflects the REDD objective to limit conversion possibilities from forestry to agricultural land to protect forests and woodland. The reduction in land availability ranges widely from 2% in Asia and 4% in Europe, to 71% in Southeast Asia and 82% in Canada due to the varying global distribution of forests and woodland. The REDD policy to restrict forest and woodland conversion is assumed to take place at the start of the simulation period, i.e. between 2010 and 2013.

The specification of the macroeconomic projections and RED and REDD policies result in three scenarios that are introduced incrementally:

- BAU scenario: business-as-usual baseline scenario
- RED scenario: BAU plus the global RED scenario
- REDD scenario: RED plus strict REDD scenario to protect forests and woodland

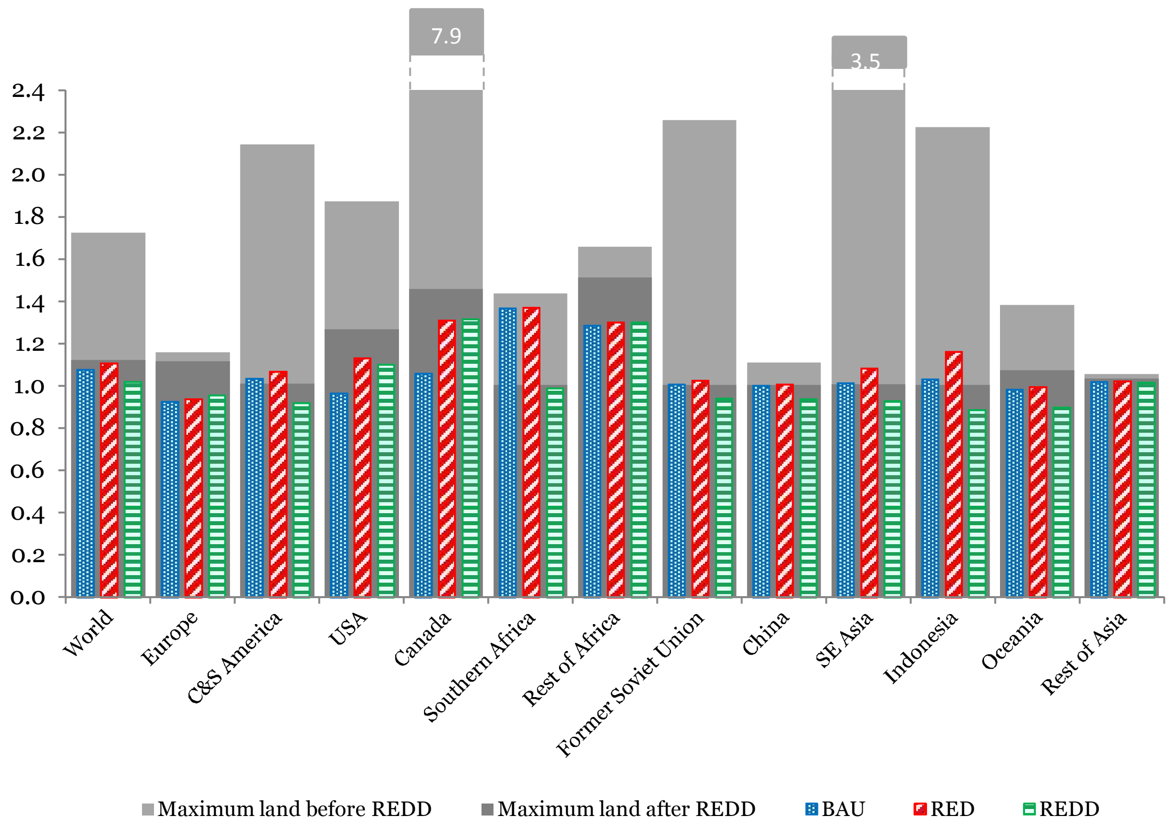
A comparison of the RED and BAU scenarios allows the impact of the biofuel policy to be quantified, and a comparison of the RED and REDD scenarios captures the effect of the forest protection policy.

4. Consequences of RED and REDD policies for land use, food security and trade

In assessing the interaction of global renewable energy directives (RED) and the REDD programme to limit deforestation and forest degradation, we find that economic and population growth, together with biofuel policies, increase the demand for agricultural products and agricultural land use. The increased demand for land is met by increased yields and the conversion of forests and woodlands. The introduction of a REDD policy to protect forests and woodlands, limits the supply of land suitable for agricultural production, leading to the intensification of production and higher land prices.

These headline results are shown at the regional level in Figure 5. The business-as-usual scenario suggests agricultural land use will increase by 2030 in all regions except Europe, the US and Oceania. Southern Africa and the Rest of Africa experience particularly strong increases of 37% and 29%, respectively. The introduction of RED policies increases agricultural land use in all regions as the additional demand for biofuel feedstocks leads to strong increases in land demand. The area under cultivation due to RED in Canada is 24% higher than the baseline value in 2030, 17% in the US and 13% in Indonesia. These regions are all land-abundant. The limited nature of Canada's biofuel policy indicates that the observed effect is a trade effect. The results suggest that the RED policies have a limited impact on land use in land-constrained regions, including Southern Africa (0.4%) and Rest of Asia (0.3%). The average worldwide increase in agricultural area is 3% following the introduction of RED.

Figure 5. Agricultural land use in 2030 (2010=1) and maximum available land relative to 2010 land under cultivation (2010 land under cultivation equals 1)



Note: The y-axis is truncated due to space and the numbers provide the ratio of land availability to land under cultivation in 2010 before REDD in Canada (7.9) and Southeast Asia (3.5). If a column is higher than the dark grey horizontal line, the expansion of agriculture is only possible by converting forest or woodland into agricultural land.

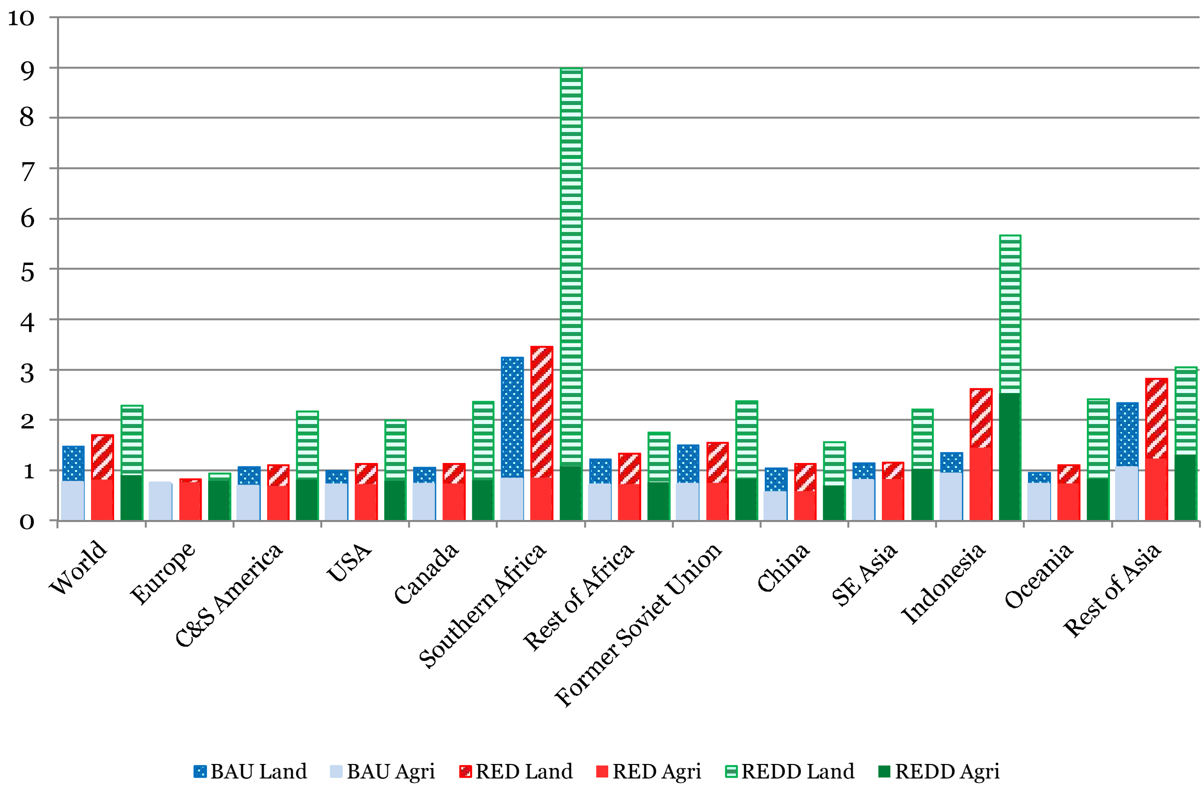
Source: MAGNET model simulations.

In many regions, the agricultural land expansion brought about by renewable energy directives is achieved at the cost of deforestation. This happens to a great extent in Southern Africa, Southeast Asia and Indonesia and to a lesser extent in Central and South America and in Russia and the former Soviet countries. This pattern is consistent with currently observed trends, which show major losses (more than 0.5% annually) in the tropical forests of West and East Africa, South and Central America and Southeast Asia.

The implementation of the REDD policy to protect forests and woodlands leads to significant decreases in agricultural land availability, as shown by the reduction in the height of the land-availability columns as we move from the RED to REDD in Figure 5. This reduction in land availability reduces total land under cultivation by 6% compared with the business-as-usual scenario and by 8% compared with the RED scenario. The largest reductions in land area occur in regions where the land restrictions are binding. Land use under REDD is 28% lower in Southern Africa relative to the RED scenario, 24% lower in Indonesia, and 14% lower in Central and South America and Southeast Asia. Europe and Canada experience small increases of less than 2% in the amount of land under cultivation.

Large reductions in land use are brought about by significant increases in real land prices following the restrictions on the amount of available agricultural land. The change in real land prices and their impact on agricultural prices are shown in Figure 6. The impact of the REDD policy on land prices is particularly pronounced; increasing land prices in all regions.

Figure 6. Real land prices and agricultural producer prices in 2030 (2010=1, overlaid bars)



Source: MAGNET model simulations.

The average land price increase under REDD is 56% higher than in the business-as-usual scenario, and 34% higher than in the RED scenario. That is, instead of increasing by 47% as in the business-as-usual scenario, the average real land price increases by 71% under the RED policy, and by 129% under the REDD policy.[7] There is a high degree of regional variation depending upon the scale of forest and woodland protection relative to current land use levels. Land prices in Southern Africa, for example, are 160% higher after the introduction of the policy to protect forest and woodlands, compared to the land price under RED. Land

[7] Note: 2.29/1.47 = 1.56.

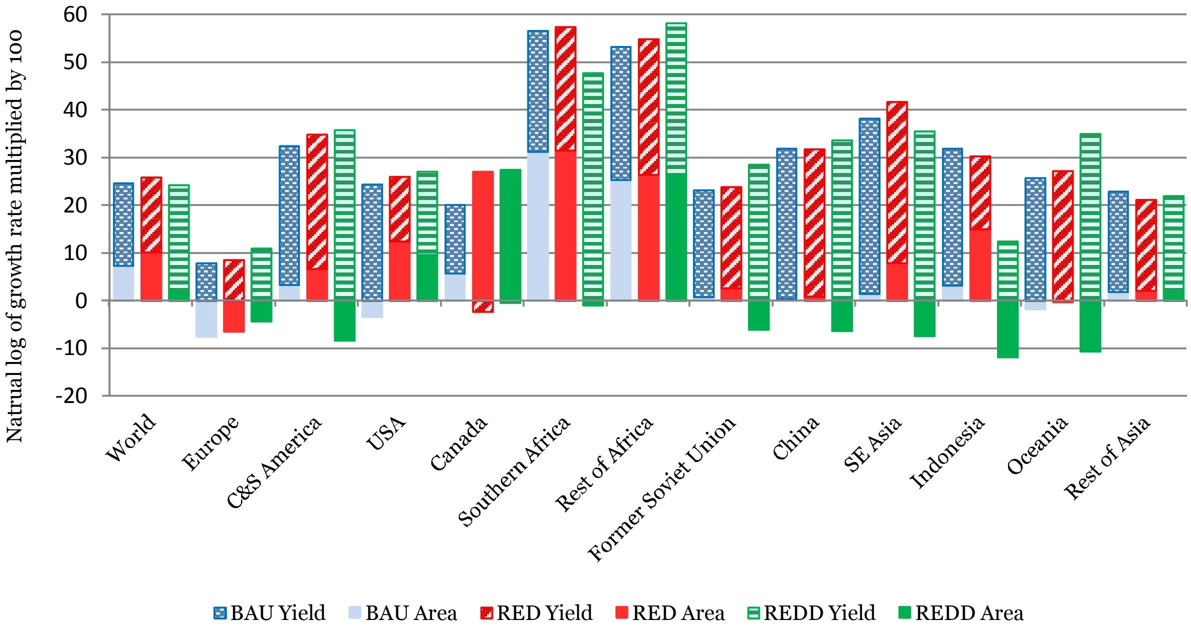
prices also more than double in Canada, Indonesia and Oceania. The smallest land price changes are observed in Europe (15%) and Rest of Asia (8%) due to the relatively small reductions in land availability of 4% and 9% respectively in these regions.

Although agricultural prices are generally projected to fall over the period in all scenarios, higher land prices lead to relatively higher agricultural prices after the introduction of RED policies and higher still after the introduction of the REDD policy (see Figure 6). The impact of changes in the land price on agricultural prices depends upon the share of land in agricultural production. Regions that favour extensive agriculture, and therefore use a large amount of land to produce agricultural products, experience greater impacts on agricultural prices than regions with intensive agriculture for which land costs are a smaller share of production costs. The combination of strong land price rises and extensive agriculture actually reverses the trend in falling agricultural prices for four regions: Southern Africa, Indonesia, Southeast Asia and Rest of Asia. Each of these regions has land costs that comprise more than 20% of total agricultural production costs. The price rise is particularly strong in Indonesia, such that agricultural prices are 74% higher after the introduction of the REDD policy than with the RED policies alone.

The introduction of restrictions on available land for agriculture leads to an intensification of agriculture. Intensification occurs when the land price rises relative to the prices of capital and labour causing more units of capital and labour to be employed per unit of land. The intensification and extensification effects of changes in agricultural production between 2010 and 2030 are shown in Figure 7. Globally, the 28% expansion in business-as-usual agricultural production is achieved by an 8% growth in land area and 19% growth in yields.[8] The introduction of renewable energy directives leads to slightly higher agricultural production growth (29%) brought about by greater extensification of land area (11%), compared with growth in yields (17%). This contrasts with greater intensification under the REDD policy where the increase in production of 28% is achieved by significant yield growth of 25% and only 2% land area expansion. The most pronounced exception to this trend is Indonesia where the RED policy changes the land use from more productive animal production to arable which causes yields to decrease.

[8] Figure 7 shows changes in logarithms multiplied by 100. Thus a 28% increase is shown as 25% [= 100*ln(1.28)]. Use of logarithms avoids having a residual in the decomposition of output growth into the contributions of area and yields.

Figure 7. Decomposition of percentage change in agricultural output by land area and yields, 2010-2030



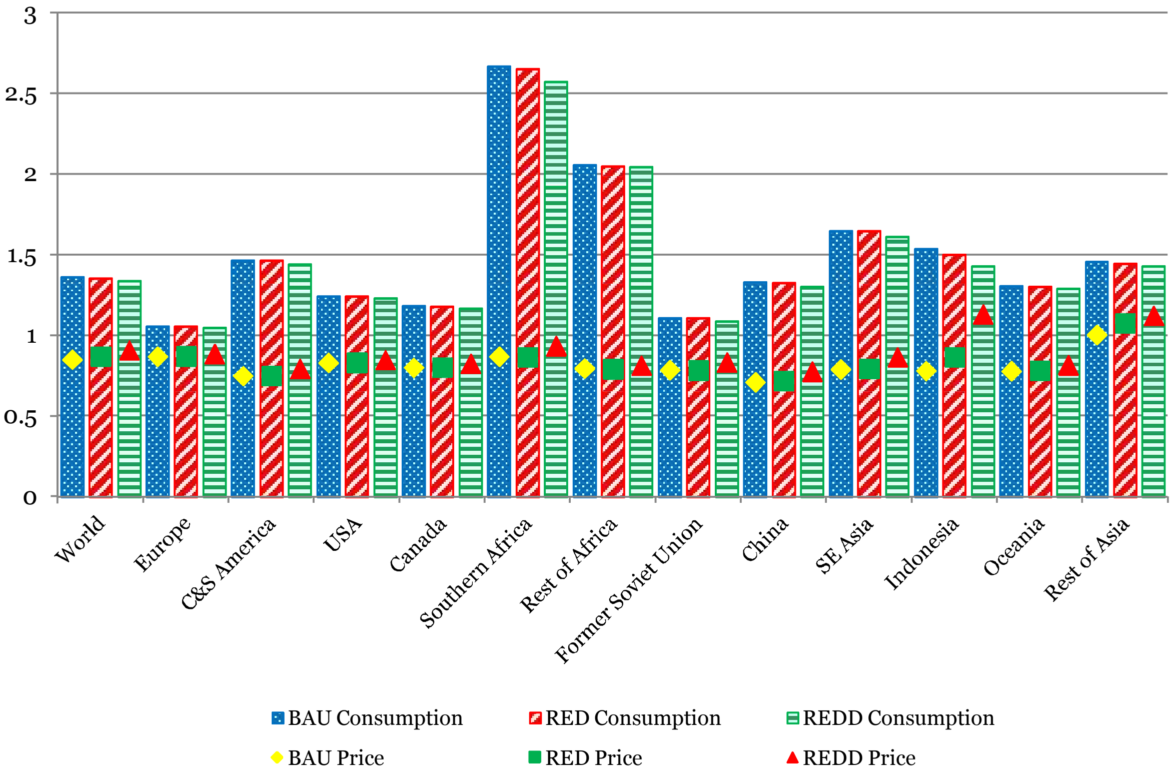
Source: MAGNET model simulations.

The results so far suggest that the introduction of the UN REDD policy to protect forests and woodlands will lead to an intensification of agriculture coupled with higher agricultural prices. The implications of these higher agricultural prices for food security are shown in Figure 8.

The impact of the RED and REDD policies on food security can be evaluated by considering the impact on food prices and food consumption by households, where higher prices and a reduction in food consumption is taken to mean a worsening of food security. On average, the worldwide consumption of food slightly decreases as a result of the REDD policy, due to a small increase in consumer prices, but the impact of the REDD policy is unequally distributed over the regions. Consistent with the large increases in agricultural prices in Southern Africa and Indonesia, consumer prices in these regions are 8% and 31% higher, respectively, after the introduction of the REDD policy compared with the RED policies alone. This leads to a reduction in food consumption of 3% and 5%, respectively, and a worsening of food security in these regions.

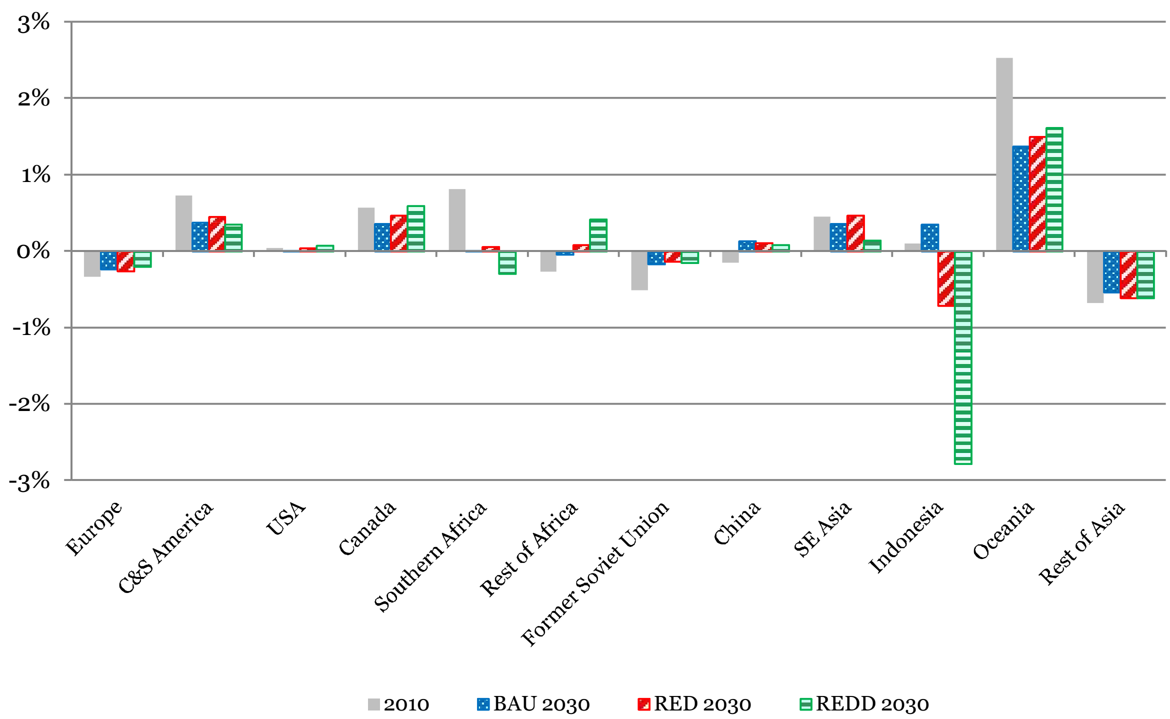
The implementation of the REDD policy leads to a slowdown in worldwide agricultural trade, as shown in Figure 9. The volume of agricultural exports decreases by 5% following the restriction on land availability. Importantly, two net exporters of agricultural products, Southern Africa and Indonesia, become net importers under the REDD scenario.

Figure 8. Consumer food prices and household food consumption in 2030 (2010=1)



Source: MAGNET model simulations.

Figure 9. Net-export value of agricultural commodities (excluding transportation costs) as a percentage of GDP



Source: MAGNET model simulations.

5. Implications for Europe

The evolution of the European economy differs from that of the global economy between 2010 and 2030. Large increases in global land demand and land prices contrast with expected falls in land demand and prices in Europe. The results suggest that the demand for land in Europe will be 7% lower in 2030 compared with an 8% expansion in global land demand.

Real land prices in Europe are projected to fall by 27% compared to their 2010 values, in contrast to an expected global increase in land prices of 47%. These trends, driven by economic, demographic and yield growth, are expected to occur despite only 80% of available land in Europe being under cultivation in 2010.

The introduction of global biofuel and forest conservation policies offsets these trends to some extent and provides a boost to agricultural production in Europe. Both policies increase the demand for land in Europe, which leads to higher land prices compared to the baseline. Land demand in Europe falls by 6% and 4% respectively between 2010 and 2030 in the RED and REDD scenarios, compared to 7% in the baseline scenario, and European land prices fall by 5% with the introduction of the REDD policy compared to 17% and 27% in the RED and baseline scenarios.

Agricultural production is higher in Europe after the introduction of the biofuel and forest conservation policies. Agricultural production increases by 2% under the RED scenario and by 7% under the REDD scenario, compared to only 0.3% in the baseline scenario. In the case of the biofuel policy, the extra production is absorbed by extra demand from within Europe. In the case of the REDD policy, greater requirements for forest conservation in other regions increase average global agricultural prices by 17%, compared to only 5% in Europe. This causes Europe to have a comparative advantage in agricultural products and boosts agricultural exports, as shown by the improvement in the trade balance in agricultural products.

Overall, Europe appears to experience net gains from global efforts to increase biofuel use and protect forests, experiencing higher agricultural production and trade, with only small increases in land prices and food prices faced by consumers. These gains arise from the long-term trend in the region towards lower land demand and the minimal requirements placed on land conservation in the region from the REDD policy, which improves Europe's comparative advantage in agricultural production.

6. Summary and conclusions

This paper illustrates the conflict between renewable energy directives and forest conservation. Both sets of policies are designed to reduce emissions but have opposite land-use effects. Global RED policies expand worldwide land use by 3% relative to the business-as-usual projection, with Canada, the US and Indonesia extending their use of agricultural land and expanding production. In contrast, the REDD policy leads to an overall reduction in agricultural production and a 6% decrease in agricultural land use. The RED policies are typically achieved through greater extensification whereas the restriction on available land for agriculture under REDD leads to a greater intensification of agriculture.

Strict REDD policies to protect all forest and woodland, particularly in tropical land-abundant regions such as Central and South America and Southern Africa, lead to higher land prices, which in turn increase agricultural and food prices. The increase in food prices slightly reduces global food consumption and leads to a more significant reduction in food security in Southern Africa and Indonesia. That said, real food prices are still lower than the 2010 level, even with the RED and REDD policies in place. Overall this suggests that RED and REDD are feasible from a worldwide perspective although the results show that there are some regional problems that need to be resolved. The results show that countries directly affected by forest and woodland protection would be the most economically vulnerable when the REDD policy is implemented.

Indeed, the introduction of REDD policies reduces global trade in agricultural products and moves Southern Africa and Indonesia to a net import position for agricultural products. This suggests that the protection of forests and woodlands in these regions reverses their comparative advantage as they move from being land-abundant to land-scarce regions. The full REDD policy setting, however, foresees providing compensation to these countries to cover their economic losses.

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FACTOR MARKETS

Comparative Analysis of Factor Markets for Agriculture across the Member States

245123-FP7-KBBE-2009-3

The Factor Markets project in a nutshell

Title	Comparative Analysis of Factor Markets for Agriculture across the Member States
Funding scheme	Collaborative Project (CP) / Small or medium scale focused research project
Coordinator	CEPS, Prof. Johan F.M. Swinnen
Duration	01/09/2010 – 31/08/2013 (36 months)
Short description	Well functioning factor markets are a crucial condition for the competitiveness and growth of agriculture and for rural development. At the same time, the functioning of the factor markets themselves are influenced by changes in agriculture and the rural economy, and in EU policies. Member state regulations and institutions affecting land, labour, and capital markets may cause important heterogeneity in the factor markets, which may have important effects on the functioning of the factor markets and on the interactions between factor markets and EU policies. The general objective of the FACTOR MARKETS project is to analyse the functioning of factor markets for agriculture in the EU-27, including the Candidate Countries. The FACTOR MARKETS project will compare the different markets, their institutional framework and their impact on agricultural development and structural change, as well as their impact on rural economies, for the Member States, Candidate Countries and the EU as a whole. The FACTOR MARKETS project will focus on capital, labour and land markets. The results of this study will contribute to a better understanding of the fundamental economic factors affecting EU agriculture, thus allowing better targeting of policies to improve the competitiveness of the sector.
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Partners	17 (13 countries)
EU funding	1,979,023 €
EC Scientific officer	Dr. Hans-Jörg Lutzeyer

SEVENTH FRAMEWORK PROGRAMME