The impact of biodiversity loss reducing strategies on land use and world food markets

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Introduction

In a contribution to the UNEP project on The Economics of Ecosystems and Biodiversity (TEEB) assessment, Ten Brink et al. (2010) has quantitatively analyzed a number of sector based options to reduce global loss of biodiversity. A first strategy in the reduction of biodiversity losses is the expanding protected areas of natural ecosystems. This reduces land available for agricultural sector and negatively influences agricultural production and food security. This paper evaluates the economic consequences of expanding protected areas and possible policy strategies that reduce the negative impact on food prices. Develop a combination of policies that reduce biodiversity losses without adversely impacting food security. The paper evaluates three possible policy options: closing the gap between actual crop yields and potential yields, improvement of agri-food commodities supply chain efficiency and shifting of consumption preferences towards low meat diet. It simulate economic consequences of these options using LEITAP model.

Methodology

The LEITAP model is a multi-regional, multi-sectoral, static, applied general equilibrium model based on neo-classical microeconomic theory (Nowicki at al., 2007 and van Meijl et al., 2006). It is an extended version of the standard GTAP model (Hertel, 1997). The core of GTAP and LEITAP models is an input–output model, which 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. Extensions incorporated in LEITAP model includes an improved treatment of agricultural sector (like various imperfectly substitutable types of land, the land use allocation structure, land supply function, substitution between various animal feed components), agricultural policy (like production quotas and different land related payments) and biofuel policy (capital-energy substitution, fossil fuels-biofuels substitution).

On the consumption side, dynamic CDE expenditure function was implemented which allows for changes in income elasticities when purchasing power parity (PPP)-corrected real GDP per capita changes. In the area of factors markets modeling, the segmentation and imperfect mobility between agriculture and non-agriculture labor and capital was introduced.

The analysis is based on version 6 of the GTAP data (Dimaranan, 2006). The GTAP database contains detailed bilateral trade, transport and protection data characterizing economic linkages among regions, linked together with individual country input-output databases which account for intersectoral linkages. All monetary values of the data are in $US millions and the base year for version 6 is 2001.

The initial data base was aggregated to 45 regions and 26 sectors. The sectoral aggregation includes, between others, agri-food and energy producing sectors including biofuel sectors[1]. The regional aggregation includes EU countries and the most important countries and regions outside EU from an agricultural production and demand point of view.

Finally, the database was updated to 2010 situation to take into account the European Union enlargement, the Agenda 2000 reform and the 2003 CAP reform, together with the macro-economic development of the world economy. Also, the 2007 EU biofuel shares in transport were targeted. This was done by running LEITAP in free consecutive time steps 2001 – 2004, 2004 – 2007 and 2007-2010.

Scenarios

This paper examines land use, production, consumption, trade, income and food security effects of four future scenarios: a baseline scenario and four policy scenarios. On the top of the Baseline Scenario, three consecutive scenarios are investigated. They implement three different policy options which are implemented stepwise on top of each other so the associated scenarios are defined as follows (Table 1):

- Baseline (= **Ba** scenario)
- Baseline + protected areas (= **As** scenario)
- Baseline + protected areas + closing the yield gap (= **Pr** scenario)
- Baseline + protected areas + closing the yield gap + reduced losses (= **Wa** scenario)
- Baseline + protected areas + closing the yield gap + reduced losses + low meat diet (= **Di** scenario)

In LEITAP, the scenarios are built as a recursive updating of the database in three consecutive time steps: 2010-2013, 2013–2020 and 2020–2030. Three periods are distinguished to take into account the future CAP and WTO agendas and timing of their implementation.

[1] To model biofuel policy we adjusted by including ethanol and biodiesel sectors.

Table 1. Stepwise introduction of policy measures

Scenario	Additional Measure	Description
Ba		Baseline with UN medium population scenario and GDP growth rates from USDA 2008 (including economic crisis)
BaAs	Protected areas and REDD (protect carbon rich areas), resulting in a more stringent land supply asymptote (As)	Protection of 20% of each biome-region combination of the GLC2000 map (leading to a total of 29% protected area). Within each biome-region combination selection was based on carbon-intensity.
BaAsPr	High agricultural productivity (Pr)	Increase of baseline yield increase by 40% (in OECD countries to a maximum increase of 1.5% per year)
BaAsPrWa	Reduced waste (Wa)	Worldwide agricultural losses are assumed to be reduced by a third (from 20% to 13%).
BaAsPrWaDi	Dietary change (Di)	Worldwide, consumption patterns slowly converge to a level 50% above the level suggested by the Willett diet

Scenario assumptions

Macro-assumptions

The scenarios assume the macroeconomic development as used by USDA (2010) in agricultural projections up to 2030 (Figure 1). They take into account the 2008-2009 economic recession and assume a subsequent recovery and then the return to the long-term steady global economic growth path. The world GDP is assumed to growth by 3.5% per year and population by 0.97% per year on average during the period 2010-2030. Conform stylized facts of long-term economic growth, capital is assumed to growth at the same rate as GDP and long term employment growth is equal to population growth.

Macroeconomic growth and population increase drive consumer demand which in turn results in a production growth. In case of agro-food products, the positive influence of GDP on demand will diminish in time since a share of agri-food products in the overall household expenses decreases when household incomes are high. According to our macroeconomic assumptions, the macroeconomic growth will strongly influence demand, production and land used to produce agri-food products in low developed countries, especially in China, Former Soviet Union and South Asia.

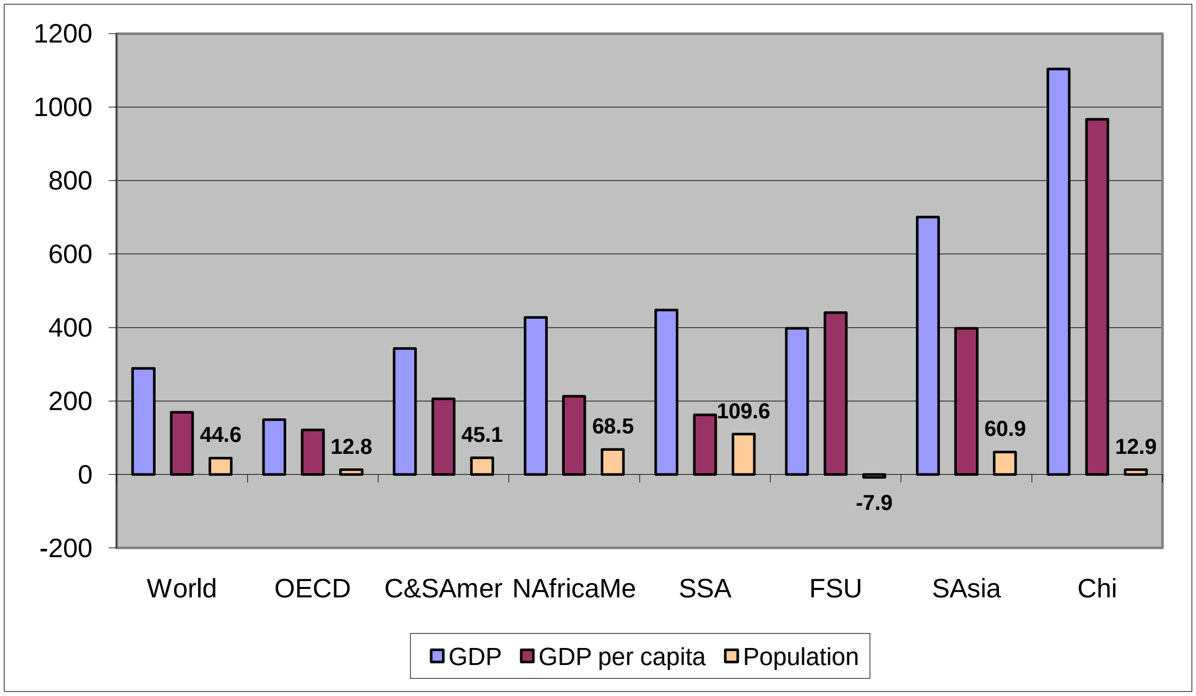

Figure 1. GDP, GDP per capita and population growth in 2010 - 2050.

The one percent growth of populations causes one percent increase of demand on agri-food products when other driving factors are constant. Therefore, we expect very significant population impact on agri-food production for Sub-Saharan Africa and also North Africa and Middle-East and South Asia.

Natural ecosystem protection assumptions

It is assumed that the area of natural ecosystems already protected in expanded by 20% at global level. Since these areas, identified as forestry, woody land and other land (eg. tundra) could be potentially used for agriculture, the world wide availability of agricultural land decreases by about 17% in this scenario. The regional increase of land protection and therefore decrease of land availability depends strongly on the biophysical characteristics of the region. Brazil, for instance, will face an particularly strong decrease of agricultural land availability of 45% of all land suitable for agriculture, while this percentage is 26 and 21% for Central Africa and Indonesia, respectively.

Land productivity and availability assumptions

The agricultural land productivity increase lowers pressure on the agricultural land and causes downward movement of agricultural prices. Autonomous land productivity growth rates (Figure 2) are taken from FAO (Bruinsma, 2003). Globally, agricultural yields increase by 1.6% per year. For Central Africa, 2.5% per year yield growth is assumed whereas for Brazil 1.1% and for Indonesia 1.4% per year.

We assume that the agricultural land productivity in low developed countries will catch up the productivity level in high developed countries. The most pronounced agricultural land productivity growth is expected for Sub-Saharan Africa, North Africa and Middle-East and

China where an average yields increases by about three times. At the same time, the average agricultural land productivity grow rate in OECD countries is equal about 50%.

Availability of agricultural land determines in great deal an easiness of agricultural land expansion. According to the biophysical data, a lot of abounded agricultural land is available in Central and South America and Former Soviet Union and also in OECD countries (Figure 3).

Improvement of agri-food commodities supply chain efficiency

It is assumed that losses of agri-food products in the production process of all commodities will be reduced 7%. This will lower agricultural production but also prices of the agricultural products that in turn will increase demand for agri-food commodities. Therefore, the expected decrease of agricultural production resulting from this measure implementation will be lower than 7%.

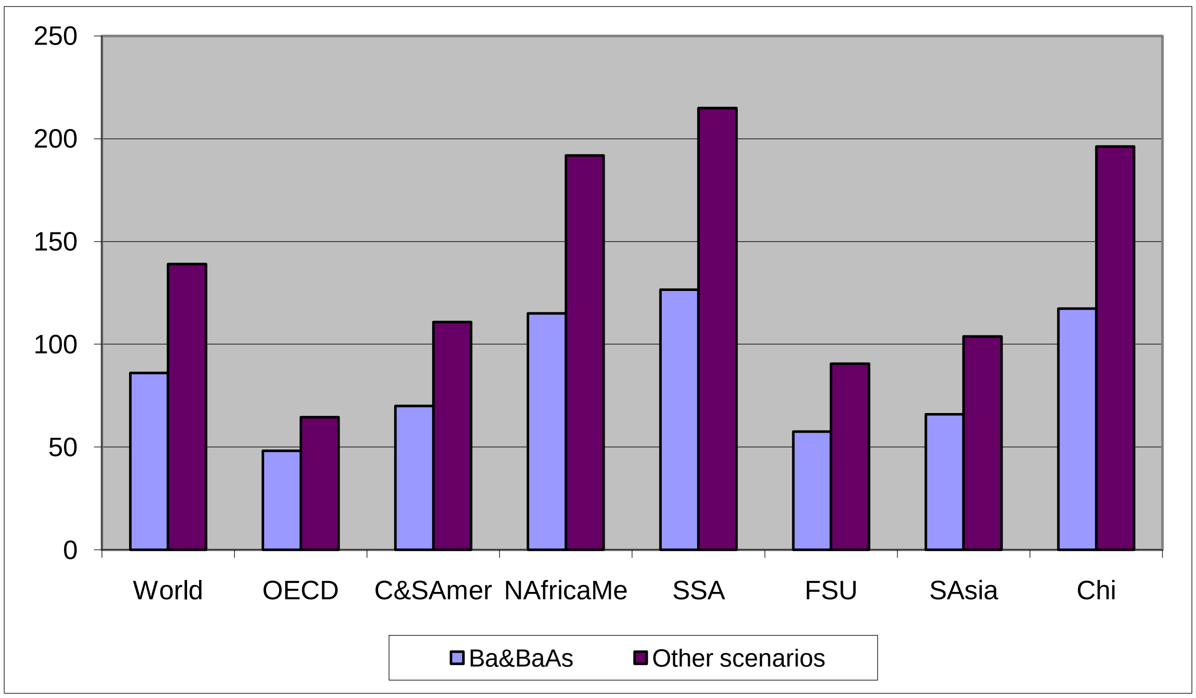

Figure 2. Autonomous yields growth rates in 2010 - 2050.

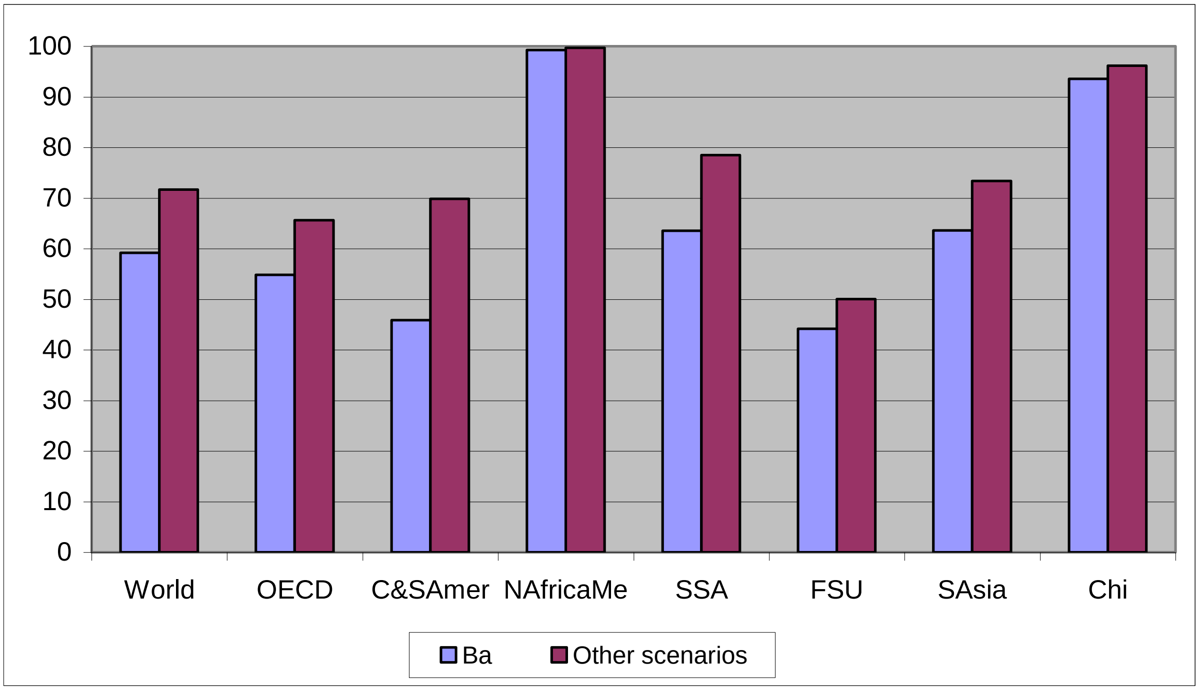

Figure 3. Percentage of available agricultural land used in the production.

Shifting of consumption preferences towards low meat diet

We assume consumption preferences will shift towards low meat WHO healthy diet in the regions where meat consumption is (predicted) to be higher than 50% of target figures proposed by WHO. The average meat consumption reduction for such a scenario for aggregated regions in 2013 - 2030 is presented in Table below.

Table 2. The average meat consumption reduction due to diet measure (Di) in 2013 - 2030

	World	OECD	C&S Amer	NAfrica Me	SSA	FSU	SAsia	Chi
Beef	-39.3	-52.8	-55.4	-25.3	-31.0[2]	-52.8	NA	NA
Pork, poultry	-1.8	-25.1	-10.5[1]	NA	NA	NA	NA	-35.5

Notes. [1] Brazil; [2] South Africa; for all regions, figures are average changes which can include countries with no diet restriction.

The diet shift has negative impact on meat production and land use for meat production. It moves land from animal to crop sector that can lead to higher crop production.

Scenario results

Agricultural production development

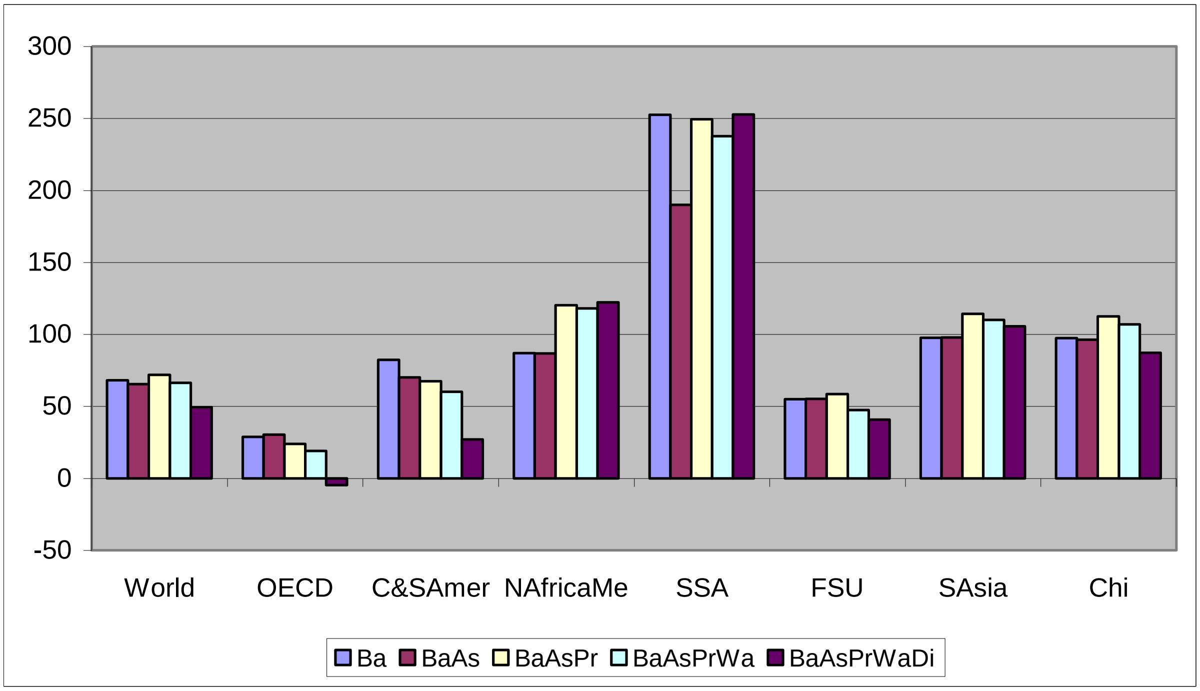

Figure 4. Agricultural production growth in 2010 - 2050.

Driven by macro-economic development and population growth, agricultural production is increasing in all scenarios and regions except of OECD in BaAsPrWaDi scenario (Figure 4). An increase of land protection leads to slight decrease (3%) of world agricultural production compared with base situation (Ba) caused by production decrease in Sub-Saharan Africa and Central and South America where the land protection increases the most.

As expected, the increase of agricultural land productivity drives the agricultural production in Sub-Saharan Africa, North Africa and Middle-East and China but also in South Asia. Competition of these regions drives OECD agricultural production down by 6.5%. Overall world agricultural production is increasing by 6.5% when this measure is in place.

Reduction of agri-food production losses in the production process of all commodities lowers agricultural output in all regions and results in 5.6% lower world agricultural production.

Finally, implementation low meat diet lowers world agricultural production by 16%. The production decreases for all regions with exception of North Africa and Middle-East and Sub-Saharan Africa. These two regions face high autonomous demand growth for agri-food products driven by population growth. The meat production decease in these regions leads to decrease demand for grassland and lower land prices which makes crops production cheaper. All these factors causes that crops production increase exceed meat production decrease for these two regions.

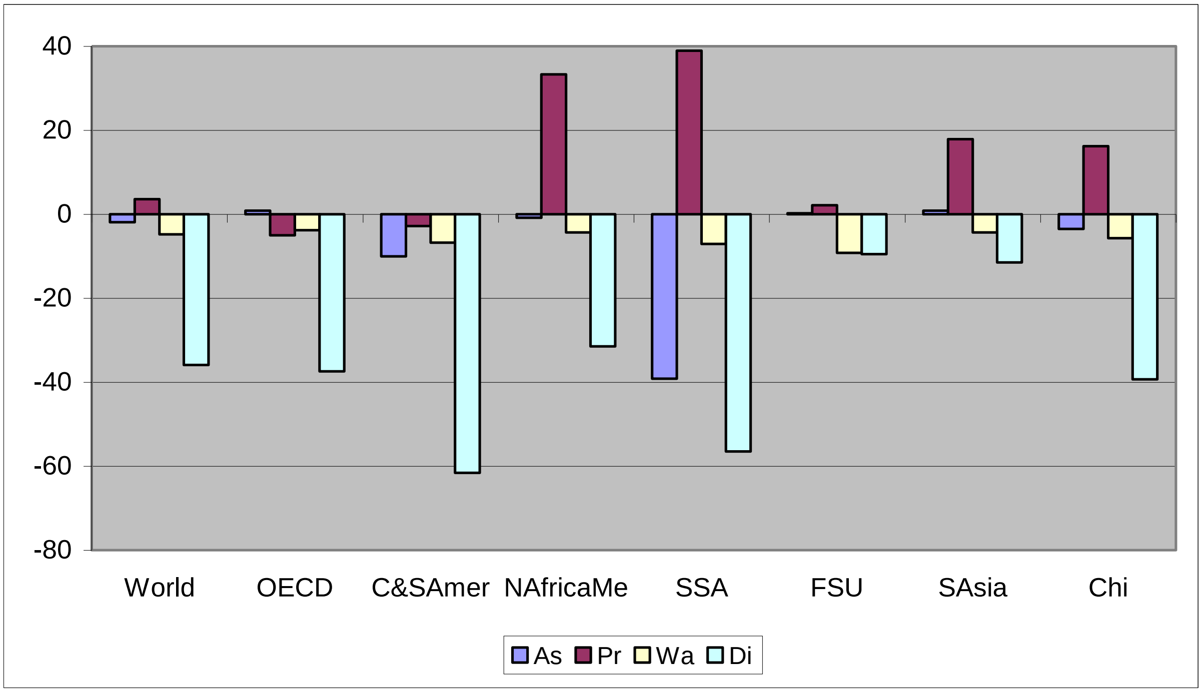

Figure 5. Impact of different policy options to protect biodiversity on livestock production growth in 2010 - 2050.

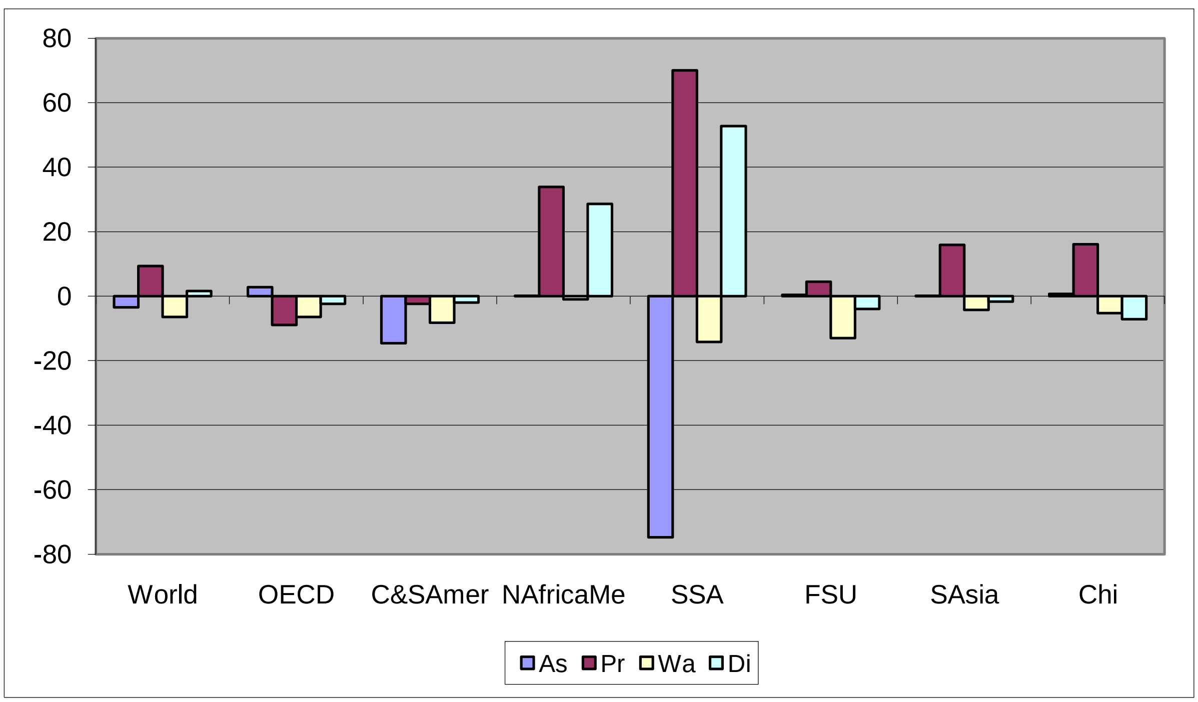

Figure 6. Impact of different policy options to protect biodiversity on crops production growth in 2010 - 2050.

Agricultural land development

Agricultural land development is determined by demand on agricultural output, availability of agricultural land and yields changes (Figure 7). Despite of high agricultural production growth, the autonomous technical progress leads to in decrease of demand for agricultural land in majority of regions and scenarios. The only region facing land demand increase in all scenarios is Sub-Saharan Africa where demand for agricultural products is growing much faster than yields and where, depending on scenario, only between 67% and 83% is used in the production process in the base situation.

The policy options implement to protect biodiversity have positive biodiversity effect since they lead to lower land use. The join impact of all these policy measures results in worldwide decrease of land use by 18.5% in 2050 compared with 2010 in BaAsPrWaDi scenario.

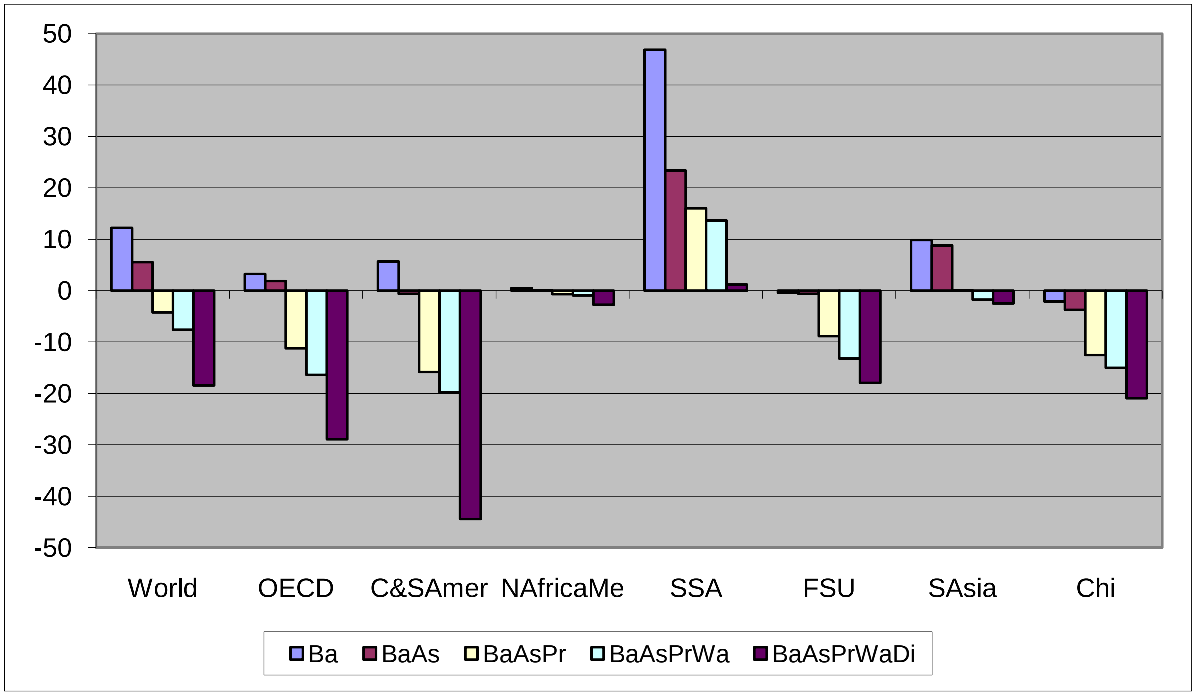

Figure 7. Agricultural land use development: growth rates in 2010 - 2050.

However, some investigated policy options leads to intensification of land use. Only increase of autonomous yields results in extensification of land use in all regions and leads to 9.2% worldwide extensification. The remaining policy options have mixed effect depending on region and jointly lead to 4.4% world production intensification. Almost 80% of this effect is caused by an increase of land protection.

Agri-food consumption development

Per capita food consumption increases in the baseline by about 16% on average, ranging from 10% in OECD countries to around 35% in Central and South America, 53% South Asia to as much as 131% in Sub-Saharan Africa (Figurer 10). Expansion of protected area leads to a small decrease in global per capita consumption of food compared to the baseline, while the additional productivity growth and reduced waste lead to a small increase in per capita food consumption

(Figure 10). The shift towards a low-meat diet also has only a minor impact on total global per capita food consumption, as meat is substituted by crops and non-meat processed food products.

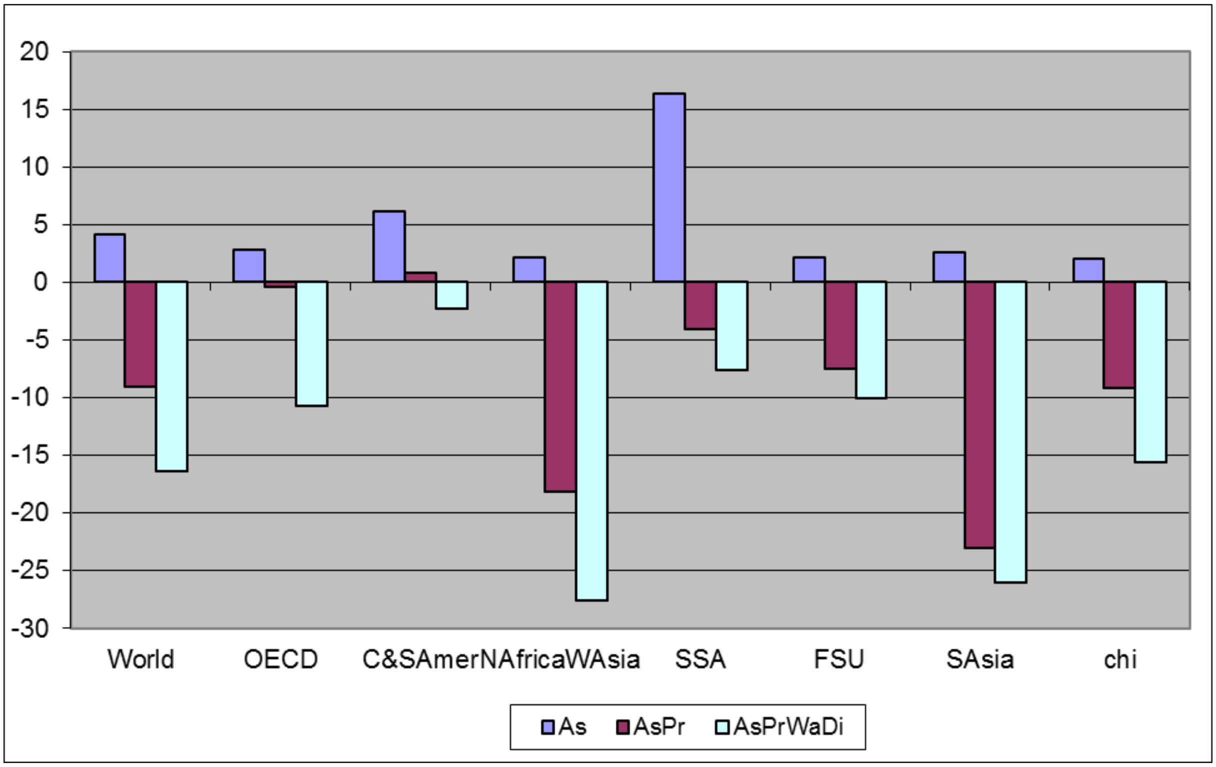

Figure 8. Real agricultural prices development compared with the Baseline: growth rates in 2010 - 2050.

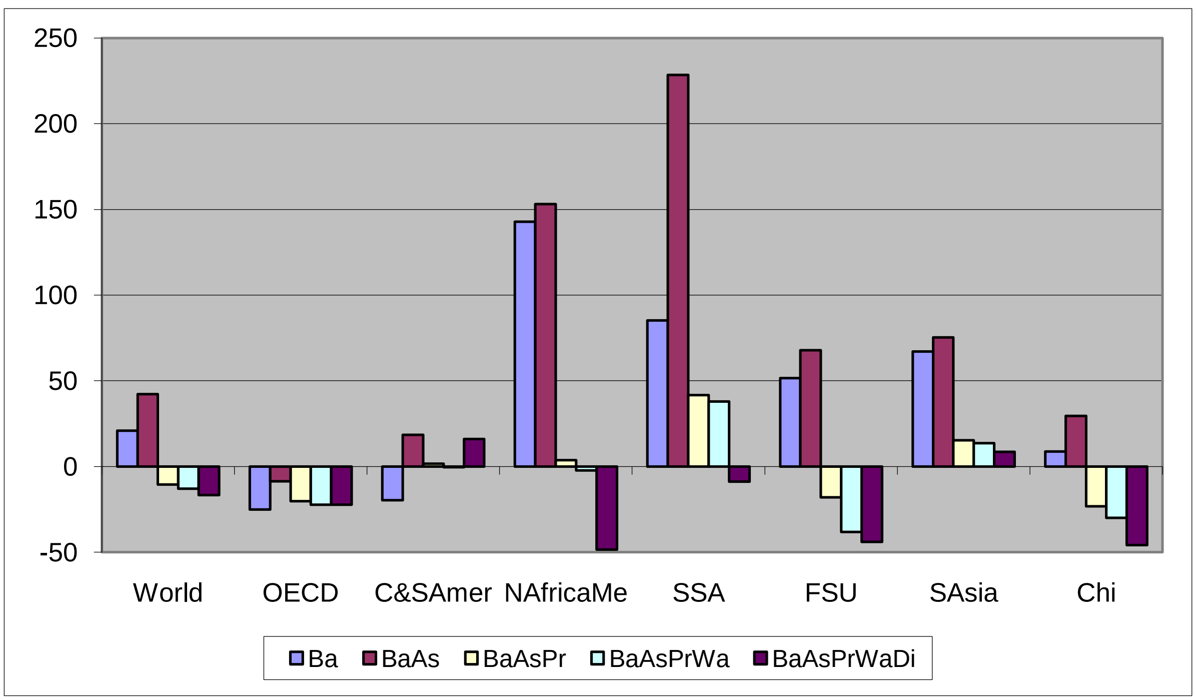

Figure 9. Real land prices development: growth rates in 2010 - 2050.

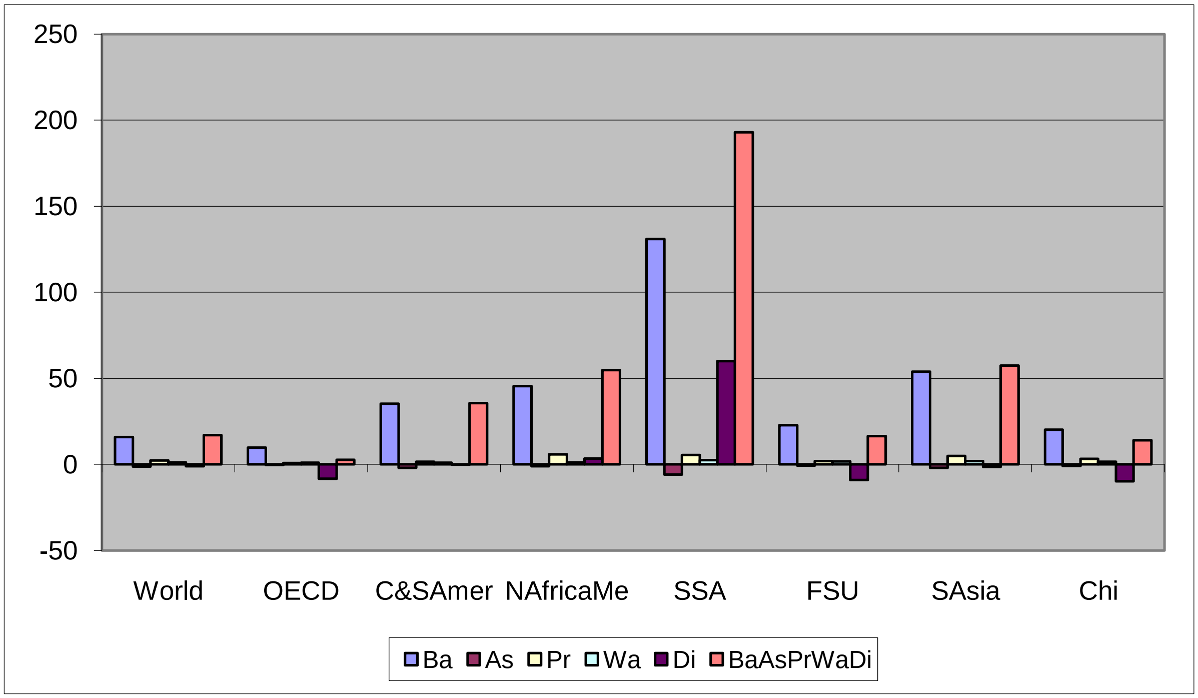

Figure 10. Per capita food consumption growth in 2010 – 2050: Baseline (Ba), different policy options and total effect (BaPrWaDi).

In OECD, FSU and China, the overall effect of this shift, however, is a small reduction in food consumption (Figure 10). In Sub-Saharan Africa, the increase in crop and non-meat processed food products consumption due to the dietary shift is much stronger than the decrease in meat, thus resulting in a significant increase in food consumption due to this measure (Figure 10). The shift towards a low-meat diet results in a reduction of prices for non-meat products by about 12% globally, as less agricultural land is needed, and land prices fall (Figure 9).

Agricultural trade development

All agricultural measures (As, Pr, Wa, Di) have an effect on the production level and therefore on availability of agricultural goods but also on production prices within a regions, and therefore on the relative competitiveness of a region in international trade. As a result, not only consumption and production, but also trade patterns change (Figure 11 and 12). Overall, world import and export decrease continuously when adding additional measures, but developments per region are very diverse. While China increases its exports in all steps except of low-meat diets (Di), OECD, Central and South America, FSU and South Asia decrease their exports for all measures except of a land protection (As). This last effect can be explained by relatively high availability of agricultural land in these regions compared to others after expanding protected areas. In case of China, low population growth and relatively low agri-food per capita consumption growth (since China is growing to the wealthy country level) causes that any efficiency gain in the agricultural production process leads to extra agricultural production surplus which can be exported. In general, an increase of domestic production of agricultural goods resulting from high land productivity (Pr) and decrease of demand on land and meat production in case of low-meat diet have the most pronounced negative impact on agricultural trade (19% and 21% decrease of trade volume respectively) since they increase the degree of regional self-sufficiency in food production (more land and higher yields).

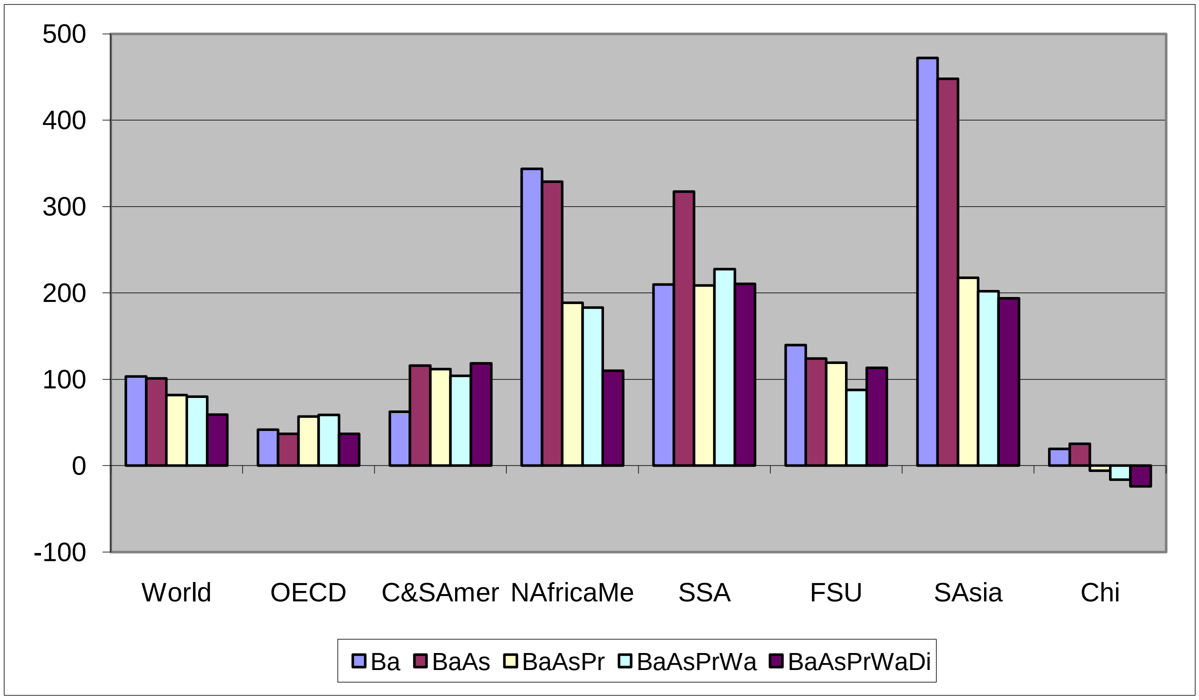

Figure 11. Agricultural imports growth rates in 2010 – 2050.

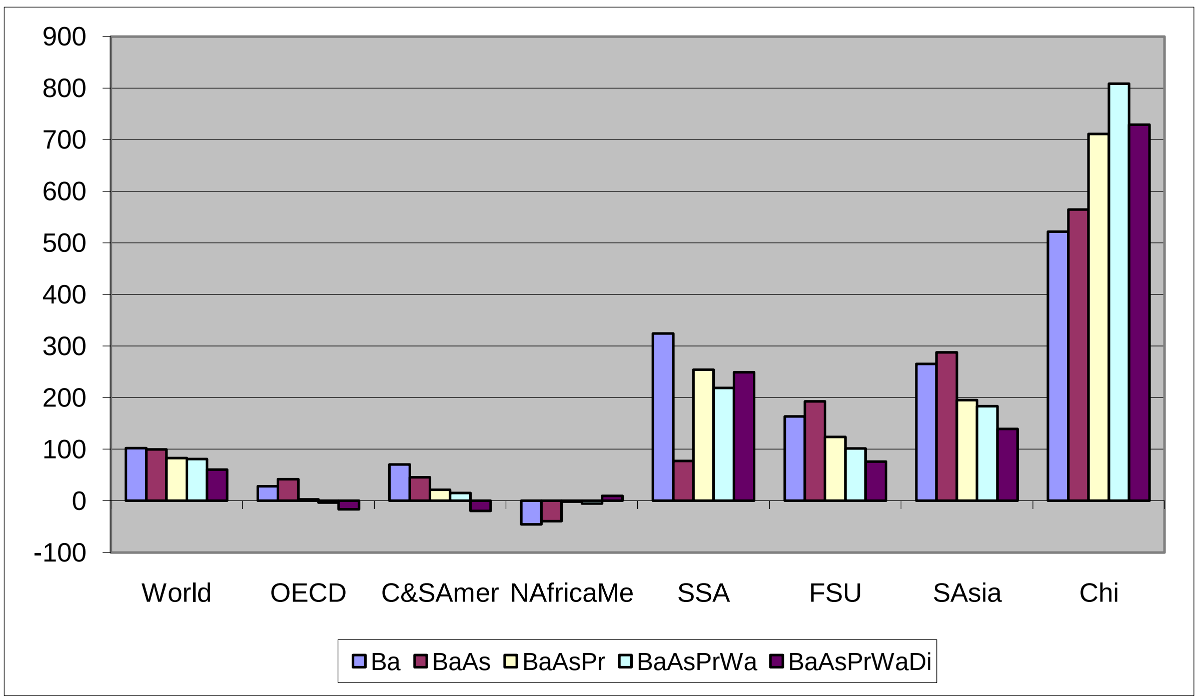

Figure 12. Agricultural exports growth rates in 2010 – 2050.

Under the option of protected areas (As), exports from all regions increase except from Latin America and Sub-Saharan Africa. This is in fact caused by the strong effect of protected areas in these two regions, whose exports decrease and imports strongly increase (Figure 12).

Conclusions

The paper shows that increase of natural ecosystems protection alone leads to an increase in land and commodity prices and leads to lower food consumption. This negative effect could be reduced or, in some cases, even reversed out if land protection would be combined with measures that reduce the pressure on land (agricultural intensification, reduced waste, dietary change).

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