LAND FOOTPRINT SCENARIOS

A discussion paper including a literature review and scenario analysis on the land use related to changes in Europe's consumption patterns

Report for Friends of the Earth Europe

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Final version,
Vienna, 28th of October 2013

Friends of the Earth Europe gratefully acknowledges financial assistance from DG Environment and Friends of the Earth England, Wales and Northern Ireland. The contents of this document are the sole responsibility of Friends of the Earth Europe and cannot be regarded as reflecting the position of the funders mentioned above. The funders cannot be held responsible for any use which may be made of the information this document contains.

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Executive summary

This discussion paper on “land footprint scenarios” prepared by SERI for Friends of the Earth Europe aims to contribute knowledge on how consumption changes undertaken by individuals (such as changes towards diets with lower amounts of meat consumption) or triggered by policies (such as EU’s renewable energy targets) impact on Europe’s global land footprint. After a short introduction to the concept of the land footprint, the discussion paper provides an extended review of the state in the academic literature on land requirements and land footprint related to consumption patterns, including relevant research on driving factors for land footprints, land footprints on the micro level of single products, as well as on the macro level of policies and countries. The second major chapter of the report summarises the results from simple scenario calculations, estimating the impacts on land footprints of future changes to key variables determining Europe’s land footprint.

Economic income has been identified as the single most important driver. With rising affluence, dietary patterns change significantly and in parallel, demand for bio-productive land areas also changes. In poor countries, basic crops such as cereals make up more than 60% of the total food supply and only around 10% of the calories are based on animal products. With increasing economic wealth, people consume more vegetables, fruit and animal proteins. Animal protein amounts to around one third of the calories in rich countries, causing huge per capita land footprints. In some world regions, notably Sub-Saharan Africa and South Asia, population growth will continue to be a major land footprint driver in the coming decades. As will diet as per capita calorie intake and meat and dairy consumption increase towards industrialised country levels. Increasing demand for bioenergy and biomaterials adds significantly to the land footprint pressures Europe exerts to the domestic environment and on the rest of the world.

The simple scenario calculations illustrated that a significant reduction of average per capita consumption of meat and other animal products would have a significant effect on reducing Europe’s land footprint. Based on Food and Agriculture Organization (FAO) data, it was estimated that a 50% reduction across all types of meat and animal products would reduce Europe’s land footprint for these products from currently around 70 million hectares for arable land to around 35 million hectares, and from 19 million hectares for grassland to 9 million hectares, with most reductions taking place in the land footprints related to the consumption of milk (and milk products) as well as pork and bovine meat.

In order to be more widely accepted, the available land footprint methods, data and tools need to be harmonised, as various calculation approaches still deliver very different results which impede direct comparison and drawing robust policy conclusions.

1. Introduction

This discussion paper on “land footprint scenarios” prepared by SERI for Friends of the Earth aims to start a debate on the limits to our consumption. By using the case of land as a limited resource, we want to explore how certain changes in consumption can increase or decrease our pressure to our natural resource base and, specifically, how it would impact on Europe’s global land footprint.

Two discussion papers will be published. This one provides a review of existing land footprint literature and explores the land footprint of dietary changes where the case of animal products will be studied. The second one will investigate how policies, such as EU’s biofuel targets, can have an impact on our land consumption.

The work underlying this discussion paper was structured in two main tasks:

Task 1 provided **a review of the academic literature** on land requirements and land footprint related to consumption patterns, including relevant research on land footprints on the micro level of single products, as well as on the macro level of policies and countries.

Task 2 performed **rough estimations** of how Europe’s land consumption and global **land footprint is affected by changes in consumption** patterns of meat and animal products.

The discussion paper is structured as follows. Chapter 2 provides a short summary of the land footprint methodology, explaining its advantages and disadvantages. Chapter 3 contains the results from the literature review, explaining the main drivers for land use and land footprints, illustrating current trends in European and global land footprints and summarising existing literature on future scenarios of land use and land footprints. Chapter 4 reports on the results from the rough scenario calculations. Chapter 5 closes the report with a summary of the main messages from all chapters and an explanation of future research needs.

2. The land footprint concept

The land footprint, or actual land demand, is a well-recognised method to assess the total domestic and foreign land required to satisfy the final consumption of goods and services of a country (Bruckner, 2012). It is thus a powerful method to illustrate the dependency of countries or world regions on foreign land, which is embodied in imports and exports (also called “virtual land”).

When interpreting land footprints it is important to notice that differences in the biological productivity are generally not considered. Land is accounted for without weighting the actually appropriated hectares: a hectare of most fertile arable land equals a hectare of dry lands reported as pastures. The land footprint results thus always represent the real or actual land use occurring in different countries and world regions, without performing any analysis with regard to different productivities, as is the case for example with the ecological footprint. This transparency of the calculation procedure is a clear strength of the land footprint concept – but does not always give the whole picture.

For example, it implies that if a country's land use per tonne of wheat is ten times higher than that of another country, ten times more land is allocated to the consumer of wheat from that country. The per-capita actual land demand of Australia is thus five times that of the USA. This is primarily explained by different land qualities: the very low land productivities of Australian pastures (extensive grazing) compared to those of the USA. Aspects related to differences in the quality of land in use and in productivity need to be taken into account when interpreting results from land footprint calculations.

Furthermore, for assessing the various environmental impacts related to certain land footprints, it is important to localize the country of origin in its specific natural conditions. Identical area and type of land use may have very different environmental impacts in different countries. For example, 1000 hectares of pasture used for raising cattle may have a larger ecological impact in Brazil than in the United States. In Brazil, pasture is often created by clearing rainforest whereas in the United States, pasturelands exist naturally in the form of prairies (Ferng, 2011). The converse may also be true. Regarding the assessment of environmental impacts of consumption activities all over the world, land footprint calculations still lack an adequate data basis for all included categories. Besides land productivity, it is important to estimate potential and actual natural primary production in order to evaluate environmental impacts. Relating land footprints to impacts on ecosystem and biodiversity is a very recent field of research, tackled in ongoing European research projects.[1]

Land footprint by itself gives useful information, but it is far more powerful when combined with the other indicators, like the material, carbon or water footprint, in order to identify true resource efficiency, and trade-offs and potential synergies across the various categories of natural resource use. For example, the production of palm oil generally has a lower land footprint per unit compared to other vegetable oils (e.g. rapeseed). However, expanding palm oil plantations is often related to high carbon releases from wetland drainage or deforestation, a consequence, which can only be revealed when using the land footprint indicator in combination with the respective carbon footprint.

3. Review of existing land footprint literature

The following chapter provides a summary of existing land footprint literature. Chapter 3.1 explains the driving factors behind land use change and land footprints, including an overview of different regional and national food consumption patterns and their links to income. In the following chapter 3.2, we present the current land consumption and land footprints of regions, countries and specific products.

3.1. Driving factors behind land use change and land footprints

A large number of driving factors influence land use change and land footprints. The following drivers, which are considered as the most important drivers in the existing literature, will be considered in more detail in this chapter:

- Dietary patterns and changes

[1] See, for example, the FP7 project „DESIRE" (Development of a system of indicators for a resource efficient Europe), where land footprint research is linked with research on ecosystem services (http://fp7desire.eu).

- Population growth and population density
- Urbanisation
- Bio-energy and bio-materials
- Policies impacting on land use

Dietary changes

Dietary changes become an increasingly dominant economic driver for land use and land use change. Diets tend to include higher levels of animal protein, vegetables and stimulants – such as coffee or tea – with rising affluence (Kastner et al., 2012). The consumption of one kilogram of beef requires up to 420 m² of land per year. By contrast, the consumption of an equivalent amount of protein based on plants requires only between 2 and 3 m² land use per year when consuming a protein rich equivalent meat substitute (see Table 1 below for more details). In other words, to the extent that growth in a country's income often drives dietary change towards higher consumption of meat, dietary change drives growth in land footprints. Weinzettel and colleagues (2013) partly prove this relationship by illustrating that national land footprints increased by a third for each doubling of income.

An easy but sufficient enough way to outline and illustrate differences in regional food consumption patterns is to introduce income growth as the main driver behind differences and changes in diets and thus in changes in land footprints.

Figure 1: Impact interrelation between income, dietary change and land footprint

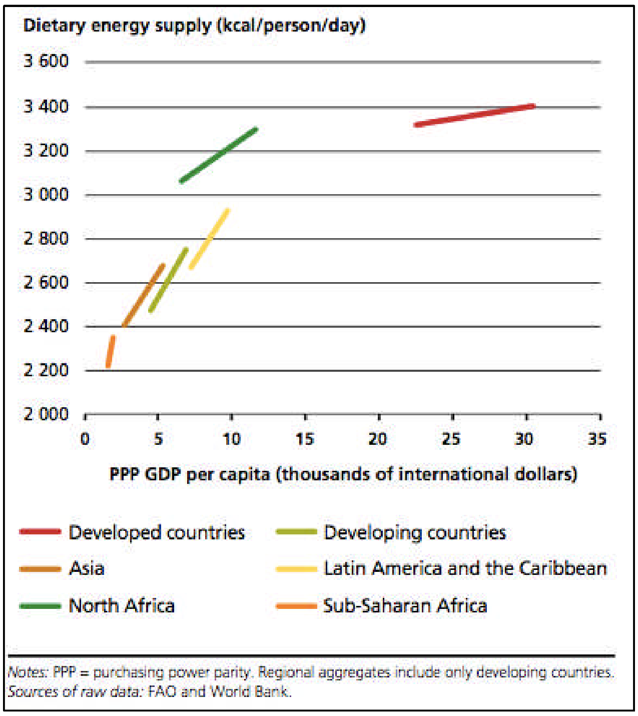
On the global level, demand for richer diets is strongly driven by the emergence of the middle class, in particular in emerging economies such as China and Brazil (Alexandratos and Bruinsma, 2012). In the EU, diets are rather stable, although some growth in higher value products, such as year-round imports of fresh fruits and nuts show continued growth. In addition, food waste seems to grow with higher stages of development (Kearney, 2010).

In the coming decades, economic growth will likely accelerate the global adoption of diets with high per capita levels of meat and dairy consumption. The example of meat consumption depicts a change in diets which is likewise linked to a higher income. Recent research shows that between the year 1961 and 2008 world population increased by a factor of 2.2, but total meat consumption quadrupled from 71 million tonnes to 280 million tonnes (FoE, 2010, calculations based on FAOSTAT data). The issue of increased consumption of meat and animal products is thus an important one and will be further investigated in Chapter 4 below.

Asia is the single most important region in this respect as the region is expected to grow its middle class from 525 million people in 2009 to 3.2 billion people in 2030 (Kharas and Gertz, 2010). However, other developing regions show similar developments towards increasing calorie intake, both through increasing quantities of food consumption, as well as dietary change (Alexandratos and Bruinsma, 2012). In developed regions (EU, US, Australia and New Zealand), diets are relatively stable at a high level of 3300-3500 calories/capita/day, which also causes negative health effects: in 2008, across the 27 countries of the EU, 59% of adult men and 48% of adult women were either overweight or obese (HDHL, 2012).

Figure 2 shows the increase in dietary energy in relation to income in different world regions – from around 2300 calories/capita/day for the lowest income countries up to 3400 calories in the most developed countries. Diets in developed regions contain, on average, one third of the available calories from animal proteins, compared with 10% or less in many of the poorer regions (FAO, 2012a).

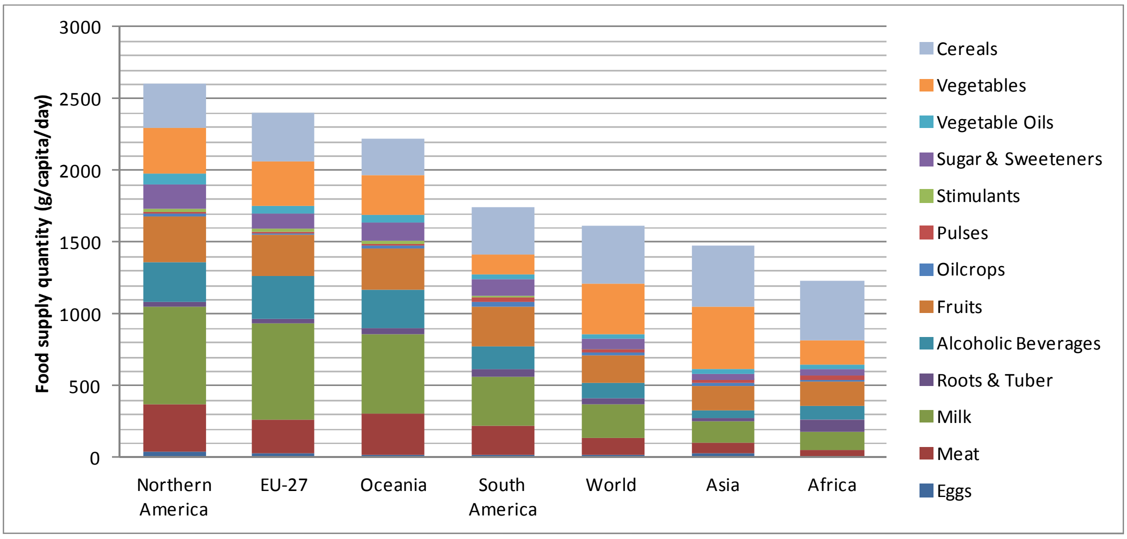
Figure 2: Food supply versus demand for food in relation to income, 2008



Source: Alexandratos and Bruinsma (2012)

Analysis of FAO data illustrated in Figure 3 supports the view that diets in low-income countries mainly consist of cereals, which make up more than 60% in the food supply, while containing limited amounts of vegetables, fruits and animal proteins. High income countries, in comparison, consume relatively large shares of animal proteins, fruits, vegetables, vegetable oils and stimulants such as coffee and alcoholic beverages. The only category which increases in all regions is vegetable oils, particularly palm and soya oil.

Figure 3: Regional food consumption patterns in the year 2008



Source: FAO (2012)

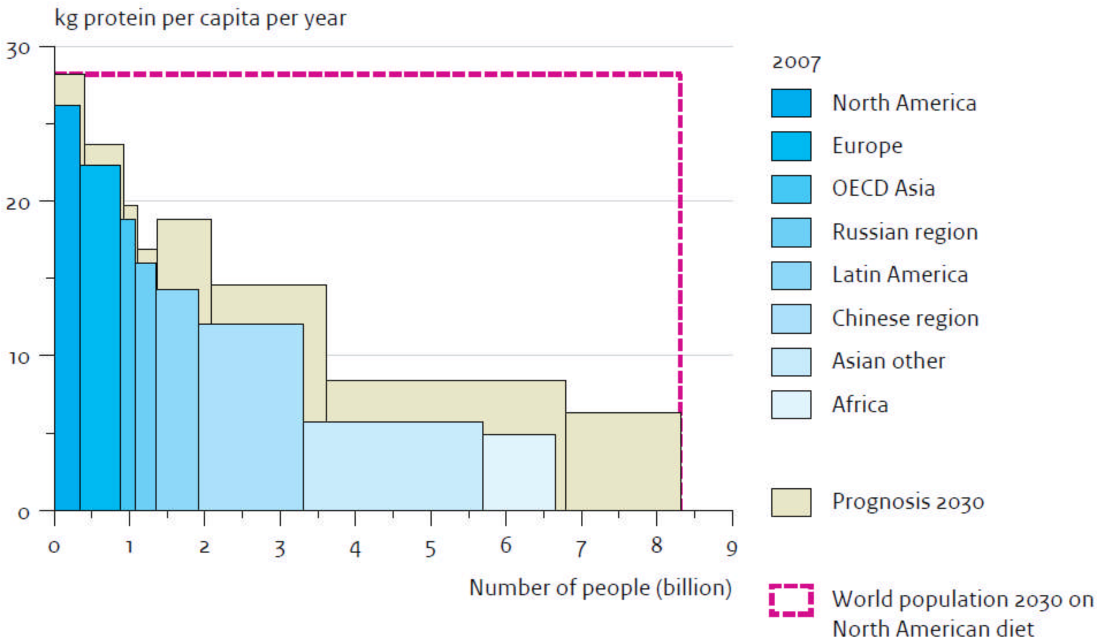
FAO data also shows that diets continue to vary greatly between regions and countries, as well as between comparable income levels. This is largely related to differences in local food supply and culture. In the EU-27, diets contain relatively high proportions of dairy products, vegetables, alcoholic beverages and stimulants (coffee, tea, cocoa). However, also within the EU large differences exist, with generally higher levels of meat consumption in more northern member states, and more fruit and vegetables in southern member states.

According to various studies, an increase in the caloric intake per person, in particular in the fast-growing developing and emerging economies can be expected. The FAO study on the global agricultural outlook to 2030/2050 (FAO, 2012b) illustrates that food consumption has increased from 2,250 calories per person per day in 1961 to 2,750 calories in 2007. Following this trend, it is projected by the FAO that 3,070 calories per person will be provided by 2050.

However, despite increased consumption, South Asia and Sub-Saharan Africa will continue to have the lowest daily food caloric intake per capita. A shift in the composition of diets will have huge impacts on the global agricultural system. As countries in the developing and emerging economies get richer, the consumption of meat and dairy products usually increases. The FAO study assumes that by 2050, Latin America, Near East/North Africa and East Asia will generally have per capita food consumption similar to that of high-income countries in 1990.

Today, the consumption levels of e.g. meat and meat products are still very uneven across the globe. On average today, every citizen consumes about 40 kilograms of meat per year. North America consumes 121 kilograms per capita, Europe (EU-15) consumes 91 kilograms, China consumes 54 kilograms and Africa consumes 14 kilograms. Without any intervention or other shifts which could affect consumption, the demand for proteins from animal products is predicted to increase by 50% by 2030 compared to the year 2000, in particular in Africa and Asia (see Figure 4) (PBL, 2011).

Figure 4: Global intake of animal protein by region, 2007 and 2030



Source: PBL (2011)

As a consequence of both increased intake of calories as well as the shift towards animal-based products, both livestock production and crop production are expected to increase significantly towards 2030.

To gain an in-depth insight into the differences in land needed to produce a certain amount of a food product, methods of life cycle assessment can be applied. A recent study (Nijdam et al., 2012) analysed 52 life cycle assessment studies (LCAs) of animal and vegetal sources of protein. It becomes obvious that animal products are by far the most important contributors to environmental impacts (see Table 1).

Table 1: Land use of protein rich products per kilogram of product

Product	Land Use (m² y/kg)	Of which grassland (m² y/kg)
Beef - Industrial systems	7 - 420	2 - 420
Beef - Meadows, suckler herds	15 - 29	2 - 26
Beef - Extensive pastoral system	33 - 158	25 - 140
cows	286 - 420	250 - 420
Beef - Culled dairy cows	7	ca. 5
Pork	8 - 15	
Poultry	5 - 8	
Eggs	4 - 7	
Mutton and Lamb	20 - 33	ca. 18 - 30
Milk	1 - 2	ca. 1
Cheese	6 - 17	ca. 7
Seafood from fisheries		
Seafood from aquaculture[2]	2 - 6	
Meat substitutes, containing egg or milk protein	1 - 3	0 - 2
Meat substitutes, 100% vegetal	2 - 3	
Pulses, dry	3 - 8	

Source: Nijdam et al. (2012)

Beef products show a high variation in land use, ranging from 7 to 420 m² y/kg. This is similar to the land use category grazing, but meat from pastoral systems has a lower demand for land per kg and year. Land use per kilogramme of cheese is between 6 and 7 times higher than that of milk. This is explained by the fact that 1 kg of cheese requires ca. 7 kg of milk. Land use for 1 kg of cheese is surprisingly just about the same as for 1 kg pork. Plant-based products are at the bottom of the scale, demanding between 1 and 3 m² of land per year for each kg protein-rich meat substitute.

Population growth and population density

Historically, population growth has been the most important factor for land use change (Boserup, 1965; Chertow, 2001). At current estimates, world population is expected to increase significantly in the coming decades, reaching 9.6 billion people by 2050 in the medium scenario (United Nations, 2013). Growth is mostly expected in Sub-Saharan Africa and South Asia, where per capita calorie values and level of meat and dairy consumption are still far below the level of industrialised countries (see above). Population growth and a change to more affluent diets will therefore lead to expanded and intensified agricultural and forestry production (Kastner et al., 2012; Weinzettel et al., 2013).

Although the previous century has seen considerable advances in the technology of production- such as the development of more productive crop varieties and the extension of irrigation and fertilizer use - there are still difficulties for technological progress to keep up with the rising demands from population growth in particular in these world regions. In addition, there

[2] Land use: only land used for vegetal feed component

are increasing problems associated with the use of many such technologies, not least of all impacts on water tables and marine pollution.

In Europe, North America, Asia and Oceania, agricultural area per capita decreased more than total land availability per capita, thus supporting the general trend towards agricultural intensification (Brouwer, 2006). Only in Africa and South America, total land availability per capita decreased more than agricultural land areas per capita, as more non-agricultural land has been converted to agricultural land. Decreasing amounts of available agricultural land and the relative stagnation of land productivity in the industrial countries stimulates imports of embodied land.

Urbanisation

Although only 1% of the earth's land is used as infrastructure and urban areas (Erb et al., 2009), urbanization has a remarkable indirect effect on land use change by stimulating food consumption and dietary change. Increasing urbanisation typically correlates with extended periods of rising GDP per capita and increasing levels of consumption of energy and raw materials; along a 'S' shaped curve, see (Wolfram et al., 2012). Furthermore, urbanisation means greater demand for infrastructure and housing. In 2009, the global urban population accounted for over 50% of the world's population; 80% in developed countries and 45% in emerging economies.

Globally, urban population is forecast to increase from 2.84 to 6.37 billion. However for East and South-East Europe, the UN forecasts a shrinking urban population and in this region the urban areas are expected to stay constant (United Nations, 2013). Global urbanisation levels are projected to rise to 70% of the population by 2050 – driven in part by both economic opportunities in urban areas and higher levels of mechanisation in agriculture. While urbanisation may proceed slowly in many industrial countries and transition countries, it may continue to grow unabated in countries where the vast majority of the population still lives in rural areas.

Urbanisation has numerous consequences, e.g. improved marketing and distribution, attracting supermarket chains, improving market access for foreign suppliers, lower food prices and, ultimately, the globalisation of food consumption patterns (Hawkes, 2006). As such, urbanisation can be considered a structural driver for land footprints, although its direct effects on land use are limited.

Bioenergy and bio-based products

Bioenergy today is the main source of renewable energy in the world, accounting for about 50 EJ (Exajoule = 10^{18} joules), i.e. around 10% of world total primary energy supply in 2009, most of the energy being consumed in developing countries for cooking and heating (IEA, 2012). In Europe (EU-27), bioenergy almost reached two thirds of renewables in 2010, representing 8.16% of total European final energy consumption (AEBIOM, 2012). In Europe, it is mostly used to provide heat (75%), and to a lesser extent for power generation and as a transport fuel.

However, increasing use of crop-based bioenergy sources for biofuel production are related to increasing pressure on land and soils through land use change. Researchers suggest that large-scale biofuel programs have significant market impacts. Furthermore, biofuel production competes with food production for productive land (Hertel et al., 2012; JRC, 2013).

Developments towards innovative bio-products to replace petro-chemical based products show high potential benefits to support a shift towards non-fossil fuel economies but their development is challenged by competition from well-established and cost-competitive 'traditional' value chains.

Bio-chemicals hold large potential benefits as these products are less toxic, allow for cascading uses and a wide range of applications. However, as with bioenergy, biomass feedstocks increase the EU's land demand, both domestically and abroad. Research on the net effects on land use change of a developing bio-economy is highly relevant, but not yet extensively available (Carus, 2012).

Policies

Various policies have important implications for Europe's current land footprint and policy changes could contribute to a significant reduction. Here, only some of them can be mentioned, as a thorough assessment of the impacts of policies is beyond the scope of this discussion paper.

In general, agricultural policies should to a larger extent support the implementation of organic and other environmentally and socially sustainable agricultural practices, for both crops and animal production since amongst other benefits they preserve existing resources like water and soil fertility. Additionally, healthy eating and environmental behaviour guidelines such as clear standards should be introduced, modified and promoted (e.g. via procurement by government) to demonstrate the possible benefits achievable. Moreover, products should be clearly labelled to be easily understood by consumers, so that they can make more informed food choices as well as stimulate the market for these products.

Research supports the hypothesis that organic agriculture can feed a world population of 9.6 billion in 2050, if modest animal protein diets are adopted and food is efficiently and more equally distributed (Erb et al., 2009). Organic agriculture, however, can reduce crop productivity per hectare compared to resource intensive industrial production and in order to maintain the same levels of consumption, land demand would increase, especially when overall yields are no longer increasing as in the past. Therefore it is recommended to direct research and technical development towards eco-functional intensification approaches, such as organic farming, that improve and maintain yields without the negative impacts of synthetic inputs, while enhancing and protecting natural resources and ecosystems necessary to secure and stable food production (FoE, 2010).

Additionally, policy action should be taken to reduce consumption of animal products, especially in developed countries. For instance this could include public awareness-raising campaigns with the aim of enabling people to adopt lower-meat diets and likewise reducing the demand for intensively-reared meat. Public procurement standards could specify less but better quality meat in schools and hospitals, for instance, alongside less junk food and more fresh fruit and vegetables. Further research needs to link up with farmers' and communities' traditional knowledge to deliver agro-ecological production – farming that balances environmental sustainability, social equity and economic viability (FoE, 2009; Wibbelmann et al., 2013).

Indirect land demand is further accelerated by climate related policies that support the production of bio-energy crops as already mentioned above. However, the EU is in the process of reducing negative impacts of policies affecting land demand and GHG emission related to bio-energy. In

September 2013 a narrow majority of MEPs voted in favour of a legislative proposal to cap "first generation" crop-based biofuels at 6% of the final energy consumption in transport by 2020, as opposed to the current 10% target for renewable energy in existing legislation, while promoting 'advanced' biofuels, and carbon accounting in the Fuel Quality Directive to include factors for indirect land use change.

Liberalisation of trade policies and globalisation of value chains have been the prime drivers to support an increase in global exports of food and agricultural products. In general, the Northern hemisphere is a major exporter of cereals, whereas the Southern hemisphere profits from (growing demand for) exported vegetable oils, oilseeds, sugar, fruit and nuts. The EU is a growing importer of these products and increasingly concentrates on exports of higher value final products. This trend, in combination with rather stable or decreasing domestic productivity growth in agriculture, corresponds with an increase in land imports (Anderson 2010).

The EU displaces all three types of environmental pressures related to agricultural production to the rest of the world through imports of products with embodied pressures (i.e. greenhouse gas emissions measured with the carbon footprint; appropriation of biologically productive land (land footprint) and related water use (water footprint) (Steen-Olsen et al., 2012)).

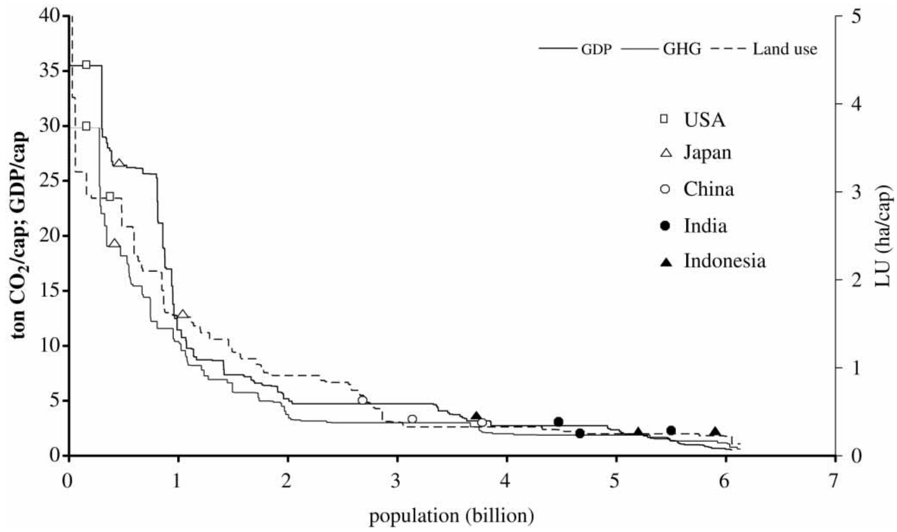
3.2. Current land consumption patterns and land footprints

Global distribution of land footprints

More than 75% of the earth's land (excluding Greenland and Antarctica) is already used by humans. Land use ranges from very intensive to very extensive. 1% of the land is used as infrastructure and urban area, around 12% as cropland, around 27% as forestry land and 36% as grazing land. Of the remaining 24%, about one half is completely unproductive, often covered by rocks and snow or deserts. The other half includes pristine forests (6 million. km^2, 4.6% of total area), including tropical rainforests as well as all other forests with almost no signs of human use (most of the latter in boreal regions) (Erb et al., 2009).

Current appropriation of the earth's land differs significantly between countries and world regions. In the following Figure 4, GDP (in international 1000 $ per cap in 2000 prices), land footprint (in hectares/cap) and carbon footprint (in tonnes of CO_2 equivalents/cap) are illustrated across 87 countries and explicitly for five countries for the year 2001.

Figure 5: GDP, land footprint and carbon footprint across world population, year 2001



Source: Wilting and Vringer (2010)

For about one billion people living in developed world regions, GHG emissions related to consumption were over 10 tons of CO_2 equivalents per capita and caused about 55% of the total global GHG emissions. The other part, around 5 billion people caused only 45% of global GHG emissions. The pattern for the land footprint was very similar to the one observed for GHG emissions. In the year 2001, about 2 billion people (32% of the world population) required more than the global average land footprint of 1 ha/cap. This group used almost 70% of the global agricultural areas for production and consumption (Wilting and Vringer, 2010).

International trade in embodied land

With evolving globalisation, ever more internationalising supply chains and differentiation of labour, international trade gains importance when assessing the overall land footprint of a country or region.

Kissinger and Rees (2010) located and measured the productive land embodied in U.S. imports during 1995–2005 and found that in a globalising world even a country able to meet most of its needs had growing dependence and impacts on external ecosystems. Fader and colleagues (2011) find that current trade actually leads to high global land savings. In their study, land savings are defined as the land that would be needed to sustain self-sufficiency under current consumption and production patterns. It calculates how much additional land would be needed in order to produce import goods on the countries' own territories. The authors suggest that globally, current trade saves amount to 41 million hectares (per year). International trade could thus potentially lower demand for land resources at the global level if trade is directed from a relatively less efficient to a more efficient country with corresponding ecological opportunity costs. Since different regions have different comparative advantages - for example in terms of production technologies and natural endowments - international trade could potentially aid the optimization of global society's overall use of natural resources (Steen-Olsen et al., 2012). This is a quite challenging finding and its verification goes beyond the scope of this paper but it is worth mentioning in order to consider all aspects related to international trade.

However, international trade can also accelerate environmental degradation when combined with unsustainable levels of consumption. Yield increases in agriculture and intensified international trade can lower prices and increase demand of resources in absolute terms, an effect also known as the rebound effect, especially for those products with elastic demand. For instance, cheap imports of soybean based feedstuff may contribute to lowering meat price and accelerating meat consumption (Quiang et al., 2012).

Europe's land footprint: EU-27 vs. rest of the world

After this introduction on the global distribution of land footprints, let us now take a closer look at the European situation. Europe generally depends on imported resources from a wide range of countries outside Europe. Table 2 splits up the embodied (imported) land by region of origin. The columns show from which continent the land area related to internationally traded products originate, while the rows illustrate the exports (of related land) of each continent to all other world regions.

Table 2: Embodied land footprint per region (vertical) in 2007, related to the region of origin (horizontal, in million hectares)

	EU-27	Africa	Asia	L-America	N-America	Oceania	Exports
EU-27	220	5	13	2	6	0.7	25
Other Europe	7	1	7	0.2	0.6	0.0	16
Africa	25	701	30	1	7	0.5	65
Asia	52	15	1044	6	43	4	119
L-America	31	8	36	380	24	0.7	99
N-America	15	8	44	19	385	1	87
Oceania	8	3	73	3	19	136	105

Source: SERI (own MRIO calculations based on GTAP and FAO data)

For the EU-27, the most important land imports stem from Asia (52 million hectares), although it should be mentioned that in this illustration Asia includes Russia and other countries from the former Soviet Union such as Ukraine and Kazakhstan, and that these countries are large exporters of commodities, especially feed. The other important 'land suppliers' to the EU are Africa and Latin America, particularly Argentina and Brazil. Within Asia, the main 'land importer' is China, with large feed and food imports from Oceania and, increasingly, from North and South America.

However, China (and Asia in general) is also a large exporter of food and agricultural products (and related land) to other world regions, particularly to the EU and North America. In the last column of the figure, it can be seen that Asia (incl. Russia, i.a.) exports 119 million hectares, which makes it a net importer of 84 million hectares, compared with a net imported area of 113 million hectares for the EU-27.

Europe's land footprint in detail

The EU is one of the most intensively used continents on the globe, with the highest share of land (up to 80%) used for settlement, production systems (including agriculture and commercial forests) and infrastructure. Despite its intensively used land, the EU-27 relies relatively heavily on areas outside the EU. Table 3 below shows the global land footprint for the EU-27 according to the different land use categories. The last column indicates that 138 million hectares (38%) of the total land requirements involve imports of embodied land.

Table 3: Global land footprint of the EU-27 related to land use categories (in million hectares, 2007)

	Wheat	Other grains	Oil seeds	Vegetables, fruit, nuts	Paddy Rice	Sugar cane & beet	Plant-based fibres	Other crops	Grassland	Forest land	Total
Total (EU-27) land footprint	31	39	33	21	4	2	5	22	101	100	358
Domesic land footprint	22	28	13	12	0.4	2	0.4	13	56	74	220
Embodied (imported) land footprint	9	11	20	9	4	0.9	4	9	45	26	138
% Embodied land	28%	28%	61%	43%	90%	35%	91%	42%	45%	26%	38%
Other Europe	0.5	0.7	2	0.3	0.0	0.1	0.0	0.5	0.8	2	7
N-America	3	1.2	3	0.4	0.0	0.0	0.4	0.8	2	5	15
L-America	0.5	4	10	3	0.2	0.4	0.1	2	9	3	31
Asia	4	3	3	3	3	0.2	3	2	17	12	52
Africa	0.2	2	2	2	0.1	0.3	0.6	4	11	3	25
Oceania	0.5	0.4	0.2	0.1	0.0	0.0	0.0	0.2	6	0.4	8

Source: SERI (own MRIO calculations based on GTAP and FAO data)

The upper row in Table 2 shows the EU's land requirements according to land category: wheat, other grains (barley, maize) and oilseeds require the largest crop areas, while grazing and forest land are the most important single categories. The 2nd row shows the domestic area used for domestic consumption - i.e. the domestic land footprint: wheat, other cereals and oilseeds, largely produced in the northern and eastern member states, and vegetables from the southern member states are the major crops grown in the EU.

Most of the main crops (and related products) involve a moderate level of embodied (imported) land, but some products are highly dependent on imports; mainly oilseeds, rice and fruits for food, as well as fibre crops (mainly cotton). 'Other crops' includes, among others, coffee, tea and cocoa, which explains the high embodied land footprint. In addition, large areas of grassland and forest land are imported with products from other regions. Embodied grassland from Asia is particularly high, which cannot (from the data) be related to food or feed products. Furthermore, Asian imported land also includes Russia and other countries from the former Soviet Union. Van der Sleen (2009) adds weight to these results and identifies rising demand for oil crops as one of the most important drivers' behind the increase of EU-27 Land Footprint for the period of 1990 to 2005.

The results generated with the SERI model reveals similar results as those from Yu and colleagues (Yu et al., 2013). The EU appropriates cropland from all over the world to meet their food demand: from Brazil (13 Mha or 20% of Brazilian cropland), Africa (10 Mha or 5% of African cropland), China (10 Mha or 6% of Chinese cropland), Argentina (7 Mha or 23% of Argentinean cropland), and South-East Asia (6 Mha or 6% of South-East Asian cropland) and U.S. (5 Mha or 5% of U.S. cropland). EU-27 has the largest foreign land displacement across the globe (27% of global total foreign land displacement). The U.S. appropriates 13%, China 10% and Japan appropriates 8% of the global land displacements. 10 Mha of Africa's total cropland is for consumption in EU countries. This quantity is potentially enough land to feed more than 65 million people suffering from food shortage. International trade puts additional burden on African agricultural land (Yu et al., 2013).

Comparing land footprints of EU-27 countries

It is important to note that within the EU-27 aggregate, the land footprint is quite different between Eastern Europe, Western Europe and the Scandinavian countries (see Table 3). Despite the fact that almost all countries have results similar to or above the EU average, which is 1.3 hectares per capita, the majority of Eastern Europe countries have consumption levels below that value. At the other end of the spectrum are the Scandinavian countries Finland and Sweden with per capita land footprint values of 4.1 and 2.3 ha. Norway is just below Finland and accounts for 3.6 ha per capita. Compared to the Australian actual land demand per capita of about 15 hectares, the top European result of little more than four hectares (Finland) is noticeably small. Nevertheless, it is more than double the EU average and four times the world average of exactly one hectare. Except for Austria, Greece, France and Portugal, all EU-15 countries show an increase in the per-capita levels of actual land demand between 1997 and 2004 (Lugschitz et al., 2011).

Thematic focus areas

In the following, we take a look at selected thematic fields of importance for understanding recent trends in the land footprint.

Land demand for non-food production

The composition of land demand changes with increasing income. Households in wealthy countries appropriate half of the required land through consuming products other than food (such as textile and wearing apparel, processed forest products including wood and paper, machinery and equipment, and services and dwellings), while the share of these consumption items is much smaller in emerging countries (Yu et al., 2013).

Differences in income levels and consumption patterns lead to large differences in land footprints. For example, households in rich countries such as the U.S., Japan and Germany consume less land for primary products, such as agricultural and forestry products; i.e. approximately 37–46% of their displaced land relates to agricultural products and 1–10% to primary forest products. On the other hand, emerging economies, such as China and India have shares of 58–92% of land for primary consumption items such as agricultural and primary forest products. In African countries, on average more than 93% of land is used for the production of food and forest items, which is mainly due to low incomes and low agricultural land productivity. The figures reveal that with the increase of income the land demand distribution within the consumption categories shifts towards the non-primary - i.e. non-food - share.

The continuing increase of household income and change of consumption patterns would further impose pressure on land resources domestically and abroad. But the driver would increasingly be non-agricultural consumption items such as appliances or services, which are usually overlooked when analysing drivers of land (Yu et al., 2013).

Biofuels

Additional demand for bioenergy, in particular in the form of biofuels, requires increased demand for agricultural land, depending on the type of feedstock, the geographical location of biofuels production, the assumed additional increases in yields (beyond normal trends), and the relative decrease in consumption of food (Searchinger, 2013; UNEP, 2009). Large-scale biofuel programs have significant impact on land use change as well as indirect land use change. This indirect change relates to the unintended release of carbon emissions as a consequence of the expansion of cropland for biofuel production (Hertel, 2010).

This means using more (conventional) biofuels in the EU, even if they are produced from EU crops would increase the overall world demand for crops. Further, if not managed properly, this could displace arable production onto land used for other purposes, both inside and outside the EU, and could consequently lead to extra GHG emissions (JRC, 2010). These indirect land use effects are thought to cancel out any carbon savings benefits compared to fossil fuels of most of the biofuels currently on the market in the EU (JRC, 2010; Laborde, 2011).

EU countries are net importers for agriculture products, the increase of biofuel production in EU countries will most likely depend on the import of crops, such as palm oil, soybeans and other oil crops, which further impose pressure on the global food markets and increase cropland intensification and expansion for example in Latin America (Yu et al., 2013).

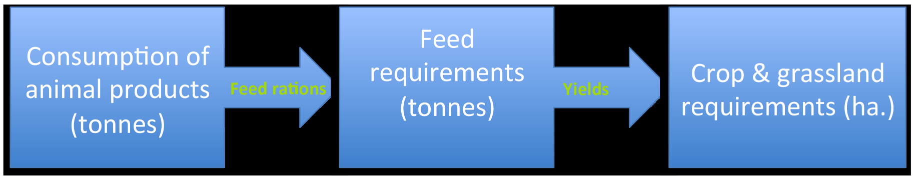
4. Scenario calculations

In Task 2 of the project, the team developed a land footprint estimate and its possible changes in the future due to changes in European consumption. In cooperation with Friends of the Earth, two focus areas were selected for these scenario estimations: (1) a reduced consumption of meat and other animal products and (2) and expansion of bio-energy consumption, with a particular focus on bio-fuels. The latter is currently still under development and will be published in a second discussion paper.

Methodology

The land footprint related to the EU consumption of animal products is based upon current meat consumption patterns and levels (2007-2009 average). Based upon feed ratios and feed conversion ratios, the volume of consumed animal products (in tonnes) has been translated into required feedstuffs (tonnes). The resulting crop, roughage and grassland requirements (tonnes) are then calculated into land demand (hectares), based upon the average EU yields (tonnes/ha) for the different feed ingredients. It shall be emphasised that in reality, yields differ significantly between countries, so the resulting numbers are very sensitive to underlying changes in yield assumptions.

Figure 6: From consumption of animal products to land use requirements



The current level of animal products consumption is considered as a status quo scenario. This scenario will be compared with a scenario where consumption of all animal products drops to 50% of the current levels, which is derived from a recent study on global potentials for agricultural production (Cassidy et al., 2013). We will only show the drop in land footprints related to this consumption change and not consider in the estimations, that this reduction will be replaced – at least partly – by plant-based proteins. The resulting land footprints will be shown in absolute terms and as a share of total land availability in the EU. Finally, an indicator of global land pressure will be presented in the case where the world adopts EU consumption levels of animal products.

Data sources and assumptions

Consumption of animal products includes beef, pork, poultry, other meat, eggs and dairy products. Current consumption figures are collected from the FAO agricultural database as domestic supply quantities in the commodity balance sheets for livestock primary product equivalents. Domestic supply of livestock products (in primary equivalents) include imports of animal products from abroad and exclude EU exports of animal products. As such, it represents the amount of animal products consumed domestically. The current consumption figures are calculated as the average of 2007-2009 figures.

It should be noted, however, that the consumption figures include product shares that are used for other (industrial) purposes – such as bones and blood or specific proteins – and wastes along the supply chain. These shares generally amount to 2-3% of meat products (household wastes not accounted for) and 10-15% of eggs and dairy products.

<u>Assumptions related to meat consumption:</u>

- Meat consumption figures in the 50% reduction scenario are equally distributed over the different animal products;
- A 50% reduction in consumption of animal products has not been replaced by alternative food products (e.g. fish, nuts, soy). The fact that EU consumption of animal products generally amounts to twice the

recommended amount justifies this assumption. In reality, however, a certain share of animal products is likely to be replaced by alternative food items (and embodied land). Depending on the type of meat that is being replaced, 10-30% of the achieved reduction will be compensated by substitution through plant-based proteins (see Table 1 above).

Feed requirements are calculated on the basis of average feed conversion ratios and the composition of feed rations. Feed rations are split up in grains, oilcakes, other feed crops, fodder (maize and grass silage) and grass. The raw data for the feed rations in the EU are based upon estimates for feed ingredients per type of animal in the study “The Protein Puzzle” (PBL, 2011). The rounded, aggregated amount for energy and protein feed crops from PBL are manually adapted to match the more detailed feed ingredient amounts in the primary equivalent commodity balance sheets of FAO (FAO statistical database).

The consumed amount of feed ingredients per animal category is then divided by the **produced amount of animal products** (also taken from the FAO statistical database) within the respective meat categories in order to calculate the feed conversion ratios (FCR) per type of animal (FCR: kg. of feed requirements to produce a kilogram of animal product). These calculated FCR’s are higher than the known FCR’s in the EU feed industry, partly because they include feed for maintaining the reproductive herd.

In the last step, the FCR’s are multiplied with the consumption figures for the different type of animal products, thus expressing the total amount of feed ingredients required to produce the amount of animal products for domestic EU consumption (including imported animal products).

<u>Assumptions related to feed calculations:</u>

- Available feed data are generally unreliable as a result of a significant share of non-market feed ingredients and a general lack of standardised feed industry estimates. For the purpose of this research, feed use calculations are based upon general, aggregated assumptions for feed rations per type of animal (source: feed industry experts, internet).
- Feed rations and FCR’s are assumed to be the same both for domestically produced and imported animal products, as it is the primary goal to calculate the footprint related to EU consumption of animal products (how much land – both absolute and relative to total EU agricultural land availability) is taken by animal production to supply EU consumption needs. In reality, feed rations outside the EU generally include more feed grains and less roughage.
- The alternative scenario of a 50% decline in consumption of animal products would be a future scenario and thus include an annual feed efficiency improvement over time (typically 1% per year in the past but slowing towards the future). The calculations in the 50% reduction scenario do not include feed efficiency improvements and may thus be considered conservative.

Land use requirements for feed crops are based upon the average EU crop yields as given by FAO (crop production statistics); the required feed ingredients (related to EU consumption levels) are divided by the respective yields to show the agricultural land involved with the total consumption of animal products in the EU. Roughage and grassland yields have been calculated on the basis of 2005 EU land use and feed consumption data in “The Protein Puzzle” (PBL, 2011).

Assumptions related to land use calculations:

- Oil meals (largely soybean meal) are allocated 100% of the land area as soybean production is largely driven by demand for animal feed (as a result of its high meal content). This means that vegetable oils (as a by-product) have been allocated zero land use in our calculations. This is not in line with reality – especially since a considerable share of e.g. rape and sunflower seeds are grown for oil purposes.
- Mineral supplements largely contain ingredients such as vitamins, minerals, which have been allocated zero land use.
- Roughage and grassland are calculated in wet yields. This is a rather unreliable method as dry matter contents differ considerably with local climate conditions and over the years. However, for the indicative purpose of this research it is considered an acceptable approach.
- The fact that EU average yields are considered for the calculation of land requirements, independently of the actual origin of the feed crops (i.e. domestically produced versus imported) delivers a rather conservative estimate for the land footprint, as EU yields are usually comparatively high.

Results

The global land footprints of EU animal products consumption have been calculated per type of animal product and differentiated to arable land and grassland (see Table 4). The majority share of land requirements is used for feed crop production (69.3 million hectares) and another 18.8 million hectares as grassland in the status quo scenario.

It is important to highlight that data on feed use are of poor quality as categories (compound feed, industrial feed, energy feed etc.) differ per source and both rations and non-market feed ingredients are not collected according to a standardised or recurrent procedure. Especially data on feed for dairy and beef cattle contain high uncertainties as ruminant feeds contain large amounts of on-farm feed ingredients, incl. wastes, and rations differ strongly between countries, climate regions and farms.

In total, milk production (and production of milk-based products such as cheese) requires the largest land area (28 mln. ha). It should be noted, however, that the footprint of milk production is based on intensive management systems (with relatively high shares of compound feed), whereas a more extensive system with lower grain levels and higher grass & roughage levels in the ration reduces the cropland footprint. Of arable land, pig meat requires the largest area, followed by dairy and beef. Both poultry and eggs have a relatively limited land footprint, as a result of their efficient feed conversion ratios.

The above implies that, in order to reduce land embodied in the consumption of animal products, a reduction in pig meat, dairy and beef consumption would render the largest benefits in relation to pressure on land resources. It should be noted, however, that ruminants and pigs are more flexible in their diets (and include more waste, by-products, local crops and, in the case of ruminants, grass) than poultry. Both poultry meat and eggs strongly depend on feed grains and soybean meal, and are thus least flexible in competition with food crops and (imported) protein ingredients. It should also be noted that animal products consumption in the EU is stagnating or even declining for most product categories, but that consumption of poultry meat is increasing.

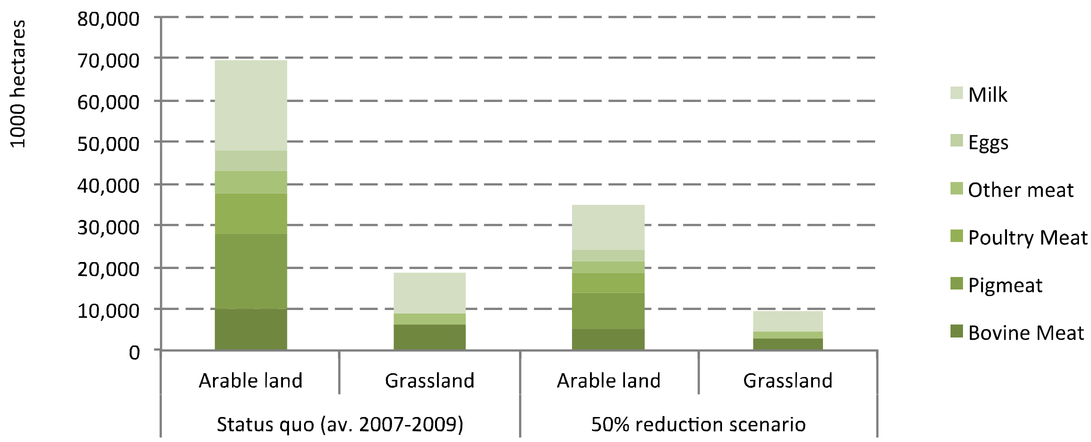
Table 5: Current EU Land footprints per type of animal product

	Status quo (av. 2007-2009)		50% reduction scenario	
Land Footprints (1000 hectares)	**Arable land**	**Grassland**	**Arable land**	**Grassland**
Bovine Meat	16,361	5,898	8,181	2,949
Pig meat	21,562	0	10,781	0
Poultry meat	7,786	0	3,893	0
Other meat	2,119	3,082	1,060	1,541
Eggs	3,329	0	1,664	0
Milk	18,126	9,851	9,063	4,925
Total	**69,284**	**18,831**	**34,642**	**9,341**

Source: SERI calculations based on FAO (2012) and PBL (2011)

Figure 7 shows the global land footprints related to EU animal products consumption for both the status quo and the 50% reduction scenario.

Figure 7: Global land footprints of EU animal products consumption in a status quo (left) and a 50% reduction scenario (right)



Source: SERI calculations based on FAO (2012) and PBL (2011)

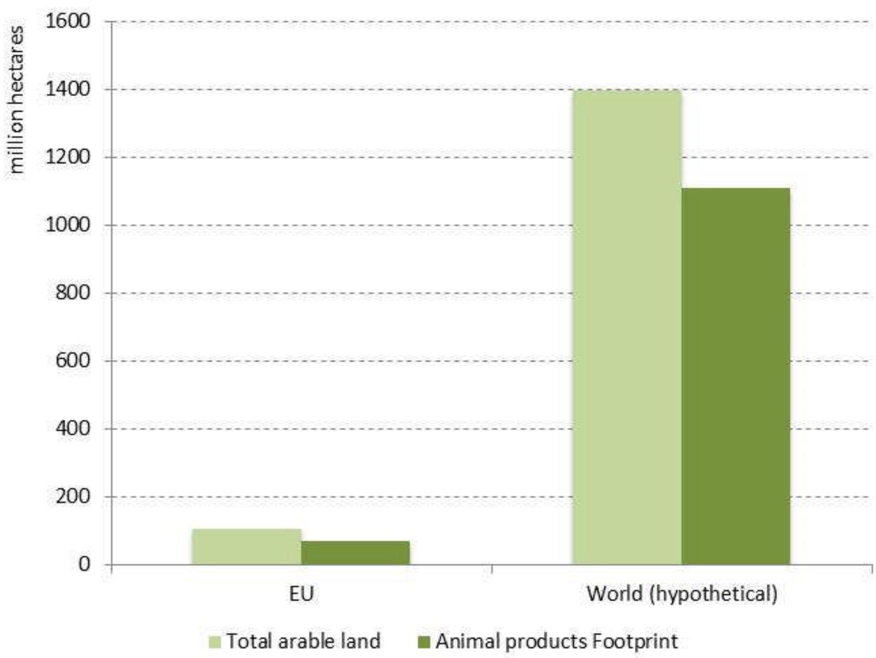
As a result of the assumptions, a 50% reduction in EU consumption of animal products will result in a 50% reduction in related land requirements, both for arable land (a reduction to 34,642 million hectares) and for grassland (a reduction to 9,416 million hectares).

More important than the absolute size of the land footprint related to EU consumption of animal products, is the share of this footprint in relation to the arable land availability in the EU. It can be used as an indicator for land pressure accompanying high animal protein diets in developed countries. As such, the indicator is applied to a situation where the global population adopts an EU animal products consumption pattern in order to indicate the land footprint and land pressure emerging from high animal protein diets.

Figure 8 shows the arable land footprint of the EU animal products consumption in relation to the available arable land resources. The percentage of arable land required to produce all feed ingredients to meet

EU demand for animal products amounts to 65% of total EU arable land use in 2011. In the hypothetical case that the high European levels of animal protein in diets would be adopted worldwide along with European production technologies and feed rations, the proportion of arable land globally used for feed production would even reach 80%. It has to be mentioned that in such a scenario grain prices would rise heavily, which in turn would impede further increase of meat production and demand, thus proving the scenario utterly unrealistic.

Figure 8: Land footprint of animal products in relation to total arable land in 2011



Source: FAO Database (total arable land), SERI calculations (footprint)

Apart from the fact that some aspects are theoretical (all feed ingredients produced domestically and the world adopting an EU diet) – the figure clearly indicates the high land pressure emerging from high animal products consumption levels and the resulting competition for land resources to supply food crops.

Last, but not least, the growing share of arable land dedicated to feed crop production and a relative shift from beef and pork towards poultry further supports the trend towards a limited number of monocultures (maize, wheat, soybeans) which is likely to have a broader impact on ecological systems and boundaries.

5. Conclusions

5.1. Main messages from the literature review

A rapidly expanding body of scientific literature explores the relations between economic and social developments and their implications for land use and land footprints. In the literature review provided in this report, the main drivers for land use and land use change were analysed.

Economic income has been identified as the single most important driver as with rising affluence, dietary patterns change significantly and in parallel with these changes demand for bio-productive land areas. In poor countries, basic crops such as cereals make up more than 60% of the total food supply and only around 10% of the calories are based on animal products. As countries get richer, people consume more vegetables, fruit and animal proteins, the latter amount to around one third of the calories in rich countries. This change in diets has significant impacts on the land footprint of food consumption. One kilogram of meat can require more than 400 m² of land per year, whereas plant-based substitutes only appropriate 2 to 5 m². While industrialised countries continue to have very large land footprints related to food consumption, the rapidly rising middle class in emerging economies will put additional pressure on global land resources in the future.

While historically, population growth has been the most important factor for land use change, population growth today is less important as a driver for increasing land footprints in many world regions. An exemption are Sub-Saharan Africa and South Asia, where population growth in the coming decades is still expected to be high and where per capita calorie intake and levels of meat and dairy consumption are still far below the level of industrialised countries. Population growth combined with more affluent diets will lead to expanded and intensified agricultural and forestry production and growing per capita land footprints.

5.2. Main messages from scenario calculations

In the context of this project, simple calculation spread sheets were developed, which allow estimating the order of magnitude of impacts on land footprints, if key variables determining Europe’s land footprint would change in the future.

The scenario calculations illustrated that a significant reduction of average per capita consumption of meat and other animal products would have a significant effect on reducing Europe’s land footprint. An estimated 50% reduction across all types of meat and animal products would reduce Europe’s arable land footprint for these products from currently around 70 million hectares for arable land to around 35 million hectares, and from 19 million hectares of grassland to 9 million hectares, with most reductions taking place in the land footprints related to the consumption of milk (and milk products) as well as pork and bovine meat. The share of arable land required to produce all animal feed to meet EU demand for animal products equals 65% of total arable land in Europe in 2011. In the hypothetical case that the EU’s high animal protein diet would be adopted worldwide, the exorbitant amount of 80% of the current global arable land resources would be required to feed the livestock.

5.3. Availability of land footprint data and further research need

The land footprint indicator, also termed actual land demand, is a concept, which is gaining growing importance in the research and policy debates on sustainable resource use. Data on the land footprint of products, sectors and countries do already exist from various sources and the number of studies is quickly growing.

In order to be more widely accepted, the land footprint tools need to be more harmonised, as various calculation approaches deliver very different results which impede direct comparison and drawing robust policy conclusions. With regard to methodological variability, two major approaches for the examination of national land footprints can be identified: input-output analysis (top-down economic accounting) and coefficient approaches (bottom-up physical accounting). So far, there is no perfect method available yet for calculating land footprints. However, a combination of economic top-down and physical bottom-up information into a hybrid accounting model is considered to have the highest potential as this would allow combining the advantages of the two basic methods. Various projects on the national and European level are currently on-going, which aim at evaluating the strengths and weaknesses of the various methodologies currently available for calculating national land footprints and suggesting best-suited options to move forward.

Also regarding data availability, clear areas of improvement can be identified. Production data for agricultural products is generally good and data from FAO is relatively reliable and widely used in the scientific literature. However, data regarding the production of feed crops, especially non-market and grassland-based feed, and forestry products are far less reliable and still contain large uncertainties. It would be an important area for future improvements to consolidate the data in these categories. In order to comprehensively and correctly capture the most important supply chains of land-based products, processing steps need to be analysed in more detail, as available data are not sufficient or in some cases strongly divergent. Furthermore, data on artificial land, i.e. built-up land and land used for mining and other industrial activities is not yet available on the global level and can therefore not be adequately considered in land footprint calculations so far.

Finally, it shall be emphasised that the land footprint indicator only provides quantitative information on the land use related to the consumption level of a country. For assessing environmental impacts related to certain land footprints, additional information needs to be considered in the assessments, including information on agricultural management practices, ecosystem conditions and water availability.

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