

Research Report

# Food and land use. The influence of consumption patterns on the use of agricultural resources

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## Abstract

This paper assesses the relationship between food consumption patterns and the use of agricultural land. First, it calculates the amount of land needed to produce singular foods, and second, it assesses land requirements of food consumption patterns. The paper observes large differences among requirements for specific foods. Especially livestock products, fats, and coffee have large land requirements. The consumption of specific foods can change rapidly over time, causing shifts in land requirements. A rise or fall of requirements, however, depends on the initial consumption pattern. Patterns based on animal foods shifting towards market foods containing more staples require less land. This dietary change direction was shown for Dene/Métis communities in Canada. Patterns based on staples shifting toward diets containing more livestock foods and beverages require more land. This change direction was observed in the Netherlands. Per capita land requirements differ among countries. In Europe, Portugal showed the smallest requirement (1814 m<sup>2</sup>), Denmark the largest (2479 m<sup>2</sup>). The Danish pressure was mainly caused by large consumption of beer, coffee, fats, pork, and butter. The trend toward food consumption associated with affluent life styles will bring with it a need for more land. This causes competition with other claims, such as infrastructural developments or ecological forms of agriculture.

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## Introduction

The World Food Summit of 1996 (FAO, 1996) reminded the world once again of the importance of food security and of the fact that the absolute number of food-insecure people is still growing. An adequately nourished population is essential for the absorption of cognitive and vocational skills, forming an important dimension of human capital (Schuh, 2000). Sufficient food of adequate quality available for all humans on this planet is a constraint for sustainable development (Annan, 2002). Four factors make food security an important issue for the coming decades: (i) the growth of the world population, (ii) changes in agriculture, (iii) a shift from local self sufficiency towards a global commodity market, and (iv) changes in food consumption

towards more affluent patterns. Especially in developing countries, the growth of the world population is large in the coming decades and requires enormous efforts from agriculture (Tilman, Cassman, Matson, Naylor, & Polasky, 2002). By 2050, the United Nations' medium projection estimates global population to be 50% larger than in 2003 (United Nations Population Division, 2002).

Up to now, changes in agriculture, the second factor, and especially the increase of production has been sufficient to meet the growth of demand (FAO, 2003). The Second World War marked a turning point in the yield per hectare of arable crops in the Western world. For example, prior to World War II, yields of wheat in the United Kingdom and the USA increased only by a few kg ha<sup>-1</sup> year<sup>-1</sup> (De Wit, 1992). Since then yields have increased consistently at much higher rates. This 'first green revolution' was due to a rapid increase in demand. In some countries, the physiological limits of yields are almost reached, however. A continuation of the increase in demand, therefore, implies huge challenges on the availability of land resources. In the coming decades, arable land expansion will be small (FAO, 2003). Moreover, continuing land degradation

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and the impact of environmental awareness of consumers put a strain on the ability to produce enough food (Bouma, Batjes, & Groot, 1998).

The third factor, the shift toward a world commodity market, not only implies a larger availability on a global level (Ivens et al., 1992), but also shifts in the specific availability of commodities. Over time, families in traditional societies have learned what will provide an adequate diet by methods of trial and error. In an economy that changes rapidly towards a global market, knowledge about nutrition forms an important constraint for food security (Schuh, 2000). Inuit peoples, for example, consume raw meat, and in this way solely provide for their ascorbic acid, an essential vitamin for humans (Receveur, Boulay, & Kuhnlein, 1997).

Food consumption patterns are repeated arrangements that can be observed in the consumption of food by a population group. They are linked to types and quantities of foods and their combinations into different dishes or meals. Tradition and religious rules are often important (Ivens et al., 1992; Whitney & Rolfes, 1999). Changes in food consumption patterns, the fourth factor, can be large and sometimes take place in a short period of time. In many countries since the 1960s, increasing affluence has often gone along with an increase of the consumption of opulent food like meat and alcoholic beverages (FAO, 2004). The four factors mentioned above all influence the amount of agricultural land required for food. This paper focuses on the fourth factor, assessing the influence of food consumption patterns on the use of agricultural land.

The production of food requires vast amounts of land. Of the global soil surface, 31% is suitable for growing crops, while an additional 33% is suitable for grassland (Penning de Vries, Van Keulen, & Rabbinge, 1995). Agricultural land, however, is becoming a scarce resource due to ongoing industrialization, urbanization, infrastructural development, land degradation and desertification (Oldeman, Hakkeling, & Sombroek, 1999). Several authors have shown the importance of consumption patterns on land requirements (Van Vuuren & Smeets, 2000; Wackernagel et al., 1997), while studies on food security have estimated that a shift from a vegetarian diet to an affluent diet with meat leads to a tripling of the land requirement (Bouma et al., 1998; Groot, Penning de Vries, & Uithol, 1998; Penning de Vries et al., 1995). In many developing countries, average food intakes are lower than requirements on the subsistence level (Azoulay, 1998). In these countries, rising incomes will increase food intakes and hence increase land requirements. This change direction has been shown for Benin, Bhutan and Costa Rica (Van Vuuren & Smeets, 2000). If consumption patterns in developing countries shift toward the affluent menus in western countries, related land requirements might rise substantially.

In an earlier study on land requirements relating to food consumption patterns, a method has been developed to calculate the amount of land required to produce specific

food items ( $\text{m}^2 \text{ year kg}^{-1}$ ) (Gerbens-Leenes, Nonhebel, & Ivens, 2002). In combination with data on household consumption ( $\text{kg year}^{-1}$ ), that study has calculated land requirements for the Dutch consumption pattern in 1990. It has shown that large differences in specific land requirements for individual foods exist, which cause large differences among land requirements for various food groups.

This study has defined food consumption patterns on three scale levels: (I) the basic level, providing nutritional energy, (II) the subsistence level, providing nutritional energy and nutrients, and (III) the cultural level, containing the actual food consumption patterns. The specific aim of the study reported here was to assess the extent of per capita land requirements for the different patterns of food on the three scale levels. It calculated the gap between land requirements for basic and subsistence levels on the one hand, and requirements for actual food consumption patterns on the other. In order to evaluate effects of changes in food patterns on land requirements, it also paid attention to inter-generational differences.

In general, existing studies on food security are based on comparison of food energy supply with dietary energy requirements. They have shown that future generations can be fed. However, these studies do not take into account foods that are low in nutrient density, which are important on a cultural scale level (e.g. coffee) or large quantities of specific foods. The present paper provides detailed information on specific land requirements and shows differences among consumption patterns. The results may contribute to the discussion on future agricultural requirements, in order not only to consider physical but also cultural requirements.

## Food systems

This paper divides food systems into two subsystems: (1) a production subsystem and (2) a consumption subsystem. Fig. 1 shows a simplified model of the factors that determine total land requirements for food. Total food consumption is determined by the size of the population and the amount and types of foods that are consumed, i.e. food consumption patterns. The subsystems are quite complex, however, and, moreover, often show a lack of transparency of physical streams.

The production subsystem comprises primary and secondary production, as well as the food industry. Primary production grows agricultural crops. Yields per hectare depend heavily on the type of system applied, leading to large variations with regard to yields. For example, average wheat yields in the Netherlands around 1900, when little fertilizer was used and cereals were grown in rotation with legumes, were about  $2.0 \text{ Mg ha}^{-1}$  (Spiertz, Van Heemst, & Van Keulen, 1992). In 1995 Dutch wheat yields have risen to  $8.7 \text{ Mg ha}^{-1}$  (FAO, 1999). Crops from the primary

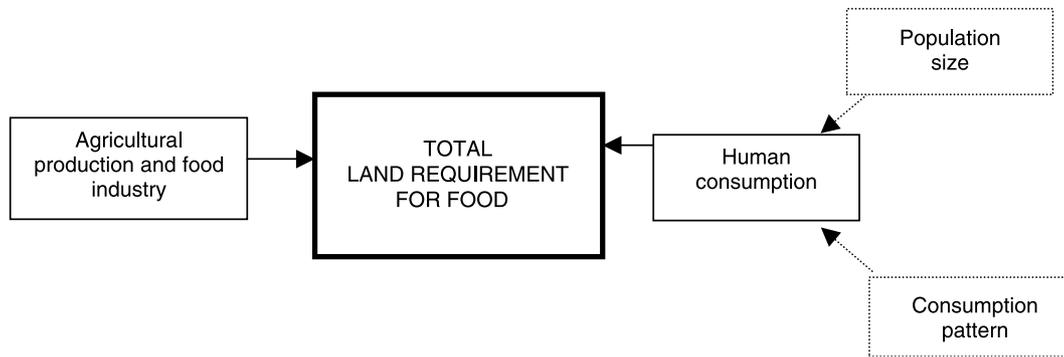


Fig. 1. Factors that determine the total land requirement for food.

production systems, such as soybeans, barley, or maize, form the basis for the secondary or livestock production.

The food industry processes commodities and manufactures an enormous variety of foods using a large number of ingredients. To make a cake, for example, basic ingredients such as sugar, flour, eggs and butter are needed, and these all have different land requirements. Therefore, land requirements for single food items can differ considerably.

### Food requirements

Food has several functions. A basic one is to provide enough energy for body functions and physical activity. To provide health, however, diets should also conform to nutritional constraints and provide sufficient amounts of vitamins and minerals. When cultural and emotional requirements are met, diets also contain foods that are low in nutrient density or provide more food than needed to stay alive. The actual food consumption patterns are of course to be found on the cultural level. Different food functions are related to different land requirements. Fig. 2 shows the three scale levels for the three food functions distinguished here (the basic, the subsistence and the cultural level), which will be briefly discussed below.

#### *Dietary requirements for the basic and subsistence level*

A basic function of food is to provide enough energy for body functions and physical activity. To provide sufficient nutritional energy, about 10 MJ per capita per day is needed (Voedingscentrum, 1998). This can be fulfilled with the consumption of about 327 kg of wheat per year. Calculations based on safe levels of food intake focus on this basic food function. Food security studies have assessed these levels from an agricultural point of view (e.g. Penning de Vries et al., 1995), in which diets were simplified. For the assessment of land requirements on the first level (the basic level), this paper adopts the food security methodology in which energy requirements were met by wheat consumption. This diet, however, can only be maintained for a short period of time because it lacks many essential nutrients.

Food requirements on the second level, the subsistence level, were based on a selected number of nutrient-dense foods such as milk products, meat and vegetables recommended by Dutch nutritionists (Voedingscentrum, 1998). It is optimal from a nutritional point of view and provides healthy body for the total life span.

#### *Food consumption patterns*

Food consumption patterns were defined as repeated arrangements observed in food consumption by a population group. They are embedded in types and quantities of foods and their combinations into different dishes or meals. Food consumption patterns depend on several factors such as personal preference, habit, availability, economy, convenience, social relations, ethnic heritage, religion, tradition, culture and nutritional requirements (Gerbens-Leenes et al., 2001). Until recently, consumption patterns were strongly influenced by the local availability of commodities, resulting in large regional and inter-generational differences (Jobse-Van Putten, 1995). During the 20th century, modern

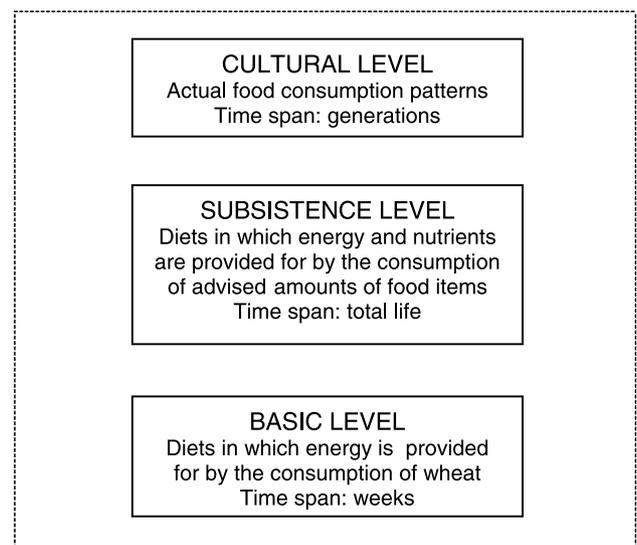


Fig. 2. Three scale levels for food requirements. Requirements for the basic and subsistence levels are hypothetical requirements, for the cultural level actual requirements.

transportation and food conservation techniques resulted in more varied consumption patterns. When health issues are taken into account and social and cultural functions of food have also to be fulfilled, a menu of wheat or a diet based on a selected number of nutrient-dense foods does not suffice. The actual food patterns are much more varied. Diets on the third scale level (the cultural level) contain foods that are low in nutrient-density such as coffee, cakes or chocolate. They also contain larger amounts of foods than diets on the subsistence level. Due to this cultural element, consumption patterns differ strongly among communities and generations. Even among affluent countries, such as the countries of the European Union, large differences exist in the consumption of specific foods (LEI/CBS, 1998; FAO, 1999). For example, in 1995, the consumption of coffee was 9.4 kg per capita in Sweden, whereas in Ireland only 1.8 kg was consumed.

## Data and methods

Total per capita land requirements for food are calculated by combining the specific land requirement per food item with the amounts consumed. Results of studies on land requirements relating to food consumption patterns are used as the basis for the calculations (Gerbens-Leenes, 1999; Gerbens-Leenes et al., 2001). In these studies, a method to calculate the land required for producing single food items has been developed and applied to the Dutch case in 1990.

Table 1  
Land requirements for foods with large consumption ( $\text{m}^2 \text{ year kg}^{-1}$ )

	Land requirement ( $\text{m}^2 \text{ year kg}^{-1}$ )
<i>Beverages</i>	
Beer	0.5
Wine	1.5
Coffee	15.8
Tea	35.2
<i>Fats</i>	
Vegetable oil	20.7
Margarine	21.5
Low fat spread	10.3
<i>Meat</i>	
Beef	20.9
Pork	8.9
Chicken filet	7.3
<i>Milk products and eggs</i>	
Whole milk	1.2
Semi-skimmed milk	0.9
Butter	13.8
Cheese	10.2
Eggs	3.5
<i>Cereals, sugar, potatoes, vegetables and fruits</i>	
Cereals	1.4
Sugar	1.2
Potatoes	0.2
Vegetables (average)	0.3
Fruits (average)	0.5

Source: Gerbens-Leenes (1999).

Table 2  
Recommended daily amounts of food items per adult per day

	Recommended daily amounts (g)
Bread	200
Potatoes	200
Vegetables	175
Fruits	200
Milk and milk products	375
Cheese	30
Meat (raw)	100
Meat products	23
Low fat spread	30
Margarine	15

Source: Dutch Nutritional Council (Voedingscentrum, 1998).

This has resulted in an overview of specific land requirements for over a hundred commodities and food items ( $\text{m}^2 \text{ year kg}^{-1}$ ). Table 1 shows some requirements for foods with large consumption.

Land requirements ( $\text{m}^2 \text{ capita}^{-1}$ ) for the three scale levels defined above were calculated by multiplying consumption ( $\text{kg capita}^{-1} \text{ year}^{-1}$ ) per food item by the specific land requirement for that item ( $\text{m}^2 \text{ year kg}^{-1}$ ) and summing the results. Data on consumption were obtained from various sources (Eurostat, 1993; FAO, 1999; Landbouw-Economisch Instituut and Centraal Bureau voor de Statistiek, 1981, 1986, 1996, 1998; Vereniging van Nederlandse Koffiebranders en Theepakkers, 1961, 1998).

At the basic level, energy requirements are met by the consumption of wheat. This menu only contains bread. For the calculation of land requirements, Dutch data on advised energy intake were used: 10 MJ per adult performing low physical activity per day. The assessment of land requirements on the subsistence level was based on Dutch recommended daily amounts of foods and energy intake. Data were obtained from the Dutch Nutritional Council (Voedingscentrum, 1998). Table 2 shows the recommended daily amounts.

At the cultural level, the study assessed land requirements related to various consumption patterns. These were the Dutch per capita requirements during the period 1950–1990 and requirements for 14 European countries in 1995 (Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain). Requirements were put into five categories: (1) beverages (beer, wine, coffee and tea); (2) fats (margarine, low fat spread, vegetable oil); (3) meat (beef and veal, pork, other meat, poultry); (4) dairy (full fat milk, semi-skimmed and skimmed milk, buttermilk, condensed milk, butter, cheese) and eggs; and (5) cereals, flour, sugar, potatoes, vegetables and fruits.

## Results and discussion

The per capita land requirement for food in the Netherlands calculated in this study was the actual requirement.

The other results were based on the same data set and must therefore be interpreted in a relative way. The study presented these results with a relative number, for which Dutch requirements in 1990 were set to 100. The number indicates the relative land requirement for the consumption pattern studied.

#### *Land requirements for the basic and subsistence levels*

Based on an average energy requirement of 10 MJ per capita per day and the consumption of wheat, the relative land requirement for the basic level was 23. If recommended daily amounts of foods advised by the Dutch Nutritional Council were consumed, the relative requirement rose to 67, three times larger than for the basic level.

#### *Consumption and related land requirements for the cultural level*

##### *Dutch food consumption and related land requirement in 1990*

Table 3 shows Dutch food consumption in 1990. Based on the Dutch production situation in 1990, the per capita land requirement in The Netherlands in that year was

Table 3  
Food consumption (kg per capita per year) in the Netherlands, 1950–1990

	Consumption (kg per capita per year)				
	1950	1960	1970	1980	1990
<i>Beverages</i>					
Beer	11	24	57	86	91
Wine	1	2	5	13	15
Coffee	1	4	6	7	8
Tea	1	1	1	1	1
<i>Fats</i>					
Margarine	17	20	18	13	10
Low fat spread	0	0	1	3	3
Vegetable oils	5	5	8	11	13
<i>Meat</i>					
Beef and veal	14	18	19	22	20
Pork	19	23	27	40	45
Other meat	2	2	3	3	3
Poultry	0	2	6	9	17
<i>Dairy and eggs</i>					
Full fat milk	188	127	107	60	42
Semi-skimmed milk	0	0	0	28	42
Skimmed milk	0	15	17	17	20
Buttermilk	16	14	11	10	11
Condensed milk	2	17	24	23	17
Butter	3	5	3	4	3
Cheese	5	8	9	14	15
Eggs	4	10	10	10	9
<i>Cereals, sugar, potatoes, vegetables and fruits</i>					
Flour	81	71	57	54	66
Sugar	35	42	46	42	37
Potatoes	129	100	85	83	87
Vegetables	66	67	81	60	63
Fruits	30	37	34	37	34
Citrus fruits	8	17	24	39	61

Source: CBS/CBS (1980, 1985, 1996).

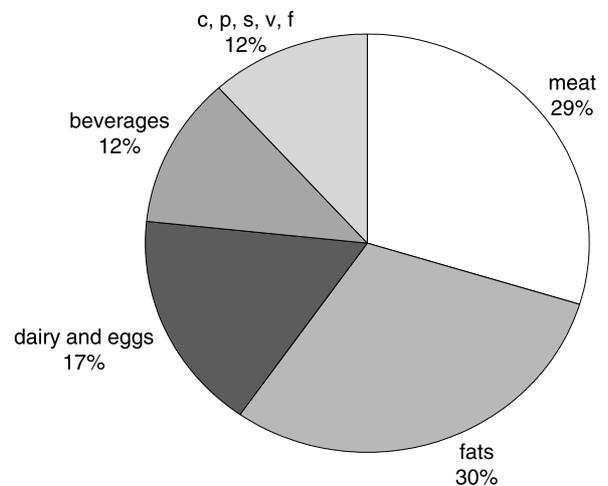


Fig. 3. Distribution of Dutch land requirements for five food categories: meat; fats; dairy and eggs; beverages; and cereals, potatoes, sugar, vegetables and fruits (c, p, s, v, f).

1909 m<sup>2</sup>. Fig. 3 shows land requirements per food category. The study found large differences among consumption categories. The categories of fats and meat showed the largest requirements: 576 m<sup>2</sup> (30% of the total) and 566 m<sup>2</sup> (30% of the total), respectively. About 323 m<sup>2</sup> was needed for dairy and eggs (17% of the total). The area needed for the category of beverages was 223 m<sup>2</sup> (12% of the total). The requirement for this category was heavily dominated by only one item: 60% of the area was needed for coffee. Although the consumption of basic foods (cereals, potatoes, sugar, vegetables and fruits) was a factor of four larger than for meat, the land required was only 222 m<sup>2</sup> (12% of the total). This was even less than the land needed for beverages.

#### *European food consumption patterns and related land requirements*

European food consumption patterns show large differences. For example, beer consumption varied by a factor of 6 between Ireland and Italy, while butter consumption varied by a factor of 16 between Denmark and Spain. These large differences in the consumption of specific foods result in large variations in the agricultural area required. Fig. 4 shows the relative land requirements for consumption patterns in Europe in 1995.

Relative land requirements based on European consumption patterns in 1995 vary between 95 and 130, a difference of 37%. Relatively, large requirements are to be found for Denmark and France with requirements of 130 and 118, respectively. The large requirement for Denmark is mainly caused by the large consumption of fats, coffee, pork, milk products and butter; for France by the large consumption of wine, meat and cheese. Medium requirements are found for countries with medium consumption of foods with large specific land requirements and a preference for foods with low requirements. Examples are Sweden (relative land

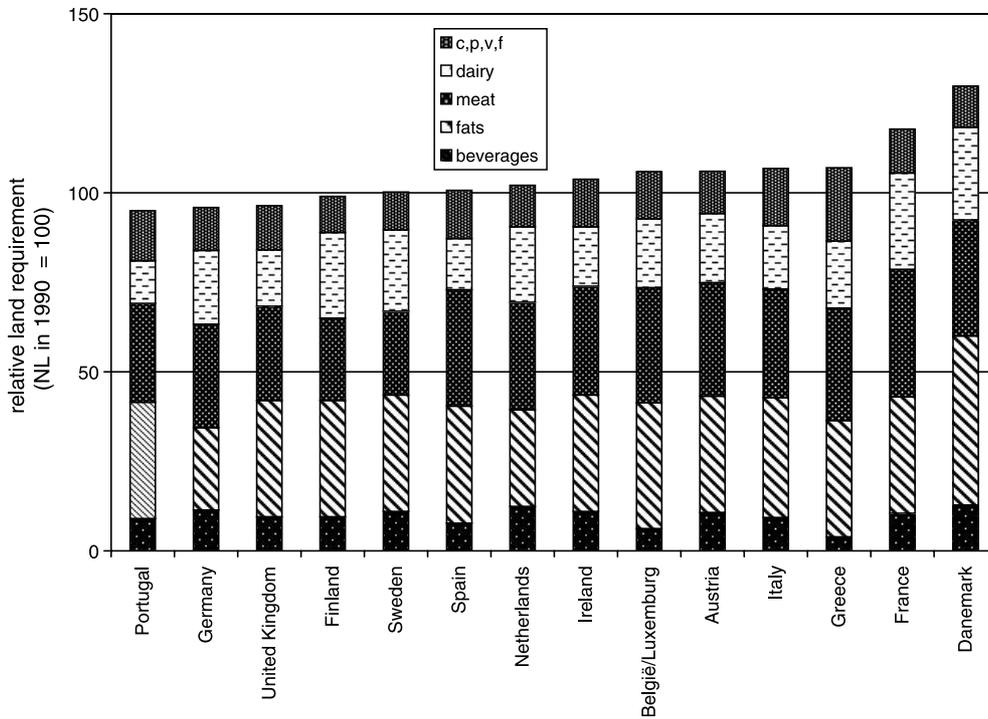


Fig. 4. Relative per capita land requirements for food divided over five consumption categories for 14 European countries (c, p, v, f: cereals, potatoes, sugar, vegetables and fruits).

requirement 100) and the Netherlands (relative land requirement 102). Relatively small land requirements are recorded for countries with small consumption for most of the categories. These are Portugal and Germany (relative requirements 95 and 96, respectively). Fig. 5 shows that the relative land requirements for the basic level and for the largest requirement for the cultural level vary between 23 and 130, a difference of a factor of 6. This is much more than the factor of 3 mentioned by Bouma et al. (1998), Groot et al. (1998), and Penning de Vries et al. (1995). In all European countries per capita land requirements were larger than requirements for the subsistence level.

*Development of Dutch food consumption and related land requirements during the period 1950–1990*

Table 3 shows Dutch food consumption between 1950 and 1990. Rising incomes favored more expensive foods, like meat, coffee and wine, while the consumption of cheap bulk foods, such as flour and potatoes, dropped. In the category of beverages, only tea consumption remained constant, while the consumption of coffee, beer and wine rose by a factor of 8–15. Total fat consumption remained constant. In the category of meat, consumption rose by a factor of 3, but shifts between types occurred within this category. In 1950, mostly beef and veal (40% of the total) and pork (54% of the total) were consumed. By 1990, the proportion of beef and veal had dropped to 24%, while pork consumption remained large (53% of the total). In 1950, consumption of poultry was negligible, but in 1990 this type formed 20% of total meat consumption. In the category of

dairy and eggs, milk consumption dropped by 36%, while cheese consumption tripled. A shift could be shown toward varieties of milk with lower fat content. Egg consumption rose by a factor of two and a half between 1950 and 1960, but then remained constant. In the category of cereals, sugar, potatoes, vegetables and fruits, potato consumption dropped by 33%, while consumption of citrus fruits rose more than a factor of 7.

Fig. 6 shows the changes of per capita land requirements for food between 1950 and 1990 as a result of changing consumption patterns (based on 1990 yields). Requirements increased rapidly from 72 to 100, 39% in 40 years. The rise

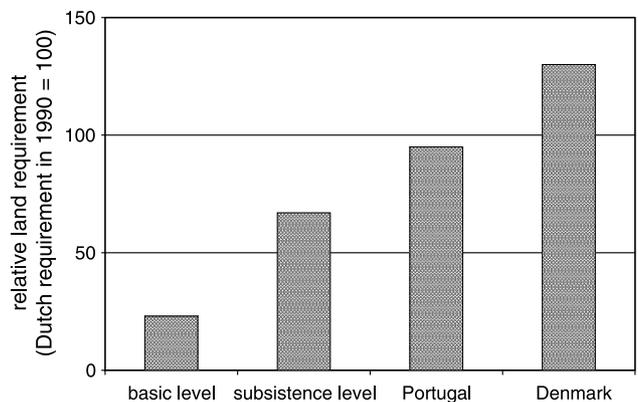


Fig. 5. Relative land requirements for two hypothetical food consumption patterns, the basic and subsistence level, and for two existing European patterns related to the smallest and largest land requirements (the Portuguese and the Danish).

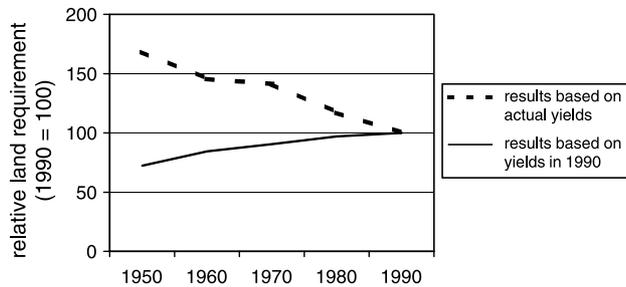


Fig. 6. Development of Dutch land requirements for food between 1950–1990. Calculations were made using yields in 1990 as input data. An indication of actual requirements is given by correcting these results for lower yields in the period considered.

was mainly due to an increase of the consumption of meat and beverages. During the period considered, however, increased production per hectare and larger import streams could satisfy larger demand and thus resulted in surpluses of certain commodities. Agricultural areas could even be taken out of production and were used for other purposes, leading to the general feeling that there is more than enough land. An indication of the development of actual land required for food in the Netherlands was calculated after a correction for the Dutch yield increases. This is also shown in Fig. 4. After this correction, requirements dropped from 168 in 1950 to 100 in 1990, implying that in The Netherlands agricultural production increases could keep up with larger demand. This study separated the different impacts of production and demand factors on the land requirements for food, so that the large influence of food consumption became evident.

Changes in food consumption patterns are related to changes in society such as increasing affluence. However, there seems to be a limit to the physical consumption of certain foods such as meat. Jobse-Van Putten (1995) has shown that Belgian and Dutch households belonging to the upper class consume less meat than lower-class households. However, considering the expenditure on food, the upper class prefers more expensive types of meat, such as veal and lamb, while the lower class buys the cheaper pork. A second example comes from Canada. In the Dene/Metis communities of indigenous peoples in the western Canadian Arctic, increasing affluence has caused a shift in traditional diets, mainly based on animal foods harvested from the local environment, to market foods containing more items of vegetable origin, such as sugar (Receveur et al., 1997). It can therefore be expected that if affluence increases further in western countries, meat consumption will stabilize but beverage consumption will probably rise accordingly, generating land claims.

In the near future, consumption patterns will form a very important variable for total land requirements on a global scale, especially dietary changes in direction towards the higher consumption of beverages, fats and foods of animal origin.

## Conclusions

The aim of this paper was to define the relationship between food consumption patterns and land requirements. Despite the physiological limit to food consumption, a difference of a factor of 6 was found between the land requirement for a hypothetical diet based on wheat and the requirement for an affluent diet based on existing consumption patterns. Even in Europe, large differences were observed between land requirements for existing food consumption patterns. These patterns can change rapidly over time, leading to other claims on the available land. In the Netherlands in the period 1950–1990, larger demand for more affluent foods such as cheese, beverages, fruits and meat led to a 40% rise of per capita land requirements.

The method described and the results presented in this paper have led to new insights with respect to the large impact of food consumption patterns on the use of natural resources. This knowledge can be a valuable contribution to research concerning land required to feed future generations.

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