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ANALYSIS

Consumption patterns and their effects on land required for food

P.W. Gerbens-Leenes *, S. Nonhebel

Center for Energy and Environmental Studies (IVEM), University of Groningen, Nijenborg 4, 9747 AG Groningen, The Netherlands

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Abstract

Vast amounts of land are required for the production of food, but the area suitable for growing crops is limited. In this paper, attention is paid to the relationship between food consumption patterns and agricultural land requirements. Land requirements per food item that were determined in a previous study are combined with data on the per capita food consumption of various food packages, varying from subsistence to affluent, leading to information on land requirements for food. Large differences could be shown in per capita food consumption and related land requirements, while food consumption, expenditure, and the physical consumption of specific foods change rapidly over time. A difference of a factor of two was found between the requirements for existing European food patterns, while the land requirement for a hypothetical diet based on wheat was six times less than that for an existing affluent diet with meat. It is argued that in the near future changes in consumption patterns rather than population growth will form the most important variable for total land requirements for food. Trends towards the consumption of foods associated with affluent lifestyles will bring with them a need for more land. Lifestyle changes, changes in consumer behavior on a household level, can be considered as powerful options to reduce the use of natural resources such as agricultural land.

Keywords: Food consumption pattern; Land requirement for food; Ecological footprint; International comparison; Agricultural productivity; Dietary change

1. Introduction

Suitable soil is a limited, necessary resource for the production of food. On a global scale, 31% of the soil surface can be used for arable crops, while an additional 33% is suitable for grassland (Penning de Vries et al., 1995). High quality arable land is becoming scarcer and scarcer due to ongoing industrialization, urbanization, infrastructural development, land degradation and desertification (Oldeman et al., 1999). Land requirements for food are, among other things, determined by population size and by the types and amounts of specific foods consumed, i.e. food consumption patterns.

* Corresponding author. Tel.: +31-50-3634611; fax: +31-50-3637168.

E-mail address: w.gerbens@fwn.rug.nl (P.W. Gerbens-Leenes).

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The discussion of world agricultural futures has usually been framed in a Malthusian context, with technological optimists opposing neo-Malthusian pessimists (Harris, 1996). The Second World War marked a turning point in the yield per hectare of arable crops in the Western world. For example, before World War II, yields of wheat in the United Kingdom and the USA increased only by a few kg ha^{-1} per year (De Wit, 1992). As a result of the first 'green revolution', yields have consistently increased at much higher rates. The continued increase in production per unit of land area and per unit of livestock has led to significant increases in agricultural productivity (Rabbinge and Van Latesteijn, 1992). Over the last decades, several studies on agricultural potentials have been published that come to the conclusion that modern agriculture can theoretically provide enough food to feed the world's growing population (Penning de Vries et al., 1995). Existing studies on food security indicate that future generations can be fed, while surpluses of certain commodities in the European Union give the general impression that more than enough agricultural land is available. The surplus could then be used for other purposes, such as the cultivation of energy crops, the development of new nature areas, ecological forms of agriculture, or infrastructural developments.

A basic food function is to provide enough energy and nutrients for body functions and physical activity, resulting in a large variety of menus that meet nutritional constraints. Calculations about food security have focused on these basic functions. However, once the physiological requirements are fulfilled, and economic resources are available, the social and cultural aspects of food become important, resulting in actual food consumption patterns that are much more varied than menus on the basic level. Increasing production can guarantee food security, but it does not guarantee a sufficient availability of all the foods needed to satisfy consumer demand because of the different functions of food.

With respect to food, a distinction can be made between physical consumption and consumption in the form of expenditure. It should be realized that there is a physiological limit to consumption. To provide energy for body functions, requirements are still in the same order of magnitude that they were in the Stone Age, which is about 10 MJ per capita per day (Voedingscentrum, 1998). Economic consumption, however, can rise almost infinitely. Many studies have shown that the overall composition of people's diets corresponds to their income (Von Braun, 1988; Vringer and Blok, 1995). In general, when standards of living are low, increasing incomes will favor more foods of animal origin, while the consumption of grains and carrots will drop (Grigg, 1994). Beyond basic constraints, rising incomes do not favor more food but rather more expensive foods, so that dietary shifts and not increasing physical consumption are responsible for changing claims on the available natural resources. In the Netherlands, for example, increasing affluence in society has resulted in a substantial rise in meat consumption over the last decades, with per capita consumption rising from 36 kg in 1950 to 90 kg in 1990 (LEI, 1978, 1993). Agricultural studies on food security (Penning de Vries et al., 1995; Bouma et al., 1998) have estimated that a shift from a vegetarian diet to an affluent diet with meat leads to a threefold increase in the land required. Results of a study on land requirements for food (Gerbens-Leenes et al., 2002) have indicated that the difference between an affluent diet and a vegetarian one could even be larger than the factor of three estimated by the authors mentioned above. However, affluent diets, such as the present diets in the countries of the European Union, not only imply the consumption of more or other types of meat, shifts occur in all food categories. The so-called non-meat changes in the menu (more oils, beverages, fruits, cheese, ice cream, cakes, and so on) seem to have a large impact on land requirements because, in general, more affluent foods require more land. For example, the land requirement (m^2 kg^{-1}) for beef, which is relatively expensive, is more than twice the requirement for pork (Gerbens-Leenes et al., 2002). The studies mentioned above indicate that dietary change rather than increasing physical consumption is responsible for larger claims on the available agricultural area.

Nowadays, per capita food consumption shows large differences between developed and developing countries. In the world's poorest countries, average food intakes are even too low to prevent malnutrition and hunger (Azoulay, 1998). Studies on food security indicate that agricultural production is capable of securing physiological requirements, but they also show that an affluent diet with meat can probably not be produced for the total world population (Penning de Vries et al., 1995). In the near future, the social and cultural aspects of food will therefore be of crucial importance for satisfying food demand on a global scale.

The specific aims of the study reported here are to examine quantitatively the range of per capita land requirements for food related to food packages that not only fulfil basic physiological needs, but also satisfy social and cultural demands. The study calculates inter-generational and regional differences in consumption, and identifies those parts of the food packages that have the largest claims on the required land area. The results are used to discuss future food security on a global scale.

The paper is organized as follows. First, it describes food consumption patterns and the factors that determine them. A distinction is made between menus fulfilling the basic functions of food and menus that also meet the needs of social and cultural demands. Next, the paper presents a method that combines available data on food consumption with data on specific land requirements for foods (Gerbens-Leenes et al., 2002). On the basis of this, it assesses the gap between land requirements for basic physiological food needs on the one hand, and land requirements for existing food consumption patterns on the other.

So far, when calculating land requirements, studies on food security have only considered differences in meat consumption. However, there are more foods requiring substantial amounts of agricultural land. Therefore, this study not only calculates the influence of meat on the land required, but also of complete food packages, including the effect of beverages. By assessing the resource costs of various food consumption options, this study makes a contribution to the current discussion on future land requirements.

2. Food consumption patterns

There is a link between food consumption and nutritional status. However, nutritional status is not a direct reflection of the intake of foods, but rather of the energy and nutrients provided by the foods (Ivens et al., 1992). The edible parts of both animal and vegetable foods consist of water, carbohydrates, lipids, proteins, vitamins and minerals. The first four are macronutrients; the last two are also referred to as micronutrients, as they occur in small quantities. A distinction can be made between types and amounts of foods needed to provide requirements for nutrients, e.g. vitamins and minerals, and amounts required to provide sufficient energy. The latter amounts depend on the physical activity engaged in by the person and are in many cases higher than the former quantities (Voedingscentrum, 1998).

To describe the food consumption of a group, one generally tries to discern basic regularities, referred to as food consumption patterns. Food consumption patterns are repeated arrangements that can be observed in the consumption of food by a population group (Ivens et al., 1992). It concerns the types and quantities of foods and their combinations into different dishes or meals. Food consumption patterns are not static, although it has been found difficult to change them (Ivens et al., 1992). Consumption patterns develop over the course of generations and can differ strongly between communities (Jobse-van Putten, 1995). They depend on several factors: e.g. personal preference, habit, availability, economy, convenience, ethnic heritage, religion, tradition, nutritional and cultural requirements (De Wijn and Weits, 1971; Ivens et al., 1992; Whitney and Rolfes, 1999; Van der Boom-Binkhorst et al., 1997; Vringer and Blok, 1995; Von Braun and Paulino, 1990; Musaiger, 1989; Wandel, 1988; Von Braun, 1988).

In general, foods are perishable. So until the introduction of modern transportation and food conservation techniques, such as freezing and cooling, only well-dried food items such as grains, coffee or dried fish could be traded (Jobse-van Putten, 1995). These foods were expensive, so until recently, people were strongly dependent on

the local availability of foods. The study of Jobse-van Putten (1995) showed that throughout European history, one of the most typical characteristics of food consumption patterns was the continuous alternation between scarcity and abundance. During the 20th century consumption patterns have shifted away from traditional food, mainly harvested from the local environment, towards a diet of market food. Gradually a more varied consumption pattern has developed (Landbouw-Economisch Instituut and Centraal Bureau voor de Statistiek, 1980, 1985, 1996).

3. Materials and methods

3.1. Starting points

In this paper food requirements were distinguished on three scale levels. These are shown in Fig. 1. On the first level, the *basic level*, energy requirements were met by the consumption of wheat. Studies on food security that compare food consumption and potential production express both in grain equivalents (GE) (Penning de Vries et al., 1995). In the consumption process, GE refer to the amount of cereals needed for the food consumed, plus the 'opportunity cost' to grow food that cannot be produced via grain. This diet will prevent starvation, but will cause malnutrition in the long run because many essential nutrients are lacking. Food requirements on the second level, the *subsistence level*, are optimal from a nutritional point of view. They are based on a selected number of nutrient-dense foods, providing bodily health for the total life span. Food requirements on the third scale level, the *cultural level*, form the actual consumption patterns. They also contain foods low in nutrient-density, for example coffee, cakes or chocolate, or higher amounts of foods than requirements on the subsistence level.

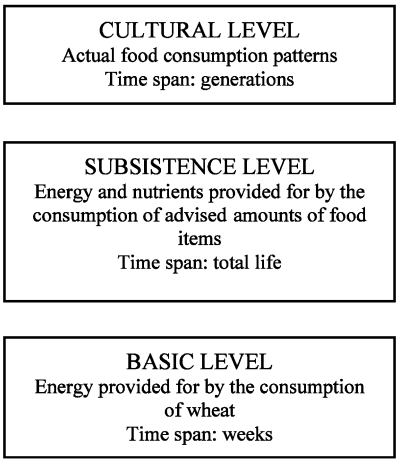

Fig. 1. Three scale levels for food requirements and related land requirements. Requirements for the basic and subsistence levels are hypothetical requirements; for the cultural level actual requirements. On the basic level, energy requirements are met by the consumption of wheat. It can only be maintained for a short period of time. Food requirements on the subsistence level are optimal from a nutritional point of view. They are based on a selected number of nutrient-dense foods, providing body health for the total life span. Food requirements on the cultural level form the actual consumption patterns and contain a broad variety of foods. They develop during generations.

The total land requirement for a certain type of food is determined by the specific land requirement for that type and by the amounts consumed. The results of a study on land requirements relating to food consumption patterns (Gerbens-Leenes, 1999; Gerbens-Leenes et al., 2002) were used as the basis for the calculations. In those studies, a method to determine land requirements relating to food consumption patterns has been developed. The method has been applied to the Dutch situation in 1990, resulting in an overview of specific land requirements for over a 100 commodities and food items (m^2 year kg^{-1}) available in the Netherlands, including imported foods such as coffee or soybeans that cannot be produced in western Europe. Land requirements (m^2 per capita) for the three scale levels defined above were calculated by multiplying consumption (kg per capita per year) per food item by the specific land requirement for that item (m^2 year kg^{-1}) and summing the results. Since calculations are based on data of the Dutch food production system in 1990, it is stressed that results obtained cannot be used to compare the various footprints of nations and are only valid to evaluate different consumption patterns. Therefore, when possible, results are presented in a relative manner.

Table 1
Specific land requirements per food item (m^2 year kg^{-1})

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

Source: Gerbens-Leenes (1999).

3.2. Land requirements for basic and subsistence consumption

On the basic level, energy requirements were met by the consumption of wheat. This menu only contained bread. For the calculation of related land requirements, Dutch data on advised energy intake were used: 10 MJ per adult performing low physical activity per day (Voedingscentrum, 1998). The assessment of land requirements on the subsistence level was based on Dutch recommended daily amounts of foods (these amounts are shown in Table 2). In order to comply with energy requirements and nutritional constraints (55% of the energy must be provided by carbohydrates, 35% by lipids and 10% by proteins) recommended amounts of foods were replenished by bulk food: wheat, potatoes, sugar and fats. Data were obtained from the Netherlands Nutritional Council (Voedingscentrum, 1998).

3.3. Land requirements for culturally defined consumption patterns

On the cultural level, various consumption patterns and related land requirements were assessed. This was done for the Netherlands during the period 1950–1990 and for 14 European countries and the United States in 1995. Food items 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*. Specific land requirements for these food items are shown in Table 1.

3.3.1. Inter-generational differences

Changes in Dutch food consumption during the period 1950–1990 were quantified and related land requirements assessed. Data on Dutch consumption were available for 27 consumption items. After World War II, the Netherlands Agricultural Economic Institute (LEI) and the Central Bureau for Statistics (CBS) started to publish

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

Food item	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: the Netherlands Nutritional Council (Voedingscentrum, 1998).

yearly data on per capita availability of foods in the Netherlands. Reliable information goes back as far as the year 1950. Earlier data were available—inventories started in 1933—but were not comparable to more recent data. The LEI/CBS data of 1980, 1985 and 1996 were used in order to calculate the influence of changing consumption patterns in the Netherlands. Data on Dutch coffee and tea consumption were obtained from the Netherlands Coffee and Tea Council (Vereniging van Nederlandse koffiebranders en theepakkers, 1998).

3.3.2. Regional differences

In order to assess regional variation of land requirements, calculations were done for consumption patterns of 14 European countries and of the United States. For Europe, calculations were based on the availability of 20 commodities in 1995. The 14 countries were the Netherlands, Belgium, Luxembourg, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Austria, Portugal, Finland and Great Britain. Data were obtained from various sources. Data on commodities came from the LEI/CBS (Landbouw-Economisch Instituut and Centraal Bureau voor de Statistiek, 1998), on coffee, tea, wine and beer consumption from the Food and Agricultural Organisation of the United Nations (FAO) (1999), information on fat consumption was derived from Eurostat (1993). To assess land requirements for the United States, data on food consumption were used as a basis for the calculations. These data derived from a consumer survey conducted by the U.S. Department of Agriculture (Agricultural Research Service, 1999).

However, calculations for Europe were based on the availability of foods, while for the United States data on consumption were used. There is a gap between available and consumed food caused by losses in the food chain, undereporting and non-food purposes (Gerbens-Leenes et al., 2001). In order to compare European and U.S. land requirements, a correction was made by calculating land requirements per recommended daily amount of energy. For the calculation, Dutch data on advised energy intake were used.

3.4. Presentation of results

Based on 1990 international data on food production, trade and consumption, the Dutch per capita land requirement for food was calculated in m^2, square meters that are actually committed to food production, in the Netherlands as well as in countries trading with the Netherlands. The other results were also based on Dutch 1990 data, and must therefore be interpreted in a relative way. Where possible, results are given as land units, with Dutch per capita requirements in 1990 set to 100 land units, indicating the relative land requirement for the consumption pattern studied.

4. Results

4.1. Land requirements for the basic and subsistence levels

Fig. 2 shows 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 land units. If recommended daily amounts of food advised by the Netherlands Nutritional Council was consumed, the relative requirement rose to 67 land units, three times more than the requirement for the basic level.

4.2. Consumption and related land requirements for the cultural level

4.2.1. Dutch inter-generational differences

Table 3 shows Dutch per capita food consumption between 1950 and 1990 and related energy intakes. In the category of beverages, the consumption of coffee, beer and wine has risen by a factor of eight to fifteen. Fat consumption has not changed much, with only shifts between specific foods occurring. In the category of meat, total per capita consumption has risen by a factor of three. Within this category, shifts between types have occurred. In 1950, mostly beef, veal and pork were consumed, while consumption of poultry was negligible. By 1990, consumption of beef and

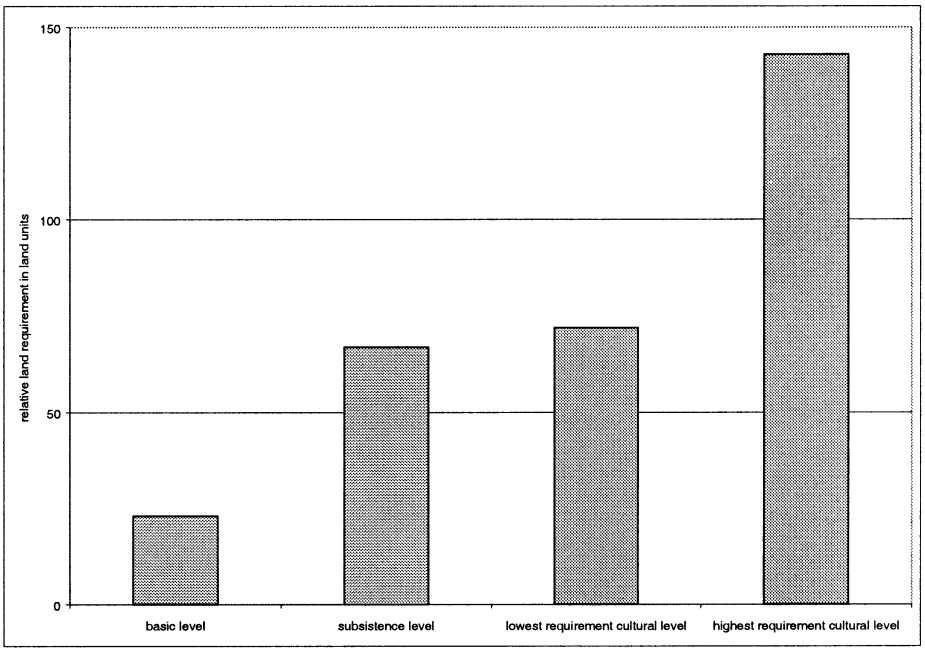

Fig. 2. Relative land requirements for the basic and the subsistence level, and actual relative land requirements for the cultural level. The latter requirements are based on existing food consumption patterns (see text for the explanation of land units).

veal dropped in favor of poultry, while pork consumption remained half of the total meat consumption. In the category of dairy and eggs, milk consumption dropped, while cheese consumption tripled. A shift towards milk varieties with lower fat content could be shown. 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 seven. Related energy intakes rose from 11.0 MJ per capita per day in 1950 to 15.2 MJ in 1980, but then dropped again to 12.7 MJ in 1990.

Fig. 3 shows that consumption changes had consequences for land requirements. Based on yields in 1990, Dutch land requirements for food rose from 72 land units in 1950 to 100 in 1990, an increase of 38%. Between 1950 and 1960, the rise was due to higher consumption of livestock products, fats and beverages. Between 1960 and 1990, the rise was mainly caused by higher consumption of meat and beverages, while the consumption of fats, dairy and eggs stabilized. The land requirement for the category of beverages tripled, mainly due to higher coffee consumption, which has a large specific land requirement, in combination with rising beer consumption. Between 1950 and 1960, the land requirement for the category of fats rose by 14%, but then remained stable. The land requirement for the category of meat only doubled, despite the threefold increase in the consumption. This relatively low rise was due to the shift from beef consumption, which has a relatively large specific land requirement, to poultry, which has a relatively small land requirement (see Table 1). In the category of dairy and eggs, the land requirement rose by 13% in the period 1950–1960 and then stabilized. Smaller milk consumption and a shift towards varieties with lower fat content and related smaller land requirements was compensated by higher cheese consumption, which has a large specific land requirement. The land requirement for the category of cereals, sugar, potatoes, vegetables and fruits remained the same. In 1950 the land requirement for foods from livestock production systems was 44% of the

total; in 1990 this contribution had risen to 47%, whereas the contribution of the category of beverages had risen from 4 to 12%.

4.2.2. Regional differences

Table 4 shows food consumption in the European Union in 1995. Large differences in the consumption of specific foods were apparent. In the category of beverages, beer consumption varied by a factor of six between Ireland and Italy, while the consumption of wine was highest in France and smallest in Ireland. Coffee consumption was highest in Sweden, five times the consumption of Ireland. Some countries had relatively high tea consumption, while in other countries, consumption was very low or zero. The consumption of fats varied by a factor of two between the country with the highest consumption and countries with a relatively small consumption. There was a variation of 62% between the highest

Table 3
Food consumption (kg per capita per year) and energy intake (MJ per capita per day) in the Netherlands during the period 1950–1990

Food item	Consumption (kg per capita per year)				
	1950	1960	1970	1980	1990
Beverages					
Beer	11	24	57	86	91
Wine	1	2	5	13	15
Coffee	1	4	6	7	8
Tea	1	1	1	1	1
Fats					
Margarine	17	20	18	13	10
Low fat spread	0	0	1	3	3
Vegetable oils	5	5	8	11	13
Meat					
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
Dairy and eggs					
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
Cereals, sugar, potatoes, vegetables and fruits					
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
Energy intake (MJ per capita per day)	11.0	11.7	11.7	15.2	12.7

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

Table 4
Per capita consumption in 1995 (kg per year) in 14 European countries, mean consumption and associated standard deviations

	Consumption category																		
	Beverages[a]				Fats[b]	Meat[c]				Dairy and eggs[c]					Cereals, potatoes, sugar, vegetables and fruits[c]					
	Beer	Wine	Coffee	Tea		Beef/veal	Pork	Other meat	Poultry	Eggs	Milk products	Condensed milk	Butter	Cheese	Cereals	Potatoes	Sugar	Vegetables	Fruits	Citrus fruits
Denmark	121.5	25.0	8.6	0.4	43.6	17.6	64.2	1.2	15.3	15.9	141.7	0.0	9.6	15.9	74.6	57.1	40.5	80.0[d]	49.0[d]	15.0[d]
France	34.5	63.2	5.2	0.2	[e]	28.1	35.9	5.3	22.6	16.0	101.6	0.7	8.3	23.3	76.2	58.5	33.3	124.0[d]	58.0[d]	24.0[d]
Greece	36.0	14.9	2.2	0.0	[e]	19.6	24.8	13.6	17.7	10.6	64.0	0.0	1.2	23.4	138.5	87.1	25.6	308.1	80.1	43.3
Italy	23.3	57.5	4.8	0.1	30.9	25.9	33.1	1.7	18.4	10.5	68.6	0.6	2.6	19.0	118.1	38.3	25.6	174.6	68.2	39.7
Austria	113.1	32.0	6.0	0.2	[e]	19.6	56.9	1.2	15.3	13.8	98.9	2.4	5.0	14.2	67.8	60.5	39.7	79.8	77.9	17.2
Belgium/ Luxembourg	109.1	21.0	2.0	0.1	32.5	21.2	46.6	2.1	23.1	14.5	83.1	2.1	5.9	14.2	72.7	94.1	42.4	99.5	68.7	32.3
Ireland	137.0	4.4	1.8	3.1	[e]	14.5	37.9	7.2	30.9	9.2	176.3	0.3	3.6	5.3	80.7	173.8	43.0	90.7	33.8	15.2
Netherlands	86.5	11.9	9.0	1.0	24.9	19.8	46.3	1.3	20.1	15.3	129.6	7.1	4.0	14.1	58.4	87.6	32.7	93.8	64.1	45.4
Spain	58.3	36.5	3.8	0.1	30.2	12.7	55.3	6.6	25.5	15.3	133.7	1.0	0.6	7.1	72.1	86.3	31.7	153.9	64.6	46.3
Sweden	66.0	12.4	9.4	0.3	[e]	18.2	36.1	0.7	7.9	12.0	150.7	1.2	5.5	15.6	65.6	57.7	40.3	98.9	41.6	1.2
Finland	88.3	5.6	7.8	0.2	[e]	19.1	32.2	0.5	8.8	11.8	199.7	0.0	5.4	13.5	69.2	56.9	33.3	76.9	30.5	15.5
Germany	131.1	23.4	7.1	0.2	21.2	16.6	55.0	1.1	13.4	13.8	91.1	5.4	7.2	18.4	75.1	72.9	32.0	86.2	64.7	29.0
Great Britain	102.0	11.4	2.2	2.3	30.0	17.5	23.1	6.0	25.1	10.1	131.2	2.5	3.3	7.8	81.6	101.3	36.8	99.4	39.5	17.3
Portugal	67.4	58.4	3.3	0.0	[e]	17.6	34.7	3.6	23.0	8.6	100.5	0.4	1.5	7.2	82.4	138.7	29.2	123.7	77.9	25.5
Mean consumption ± SD	83.9 ± 35.8	27.0 ± 19.3	5.2 ± 2.7	0.6 ± 0.9	30.0 ± 6.5	19.1 ± 3.9	41.6 ± 12.2	3.7 ± 3.6	19.1 ± 6.3	12.7 ± 2.5	119.3 ± 38.2	1.7 ± 2.1	4.6 ± 2.6	14.2 ± 5.6	80.9 ± 20.7	83.6 ± 34.9	34.7 ± 5.6	120.7 ± 58.9	58.5 ± 16.2	26.2 ± 13.2

[a] Source: FAO (1999).
[b] Source: Eurostat (1993).
[c] Source: LEI-DLO/CBS (1998).
[d] Data of 1992.
[e] For these countries no data were available, the mean of fat consumption in the EU (30 kg) is used.

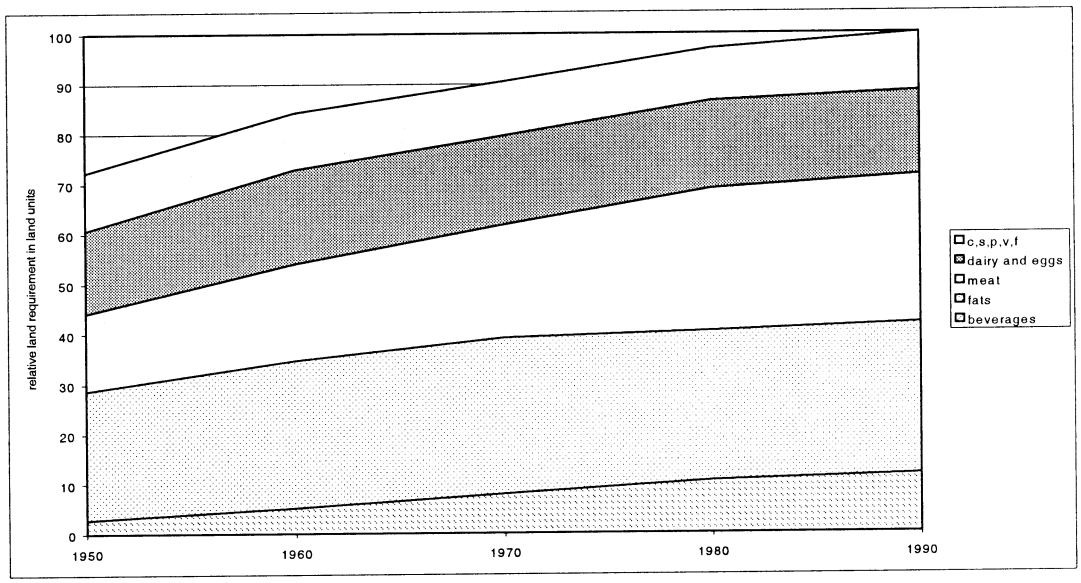

Fig. 3. The development of the relative per capita land requirement in the Netherlands during the period 1950–1990 based on 1990 yields for the five consumption categories: beverages; fats; meat; dairy and eggs; and cereals, sugar, potatoes, vegetables and fruits (c, s, p, v, f) (see text for the explanation of land units).

and the lowest levels of meat consumption. The Scandinavian countries and Ireland showed high consumption of milk products, while consumption in Italy and Greece was relatively small. Butter consumption varied by a factor of 16, cheese consumption by a factor of four and a half and cereal consumption by a factor of two. Some countries were high potato consumers (Ireland and Portugal), while consumption in countries such as Italy and Finland was low. Sugar consumption was high in Ireland, consumption of vegetables and fruits in Greece.

Table 5 shows the relative per capita land requirements per country, per capita energy intakes (MJ per year) and sums of the number of standard deviations per food item. These sums were divided into two categories: food items with specific land requirements above and below the mean (6.6 m^2 year kg^{-1}). The mean European relative land requirement for food was 105, but large differences occurred between individual countries. Portugal showed the lowest land requirement (95), while the requirement for Denmark was highest (130), 37% higher than the lowest value. Energy intakes were 28% higher in Denmark than in the country with the lowest intake, the Netherlands. However, high land requirements were not necessarily correlated with high energy intakes. For example, the land requirement for Greece was only 1% higher than for Belgium, while Greek energy intakes were 5% higher. Relatively large land requirements were mainly caused by high consumption of foods with large specific land requirements. Table 5 shows that most of these consumption patterns were characterized by positive sums of the number of standard deviations of foods showing requirements above the mean of 6.6 m^2 year kg^{-1} (e.g. Denmark and France). Medium land requirements were the result of medium consumption of foods with large specific land requirements, while foods with small land requirements were preferred (e.g. Ireland and the Netherlands). Relatively small land requirements were mainly found in countries with a relatively low consumption in all categories (e.g. Great Britain and Portugal). Sums of numbers of standard deviations were negative.

In three countries, France, Italy and Ireland, a correlation between beer and wine consumption occurred in which high consumption (mean + SD)

of one beverage correlated with small consumption (mean − SD) of the other. In Ireland and Great Britain, this effect was also observed for the high tea and low coffee consumption. A relationship between high consumption of milk products and low cheese consumption could be shown for Greece and Ireland. In the category of meat, high consumption of a specific type in combination with low consumption of another occurred in Greece, Ireland and Spain. Other correlations between the consumption of specific foods were not evident.

Fig. 2 shows hypothetical and estimates of actual land requirements. In order to make an estimate for the range of land requirements related to food consumption patterns, European patterns were used as the basis for the calculations. For the assessment, lowest and highest values for the five consumption categories considered were added. The lowest outcome was called the 'lowest cultural level', while the highest outcome was called the 'highest cultural level'.

Relative land requirements varied between 23 and 143, a difference of a factor of six. The estimate of relative land requirements based on European consumption patterns in 1995 varied between 72 and 143, a difference of a factor of two. All requirements based on existing patterns were larger than the requirement for the subsistence level.

4.2.3. Correction for energy intake

Fig. 4 shows relative land requirements per advised energy intake for the European countries and for the United States. Large differences were found between the European countries on the one hand, as well as between Europe and the United States on the other. European relative land requirements varied between 69 land units (Ireland) and 82 land units (France) per 10 MJ, a difference of 19%. The relative requirement for the United States was 100 land units per 10 MJ, 34% higher than for the European mean. This was mainly due to the high proportion needed for meat in the U.S.: 45% of the total. In Europe, the country with the largest requirement for meat (Spain) showed a proportion of only 32%. The second large difference related to U.S. and European

Table 5
Relative land requirements in land units for food consumption patterns in 14 European countries in 1995, related energy intakes (MJ per capita per year) and sums of number of standard deviations for foods with relatively large or small specific land requirements

Consumption pattern of	Relative land requirement in land units[a]	Energy intake (MJ per capita per year)	Sum of number of deviations per consumed food item	
			Land requirement >6.6 m^2 year kg^{-1}	Land requirement <6.6 m^2 year kg^{-1}
Denmark	130	5991	+4.3	+2.3
France	118	5241	+5.3	0.0
Greece	107	5607	+1.4	+0.5
Italy	107	5202	+0.5	+1.0
Austria	106	5104	−0.5	+2.8
Belgium/Luxembourg	106	5353	−0.8	+4.1
Ireland	104	5491	−0.7	+2.5
Netherlands	102	4672	0.0	+3.8
Spain	101	5028	−4.7	+4.7
Sweden	100	4698	+1.0	−7.0
Finland	99	4666	−0.1	−7.6
Germany	98	4851	−0.6	+1.7
Great Britain	96	4855	−0.6	−2.5
Portugal	95	5008	−4.3	+0.3

[a] See text for the explanation of land units.

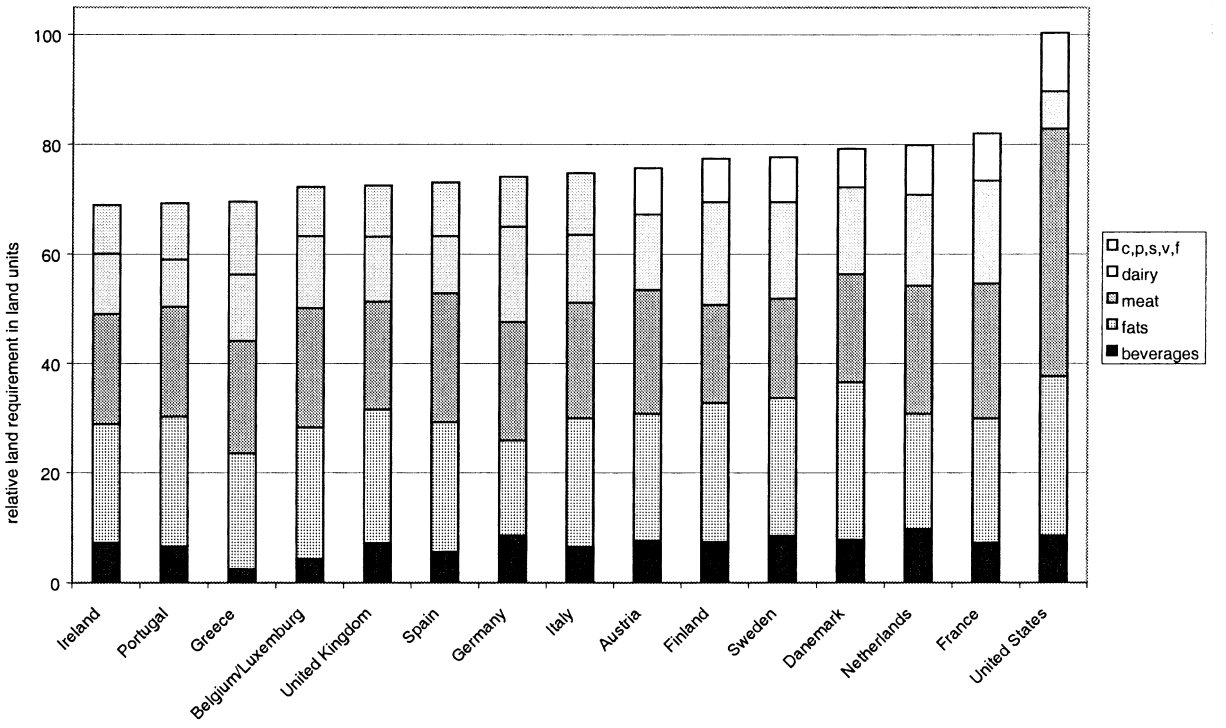

Fig. 4. Relative, per capita land requirements for food in 1995 based on an energy intake of 10 MJ per day, divided over five consumption categories for 14 European countries and for the United States (see text for the explanation of land units). c, p, s, v, f: cereals, potatoes, sugar, vegetables and fruits.

consumption patterns was the relative low requirement for dairy in the U.S., only 7% of the total. In Europe, the country where dairy consumption was lowest (Portugal) still showed a requirement that was almost twice as high as for the U.S.

5. Discussion

Cultural, non-physiological requirements claim a substantial part of the land area needed for food. Therefore, in western countries the influence of food consumption patterns on related land requirement is substantial, resulting in large regional as well as inter-generational differences. The physiological requirement is only 67 land units. In Europe in 1995, the non-physiological requirement varied between 28 land units for the Portugese consumption pattern and 63 land units for the Danish pattern, while in the Netherlands the non-physiological requirement rose from five land units in 1950 to 33 in 1990. In Europe regional and inter-generational differences are mainly caused by variation in the consumption of meat and different drinking habits. Affluence seems to be related to high fat consumption, claiming about one-third of the total agricultural area. For example, in the Netherlands after World War II, increasing incomes caused a rise in fat consumption due to higher consumption of affluent, fatty foods such as ice cream, cakes and high-fat junk foods. Severe negative health effects (De Wijn, 1968) were the reason that low-fat foods were developed so that total fat consumption did not rise further.

The attitude of agricultural scientists towards the issue of land requirements assumes that these requirements are mainly determined by the agricultural system applied, while food consumption

is simplified. Penning de Vries et al. (1995), Bouma et al. (1998) recognize only three diets, a vegetarian one, a moderate one and an affluent one with meat, the last requiring three times as much biomass as the first. This paper demonstrates that not only meat consumption, but also the consumption of fats and beverages require large agricultural land areas. Food security studies do not assess the influence of beverages on land requirements because they are not considered to be food. However, in Europe 10% of the total land requirements are needed for the production of only four beverages—beer, wine, coffee and tea. The amount of land needed for beverages is actually even greater because no data were available for the consumption of soft drinks and juices. Consumption of these beverages has risen in the past decades; Table 3 shows a large increase in the consumption of citrus fruits, a basic ingredient for juices, and a rise in the consumption of sugar, an ingredient for soft drinks. There are several reasons why requirements for beverages should be included in the calculations. The first reason is that the ingredients for beverages are produced in agricultural systems, hence they stake a claim on the same agricultural resources as foods. Sometimes even the same ingredients are used. For example, 28 kg of barley are required for the production of 100 l of beer (Kramer and Moll, 1995), while 400 kg of barley is needed for the production of 100 kg of pork (Nonhebel, 2001). In Great Britain, per capita consumption of beer is 100 l per year and of pork 23 kg, requiring 28 and 100 kg of barley, respectively. This example shows that the claim of beverages on agricultural resources cannot be ignored. The second reason is that, when compared to foods, the nutritional value of many beverages is low, implying that, in contrast to food, there is no clear physiological limit for beverage consumption. There seems to be a maximum to the physical consumption of certain foods such as meat, for example. Jobsevan Putten (1995) has shown that Belgian and Dutch households belonging to the upper cIasses consume less meat than lower-class households. However, if consumption is regarded as expenditure on food, the upper classes prefer more expensive types of meat, such as veal and lamb, while the lower classes buy 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 the direction towards the higher consumption of beverages, fats and foods of animal origin. In this respect, the differences between the U.S. and European food consumption patterns are large. If Europeans shift towards the American level of meat consumption patterns, land requirements will rise by 17%. On the other hand, if Americans adopt European dairy consumption, the U.S. land requirement for food will rise by 12%. On a global scale, it should be realized that a large part of the population is undernourished. Vitamin A deficiencies in particular, which can be solved by higher fat consumption, are a major problem (Whitney and Rolfes, 1999). The provision of enough quality food for the total world population on at least the subsistence level requires an increase in the agricultural production of certain commodities. In developing countries, rising incomes not only change food choice but also increase the total per capita food intake. This change in direction has been demonstrated for Benin, Bhutan and Costa Rica (Van Vuuren and Smeets, 2000). If consumption patterns in developing countries shift towards the affluent menus of western countries, related per capita land requirements will rise substantially. In these regions, two or even threefold increase in requirements, which is much greater than the influence of the growth in the world population, is certainly possible. Shifts towards more affluent diets will concur with other claims on the available land, such as infrastructural developments, ecological forms of

agriculture, biodiversity, energy crops or food production for the world market.

6. Conclusions

Rising claims on agricultural land resources are caused by an absolute increase in food demand in third world countries on the one hand, and by dietary shifts in developing as well as in developed countries on the other. In developing countries, requirements will first need to fulfill basic dietary needs, provided for by nutrient-rich foods such as fats, foods of animal origin, and fruits. Food security studies have shown that future generations can be fed in a way that meets nutritional constraints. However, it should be realized that the social and cultural requirements of food claim large parts of the available land resources. The social and cultural claims of food on land requirements are substantial and will possibly grow in the near future. The amounts of specific foods that form the basis of the consumption patterns can change rapidly. As has been shown for the Netherlands, dietary changes can take place in a relatively short period of time. In western countries, the increasing consumption of beverages, claiming the same agricultural areas as foods, is important.

In order to define future land requirements for food on a global scale, the social and cultural needs of food consumption patterns should be incorporated into the calculations. These requirements have a large impact and can change rapidly. Since it is not certain that yields will rise further in the future, the trends towards the consumption of foods associated with affluent life styles will bring with them a need for more land, since requirements are relatively large. This dietary change in direction is especially important for developing countries, where many people are still undernourished. The effects of changes in food consumption patterns on land requirements will be even greater than the growth in the world population. This effect might double the need for agricultural land.

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