

# Prospects for feeding the world and for rural landscapes

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## ABSTRACT

This paper discusses prospects for meeting world cereal demands up to the year 2020. Also considered are the issues of marginal lands, the persistence of large numbers of undernourished people, and some possible changes in rural landscapes. It is concluded that if R and D investment is maintained in agriculture, crop yields will grow fast enough for the world to continue improving per capita food consumption. Undernourishment will however only decline rapidly if there is, in addition, more targeted investment in infrastructure and institutions to alleviate rural poverty. Increasing food production in the world's favourable arable lands can be sustainable and can relieve the pressure on the remaining forests, woodlands, uplands and dry marginal areas by making arable cropping there unattractive financially. Again targeted investments will be needed to facilitate the shift out of arable annual cropping to perennial cropping, land stewardship, and nonfarm employment.

## KEY WORDS

Food security, cereal yield, crop area, yield progress, rural landscapes

## INTRODUCTION

Many have written recently on the subject of feeding the world, in particular Alexandratos (2), Evans (9), IFPRI (19, 21), Cassman (5) and Fresco (14), and I draw heavily on these sources. In the end however this is my view of what are the most important issues in this vast field. As I look at the food supply versus demand issue, I will concentrate on cereals, which comprise around 50% of all food calories of mankind (9), not including their growing indirect contribution through feeding of grains such as maize and sorghum to food animals. Starting with the big picture, I then pass to the issues of land degradation, marginal lands and the uneven distribution of food. Finally I would like to speculate about the future structure of world agriculture, particularly rural landscapes. Much of my focus will be on developing (dev'g) countries, but developed (dev'd) countries cannot be ignored.

## GLOBAL FOOD SECURITY

### The big picture

If we take, as did Cassman in his recent paper (5), real grain prices on the world market as a bell wether to reflect the balance between supply and demand, the world's grain consumers are doing well. Prices have been declining for over 100 years, and the last few decades or so have been no different, despite a few shocks in the 70s and 90s, and despite the dire predictions of Lester Brown and others. Grain availability per capita has increased in the last 30 years, and especially so in most dev'g countries. This has been the result of some crop area increase, often associated with cropping intensification due to irrigation, but mostly it is the consequence of yield increase. The latter in turn is the combination of improved varieties, more artificial fertiliser, and a greater proportion of crops being irrigated. It is impossible to be precise regarding the relative importance of these factors due to the positive interaction between all three. By way of illustration, the summary figures for progress since 1970 in developing Asia are impressive (Table 1).

**Table 1 Key statistics for population, food and income in developing Asia in 1970 and 1995; source Asian Development Bank (3)**

<b>Population</b>	<b>Food</b>		Cereal	Cereal	Cereal	<b>Income</b>
	<b>cons-</b>	-	production	area	yield	
million	<b>umption</b>		m t	m ha	t/ha	\$/cap/year

Kcal/cap/d						
1970	1750	2045	313	235	1.32	177
1995	2793	2537	650	247	2.63	512
% change	+60	+24	+107	+4	+100	+189

FAO have made detailed projections of food production to 2010 (2), but I will focus on projections to 2020 by IFPRI economists using their IMPACT model (19,21), which seeks prices which balance supply and demand according to appropriate elasticities. IFPRI suggests there will be continuing increased availability of cereals per capita, and further declines in real prices of grain, albeit at slower rates than in the past. **Table 2** shows the aggregate quantities for cereal demand and supply. Noteworthy is the lower population (7.5 billion) than would have been projected only a few years ago; this is the median United Nations projection of 1998, which also puts peak world population at no more than 10 billion late in the century. Cereal demand increases 54% in dev'g countries, comprising a 40% increase in the food component, and a 100 % increase in the feed component to reach 445 m t. Notwithstanding the large increase in their own production, there will be an almost doubling in dev'g country cereal imports. Nevertheless they will still be growing 88% of their cereal consumption. The former Soviet Union and eastern Europe (both considered dev'd) will emerge as net exporters. The numbers also disguise an increase in exports from some Latin American nations to other dev'g countries. Finally dev'g country meat consumption will double, and net imports will increase 8-fold, but will still only amount to 3% of consumption.

**Table 2. Developing (dev'g) and developed (dev'd) country population, and demand for and supply of cereals in 1995 and as projected for 2020 by the IMPACT model (IFPRI 1999).**

	1995			2020		
	Dev'g	Dev'd	World	Dev'g	Dev'd	World
Population (million)	4495	1172	5666	6285	1217	7502
Cereals						
Demand	1071	706	1776	1652	814	2466
Supply: Area (m ha)	440	252	692	470	258	728
Yield (t/ha)	2.2	3.2	2.6	3.1	3.9	3.3
Prodn. (m t)	965	812	1776	1460	1006	2466
Net Imports (m t)	+106	-106		+192	-192	

Detail of the sources of cereal growth to 2020 are contained in **Table 3**. Note that these are exponential growth rates. Cereal crop area growth rate drops away to almost nothing in the dev'd world, and only manages 0.4% p.a. in the dev'g world. Yield growth becomes an even bigger fraction of future production growth, but at rates which are noticeably less than the last decade or so. Maize demand in dev'g countries will grow at a greater rate (2.4% p.a.) than wheat and rice (1.6 and 1.2 % p.a., respectively) because of the rapidly rising demand for animal products all over the dev'g world. Earlier IFPRI publications (21) highlighted the high sensitivity of model outcomes on yield growth (and prices) to reduction in the investment in public agricultural research. Later (19,20) IFPRI emphasized the importance of investment in rural infrastructure and institutions, as well as research, if the yield projections are to be met.

**Table 3 Current production, and past and projected future rates (in bold) of cereal area and yield growth (% p.a.) in developing (dev'g) and developed (dev'd) countries, calculated from IFPRI projections (19,20) and FAO statistics (11)**

Cereals		Wheat		Rice		Maize	
Dev'g	Dev'd	Dev'g	Dev'd	Dev'g	Dev'd	Dev'g	Dev'd

Prodn. 1998 (m t)			290	299	550	13	281	223
Area growth, % p.a.								
1966-1982	1.0	0.2	1.5	-0.1	0.6	3.7	1.7	0.7
1982-1998	0.4	-0.4	0.4	-1.2	0.2	-1.2	1.0	0.3
<b>1995-2020</b>	<b>0.4</b>	<b>0.1</b>	<b>0.4</b>	<b>0</b>	<b>0.2</b>	<b>0.1</b>	<b>0.6</b>	<b>0.1</b>
Yield growth, % p.a.								
1996-1982	2.7	2.4	3.7	2.3	2.3	0.2	2.9	3.1
1982-1998	1.7	1.0	2.2	1.3	1.3	2.0	2.1	1.3
<b>1995-2020</b>	<b>1.3</b>	<b>0.8</b>	<b>1.5</b>	<b>0.8</b>	<b>1.2</b>	<b>0.8</b>	<b>1.3</b>	<b>0.8</b>

Evans (9) has an excellent discussion of all plausible means of meeting these growing future food demands, including reductions in post harvest losses and in grain fed to animals. Most debate, however, centres around the projected yield increases of Table 3, something Cassman (5) has considered in detail recently. He has closely watched maize yields in USA and rice yields at IRRI and sounds a note of caution. He points out that linear growth rates imply falling exponential rates, and that world maize yields are at 4.34 t/ha in 2000 according to the linear trend, the slope of which (60 kg/ha/yr) is only 1.4% p.a., and close to that projected in Table 2 until 2020. He argues that breeding progress for yield in rice at IRRI has been slower than claimed.

In discussion of future yield growth, I think it is useful to look both at likely movements in (i) **potential yield** and (ii) closing the so-called **yield gap**, the difference between on farm **attainable yield** and **actual yield**. Attainable yield can be considered as potential yield discounted, for example by 20%, for economic and other on-farm considerations. It is also useful to separate irrigated and well watered situations, where **potential yield** determined by radiation and temperature prevail (13), from rainfed regions where yields are inevitably cut due to lack of water, defined as **water-limited potential yield**.

Increases in genetic yield potential through new cultivars tend to be reflected in similar relative increases at the farm level. Some farm yields are already approaching attainable ones in favoured regions (e.g., Iowa, irrigated Yaqui Valley of Mexico, Indian Punjab, central Luzon), meaning actual farm yields are limited by potential yields. For both these reasons increase in yield potential is important. Little or no evidence was presented in a 1998 symposium on the subject that the growth rate in **genetic yield potential** of most crops is decreasing (6). In most crops rates are around 0.5 to 1.0% p.a, but from time to time there have been breakthroughs, like semidwarf wheat and rice, and hybrid rice and maize. Overall the power seems still to reside with the breeding, not to mention the role of agronomy in realizing genetic potential in favoured and water-limited environments. But breeding for yield is taking more resources (8), and will in the future need even greater input from allied disciplines such as physiology and molecular biology.

In many places there remains substantial scope for closing the yield gap, with actual yields less than one half of attainable ones (e.g., most of sub Saharan Africa). In the dev'g world this requires applied and adaptive agricultural research, and agricultural extension, posing many challenges to crop agronomists (e.g., site specific nutrient management, conservation tillage, crop rotation, etc.). But there must also be attention to rural infrastructure, institutions, and agricultural policy. Lately there has been a lot of attention to innovative technology transfer paradigms, many of which contain reference to farmer participation and to action research. None of these activities are sufficient in themselves, but taken together yield gap closing should result.

In conclusion, and not wanting to down play the critical role of maintaining real investment in agricultural R and D, as emphasized by the IFPRI sensitivity analyses (21), I believe that a 1.3% p.a. growth rate in cereal yields out to 2020 is well within the capability of dev'g countries. A rate of 0.8 % p.a. seems fine for dev'd countries, bearing in mind that some of the slow down in Table 3 in 1982-1998 has been due to the upheavals in the ex-USSR.

## Land degradation, irrigation and the big picture

The world's vegetated land is 8700 million ha, comprising forest and woodland (4000 m ha), permanent pasture (3200 m ha), and in 1997, arable crop land (1380 m ha) and permanent crop land (trees and shrubs, 131 m ha) (11,23). Scheer and Yadav (23) cite a 1992 study pointing to 38% of the world's arable crop land being degraded, having lost some or much productive capacity, principally due to water erosion, but nutrient loss and salinization are also important. The % degradation of crop land is greatest in Africa (65%) and Latin America (51%). They also cite estimates that the productivity depressing effect of the increasing degradation of cropped land globally amounted to a yield loss of about 0.4% p.a. over the last 45 years. But this is **temporary degradation**, and not loss of crop land area, such that the past yield gains referred to above in Table 3 are net of this loss, while likewise our forward projections may assume it will continue. And if it were slowed, or even reversed through more sustainable farming practices, then this would add to expected yield growth. Research points to many ways that the soil base of arable cropping could be improved.

More relevant to our discussion here is **severe degradation**, leading to permanent loss of cropland, essentially irreversible things like severe erosion, permanent salinization, exhaustion of non renewable water resources and loss of water to non-agricultural activities (to this we should also add cropland loss due to urbanization, but in Asia, where this is greatest, I estimate that it does not exceed 0.1% p.a.). How much crop land loss is occurring is not clear. If severe degradation was running at 5m ha p.a., a high estimate, it would amount to 0.3% p.a. loss of crop land. Recent estimates for China and India, where talk of land losses due to degradation and urbanization is most common, do not show net loss of arable areas (FAO 1999).

It should also be pointed out that although potential new arable land of reasonable quality is scarce in the dev'd world and Asia, several hundred million hectares do exist in sub Saharan Africa and South America (7). There, net crop area increases in excess of the 0.4% p.a. referenced in Table 3 seem quite possible. Remoteness appears to be a major economic constraint on the development of this new land; dev'd society may wish to impose other constraints, but it is unlikely the dev'g countries with favourable potential arable land would feel bound by this.

The % of crop land irrigated and the intensity of cropping (crop area p.a. relative to cropland or arable land) are two other important aspects of land management. In 1997, 268 m ha, or approximately 19% of all arable land, were irrigated, of which 218 m ha were in dev'g countries (11), an area which included 48% and 43% of their wheat and rice areas, respectively, and a significantly greater proportion of the production. Irrigation expansion in dev'd countries appears to have almost ceased. For dev'g countries, Alexandratos (2) estimated that irrigation area, after increasing at 2% p.a. between 1970 and 1990, will only increase at 0.8% p.a. from then until 2010, while cropping intensity on irrigated lands may also increase slightly, from 110% in 1990 to 124%. This excludes China, for which the national average in 1997 was claimed to be 154% across all arable land, meaning that much of the land carries two crops per year. Development of new irrigation is becoming more expensive and water is becoming scarcer. There is clamour about a water crisis, but demand management and better agronomy to increase irrigation efficiency, which is presently very low in most dev'g countries, and water recycling in industry, could prevent increasing non-agricultural demands for water from reducing crop irrigation for some time to come (22). Overall then, irrigated cropping should continue to contribute positively to the yield growth, but not to the extent seen in the last 30 years.

### **Marginal lands and the big picture**

Favoured crop lands (irrigated and moderate to high rainfall areas) have undoubtedly shown remarkable yield progress in the last three decades. It is commonly stated that the remaining crop lands, variously defined as less-favoured or marginal, have largely missed out on progress. Marginal lands usually suffer from insufficient rainfall (some lands are considered marginal for other reasons, like irreversible soil problems of shallowness, excessive slope or high acidity, but lack of water is by far the main cause). I will use the definition of CIMMYT (18) that a rainfed environment is marginal when the **water-limited potential yield** of a crop falls to less than 40% of its **potential yield**. For example by this definition much of the Australian wheat belt is marginal. There is growing pressure for more focus on marginal crop lands of dev'g countries (e.g., 14,16). Partly this is because such areas are commonly perceived to have the

greatest rural poverty and land degradation, while others see poorer progress to date, and hence greater scope for future progress through research. It is this last-mentioned issue which interests us here.

It is difficult to get a measure of the area and production of marginal crop lands. Much of the wheat of North America, Australia and eastern Russia is produced under marginal moisture conditions, but apart from this, most marginal crop land is in dev'g countries. CIMMYT (18) estimates for the mid 80s indicate that 36 % of the area and 18% of the production of dev'g country wheat is marginal. For rice, if marginal production is assumed to be all that rice which is not banded and fully flooded through irrigation or high rainfall, and if we take the latter to be half of the rainfed lowland area, we can estimate from IRRIs recent numbers that 32% of area, but only 15 % of production, is marginal. For maize in the mid 90s, CIMMYT estimated (17) 22% of the non-temperate area of 65 m ha, and 15% of its production, is marginal (there are however also 31 m ha of temperate maize in dev'g countries, and 43m ha in the rest of the world, most of which is definitely not marginal). Sorghum, millet, and barley are the marginal area cereals, and some 60% of their area and 40% of their production appears to come from marginal areas (2). However these crops only contributed 11% of total dev'g world's cereal production in 1998.

Overall it would appear that no more than 20% of world cereal production takes place in marginal lands, an amount relatively insignificant for the big picture. In addition, although there may be the impression that yield progress has been slower in such lands, especially in dev'g countries, there has been good progress in dev'd countries, as technologies spill over from more favoured areas and others are developed especially for dry areas. High yield potential wheat varieties are one example of spill over, while conservation tillage and chemical fallowing are examples of techniques targeting dry areas. The consequences are well illustrated by wheat yield change in Australia (13), a largely marginal production region (average crop ET of around 300mm). Wheat yield increase has averaged 1.0% p.a. since 1950 (4), and over 2 % p.a. in the last decade. Herbicides, more timely operations, improved varieties, reduced tillage techniques, and more recently, better crop rotations and greater use of nitrogen fertilizers are all implicated in this progress. Similar progress in wheat yields under dry conditions can be pointed to in dev'g countries like Turkey and Tunisia. In conclusion, although at first glance it might appear that marginal crop lands are a major constraint on future yield progress needed to feed the world, progress can be made if research and extension is focussed on the problem. Besides even if it isn't made at the rate anticipated in Table 3, the relatively small contribution to global production from the marginal lands means that the pressure on good lands is not greatly increased.

### Uneven distribution of food and targeted interventions

Many observers point with deep concern to the persistence of serious malnutrition in the world despite an apparently positive big picture of growing average per capita food production and a falling % of undernourished (e.g., 14). According to IFPRI there are currently 800m people, largely in dev'g countries, who do not have access to sufficient food to lead healthy, productive lives. Some 160m of these are children, more than one in every four in dev'g countries. The majority of these people are in rural areas. Their numbers are not projected to decline rapidly, unless special attention is paid to both **food access** as well as **food availability** for the undernourished, the former meaning that they have the livelihood to acquire adequate amounts and quality of food. Studies in India have shown that investment in rural roads through its effect on nonfarm rural employment has the biggest impact on rural poverty, followed by investment in agricultural research and development, and then investment in education, and finally in rural development (12). More recent work in China also supports investment in agricultural R and D, and in roads for greatest alleviation of poverty. These studies point out that many of these investment policies can be better targeted at the undernourished poor (e.g. land reform, market development for inputs and outputs, microcredit, womens education, nonfarm rural employment, research against micronutrient deficiencies, etc.). However targeting marginal areas referred to above may not necessarily be the most effective: at least one review of the situation failed to find a clear association between these and greater poverty (17). Still, wise targeting of substantial investments in the rural sector will be necessary if the absolute numbers of undernourished can be brought down to 300m by 2020, the goal of the recent World Food Summit.

It is an open question as to how much mainstream agricultural research and development should be focussed on the twin problems of abject rural poverty and malnutrition. Some pose it as a moral imperative for the public research sector such as the CGIAR and Government researchers (e.g., 14). Others justify it on the grounds that the private research sector will never be interested in poor farmers, many of whom are at subsistence levels, selling and purchasing little, whereas they may be interested in the relatively wealthy commercial small farmer sector of dev'g country agriculture. However until it is clear that the private sector can service the commercial farmer sector, it may be unwise to reduce the current level of public investment so directed, in order to better target the very poor sector, because it is clearly the commercial sector which largely feeds, and will continue to feed, the dev'g world. At the same time there are some research fields of likely benefit to all farmers (e.g., disease resistance breeding). There are also potential new technologies currently in the hands of the private sector which could be of great benefit to even the smallest farmers (e.g., varieties with stable insect resistance through genetic engineering).

### **Other issues and the big picture**

The last section hinted at one of the many other issues impinging on the big picture of research and development investment keeping the world ahead of the "population monster". I refer to ownership by the private sector of biotechnologies which may be important in meeting this challenge, and to uncertainties about their availability to dev'g countries and especially to poor farmers. Also threatening progress is uninformed negative comment on the potential benefits of genetically engineered cultivars to dev'g country agriculture. Again on the theme of intellectual property, we have growing uncertainties about the ownership of both unimproved and improved plant genetic resources: this could stifle the very beneficial and ready global exchange of germplasm which has characterized the last four decades of rapid breeding advances. Other issues include the clear decline in public sector agricultural research investment, which the IFPRI model predicts will have a notable depressing effect on productivity growth. Then, further out there are concerns about global climate change, global energy supplies, and the like. Space however doesn't permit discussion of all these important issues. Suffice to say that, like Evans (9), I am a cautious optimist, believing that mankind will find a way to beat these challenges, that agricultural research will be a necessary, but not by itself a sufficient, part of this struggle, and that arable agriculture will remain a dominant part of many, but not all, rural landscapes.

### **FUTURE RURAL LANDSCAPES**

It is towards the shape of future agricultural or rural landscapes that I would like to direct my final comments, for my cautious optimism about feeding the world suggests we should also start to think beyond that challenge. Rural landscapes can have components of social and cultural, as well as economic values. In addition to the agricultural (and forestry) crop land, for food, feed, fibre, and/or feed-stock, under both annual and perennial crops, there is natural vegetation and the wild life, and there is likely to be water bodies. There are also dwellings, villages and even towns with industry, and infrastructure such as transport, communications and power supply systems. The goods which this landscape can produce, in addition to the strictly agricultural ones, are clean water, a sink for CO<sub>2</sub> and perhaps urban waste, and space and an environment for non-agricultural production, for living, and for recreation. Finally people can have aesthetic perceptions about the landscape; its beauty, harmony, diversity, etc.; such views are however somewhat subjective.

### **Views from western Europe**

A recent visit to regions of favourable soils in northern Europe in the height of a bounteous summer brought this home to me. Ten tonne/ha winter wheat crops and 4 t/ha canola crops appeared amongst dense hedge rows, rich dairy pastures, wild-flower filled set-aside land, small patches of forest, ponds and streams, and prosperous-looking villages, some with obvious industrial activities. This was a most agreeable scene and, given the environmental regulations now in place, one which I suspect is quite sustainable biophysically. A recent analysis of the favoured cropping areas of south-eastern Scotland presents the same picture (15). How has this come about? There is no doubt that one factor was the large amounts of support injected into European agriculture by the old Common Agricultural Policy (CAP). But this support is changing, and the Agenda 2000 of the EU is giving much less direct support to

production (although the presence of sugar beet fields reminds one that the distortions have not gone yet), and much more to environmental services, and is backing this by fostering environmental regulation. Partly this has come about because of the low price of grain on the world market, for this makes production support too expensive. There is also the uniquely European reaction against modern high-input agriculture, spawned in a sense by the abuses of the CAP. But I believe that modern grain production can continue in the favoured areas, for with increase in the size of operating units (not necessarily farms), the very high potential yield and new technologies, they can be globally competitive and environmentally sustainable in all senses. Less favoured areas will be withdrawn from arable cropping and/or intensive grazing, and will return to perennial crops, parks, natural vegetation and wildlife. This is a vision of European agriculture that I can recall was advocated strongly by C.T. de Wit. The elevated sensitivity of the Europeans towards food quality (contamination with agricultural chemicals, GMOs, nutritional value) however remains an issue. Since this sensitivity is not very scientifically based, it would seem to contradict their enlightened approach to rural landscapes.

### **Grain fields of the New World**

Are there implications for the rest of the world in the rural landscape developments in western Europe? Let us start with the grain growing regions of relatively low population density in the New World. I refer to the vast plains of North America, the new crop lands of central-southern Brazil and of Argentina, and the wheat lands of Australia. These largely rainfed regions have for over 100 years been driving down the real cost of producing grain (not rice), and pressuring the European producers. It has come about through relatively cheap land, efficiency gains from the consolidation of operating size, technologies derived from agricultural research, and outstanding rural infrastructure and agricultural institutions. We are all aware of the protracted process of consolidation, or substitution of capital for labour, in the Australian agricultural landscape. Currently (1996-99) the average Australian grain farm is 1653 ha with 521 ha of grain crop harvested annually (1). Since 1920 at least, size seems to be growing at around 1.5% p.a., with farm population density falling at the same rate. This reduction in farm population density is surely a major cause of our rural decline. It has also happened in North America, and although there has been massive Government support in USA lately, ostensibly to prevent agricultural income decline, in none of these places has there been the level of recognition of the importance of “maintaining” the rural landscape as is found in Europe. Perhaps it is a consequence of the distances involved in these relatively people-sparse landscapes. Perhaps it is part of the New World culture.

The New World grain regions are facing the severest competition pressures, whereby the most efficient (tending to be the largest) do well enough, but the least efficient disappear, and whereby marginal lands have been and will continue to be simply abandoned if real prices continue to fall. Wheat farming has disappeared from the marginal hill lands of eastern USA. In Australia it has gone from some of the semiarid lands of southern Australia, although new tillage techniques have permitted recent expansions of the dry margin in the east, and have actually put the driest cropping parts of the Great Plains of North America on a sounder basis. Parts of Australia’s croplands may well be marginalized by rising salinity and abandoned over the next century. It is not at all clear to me when the process of consolidation will stop, or whether the still predominant family farm will be overtaken by the corporate grain farm. But if we consider the unwillingness of the nations involved to intervene in a targeted fashion, it seems we are destined to develop a landscape of vast fields, managed by remote sensors and robotic tractors, and producing the world’s least expensive grain. But these regions will be producing the grain which, in tomorrow’s global free market, will meet the import demands of the dev’g world, at very attractive prices to the consumer, and I would add, utilize modern cropping techniques which pose little threat to the agricultural resource base. There may be islands of population, with irrigated horticulture and intensive animal industries, and scattered national parks, but for the most part it will not be a rich or diverse scene to the common observer. Indeed it may be a monotonous and bleak rural landscape for many, with abandoned farmsteads and struggling small towns.

### **Food bowls of the developing world.**

Finally we turn to the prospects for rural landscapes in the dev’g world. I will concentrate on the important densely-populated food-producing regions of the dev’g world, often irrigated, usually having cropping intensities well over 100%, and in Asia inevitably growing rice. These include the great river

valleys, tropical highlands, and wet islands: IndoGangetic plains, the lower Yangste, Yellow River and Nile valleys, the central African and American highlands, Java, Taiwan, Sri Lanka, etc. The agricultural potential is higher than in Europe, due to available water and favourable temperature, but so is the population density: Egypt has around 1000/km<sup>2</sup> in the Nile valley, Java about the same, Bangladesh overall has 870, Taiwan 610, and Shandong and Henan Provinces in China, 580 and 560, respectively. In comparison, The Netherlands is the most densely populated European nation with 460/km<sup>2</sup>, while Germany has 235. Densities in dev'g countries are likely to increase 20-30% by 2020, whereas European numbers are fairly stable. Can Bangladesh, which has 58% of its population in agriculture, ever look like The Netherlands, with only 3.6% of the population engaged in a productive and sustainable agriculture, in a rural landscape of prosperous towns with space for land to be set aside for nature and recreation?

One and a half centuries of economic growth, driven by technological innovation, are behind the transition in Europe (The Netherlands had 60% of its population in agriculture around 1850). IFPRI (20) suggests that economic growth will be high in South and East Asia from now until 2020, averaging around 5% p.a.. Even so by 2020 per capita real incomes will have only reached 1/25<sup>th</sup> of dev'd world ones today. Nevertheless this growth, which amounts to a doubling of per capita income, must impact on the shape of agriculture. There will be higher real wages, and a rapidly growing demand for more diverse and higher value foods, especially fruit, vegetables, animal products, vegetable oil and even sugar. With globalization keeping staple grain prices steady (rice may be an exception), this will mean that farmers move towards the higher value crops, especially those which are more labour intensive. Where grain cropping persists, mechanization will grow steadily and the size of operating units will increase. These processes are already happening in South Asia and China. Mechanization is evident in the growing numbers of threshers, pumps, then tractors and finally harvesters, while the consolidation of operating units is coming about more through land renting as through land purchase. Curiously renting is also something evident in Europe: in both situations land prices far exceed that justified by its agricultural productivity. There will also be continued rapid urbanization, such that by 2020 IFPRI (19) predicts that 52% of the dev'g worlds population will be urban, up from 38% in 1995; rural populations will have almost stabilized. But given the huge pressure on arable land, some coming directly from the urbanization and economic growth itself, it is hard to see that there will be any land left over for natural vegetation or wild life. The only recreational lands will be city parks, sports grounds (including golf courses), and the odd peri-urban green belts. The only hope for forests, woodlands and rangelands will lie in the less densely populated lands: the remaining humid forests, the uplands and the dry marginal areas.

Just as in Europe, growth in wealth and agricultural productivity will permit the concentration of arable cropping on the best lands, freeing up other land for other purposes. This can happen and must be encouraged in the favoured densely-populated lands of the dev'g world. But whether dev'g countries have the means to keep population pressure down in the remaining less-densely populated lands, and to convert farmers in less favoured lands to perennial cropping and land stewardship is doubtful. Whatever happens, continued growth in agricultural productivity, especially in the good lands, is essential to save the relatively untouched environments, or permit eventual rehabilitation of damaged lands, as in civilization ravaged southern Europe. It has often been pointed out that if India had not experienced the crop yield growth of the last 35 years, to feed itself it would have had to plough up another 100m ha or one third of its total land area, including all its forest and woodland!

## CONCLUSION

With investment in agricultural research and development the world can feed itself. This will be facilitated by targeted investment in rural infrastructure and institutions, and by the more rapid elimination of the persistently high numbers of rural poor and undernourished. Increasing productivity of annual crops on the favourable arable lands of the world could make such cropping unattractive in the less favourable landscapes, and could eventually lead to a differentiation of landscapes according to their multiple functions, as appears to be happening already in western Europe.

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