BACKGROUND PAPER

FOR THE WORLD DEVELOPMENT REPORT 2008

Global Agricultural Performance: Past Trends and Future Prospects

Mette Wik[1], Prabhu Pingali[2], and Sumiter Broca

[1] Department of Economics and Resource Management, The Norwegian University of Life Sciences.
[2] Economics and Social Division, The Food and Agriculture Organization of the United Nations.

1 Introduction

Since 1960, the world population has more than doubled, from approximately 2.9 billion in 1960 to more than 6.7 billion today. The demands placed on global agricultural production arising out of population and income growth almost tripled. Global agriculture has been successful in meeting this increase in demand. Steady growth in agricultural output and a long-term decline in real commodity prices attest to this success. While the 820 million undernourished people in developing countries must not be forgotten, it should also be recognized that the proportion of people suffering from hunger has fallen by half since the 1960s, from more than on-in-three to one-in-six, even as world's population has doubled. Progress is possible.

Agricultural growth contributes directly to food security. It also supports poverty reduction. And it acts as an engine of overall economic growth in much of the developing world. The success of the agricultural sector has not been shared uniformly across regions and countries, however, and it is unclear whether this success can be sustained much less extended to those left behind. Many of the least developed countries, particularly in sub-Sahara Africa and in marginal production environments across the developing world, continue to experience low or stagnant agricultural productivity, rising food deficits, and high levels of hunger and poverty.

By 2050, world population is projected to grow to between 9 and 10 billion people. Most of the growth is expected to occur in poor developing countries, where income elasticity of demand for food continues to be high. The population increase, combined with moderately high income growth, could result in a more than 70 %[3] increase in demand for food and other agricultural products by 2050.

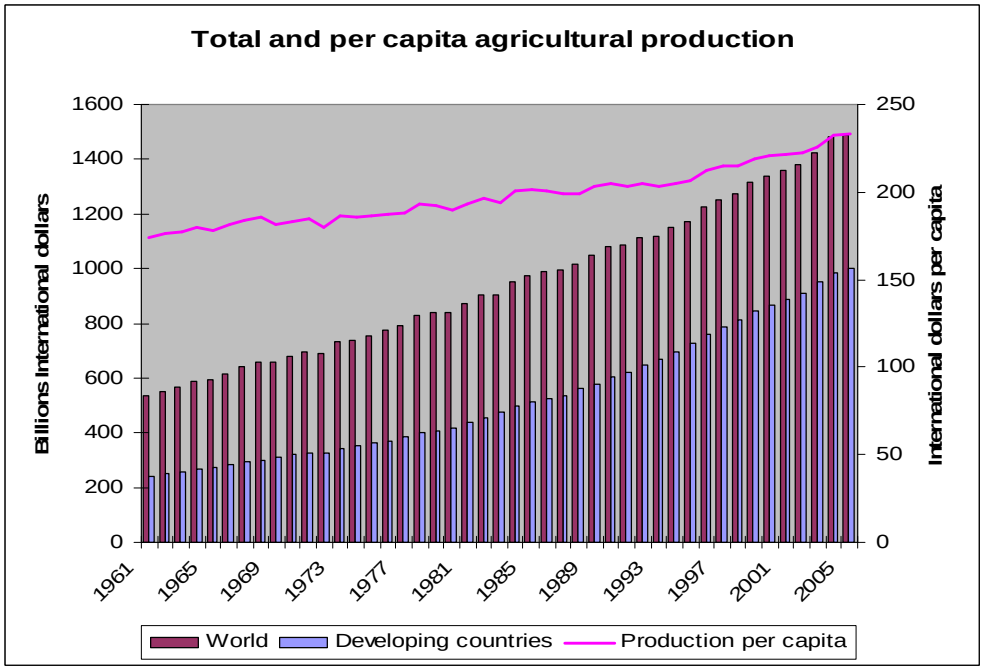
This paper attempts to answer the following questions: How did production of crops and livestock products evolve in the different regions over the past 45 years? In what way has increased supply of and demand for agricultural commodities affected terms of agricultural trade? What are the sources of agricultural growth? And what are the main challenges and opportunities for agricultural production in the future?

2 Increased agricultural production, driven by productivity growth in developing countries.

The value of total agricultural output (all food and non-food crop and livestock commodities) has almost trebled since 1961 (Figure 1), an average increase of 2.3 % per year, always keeping ahead of global population growth rates (1.7 % p.a.). Much of this growth originated in developing countries (3.4 – 3.8 percent p.a.). The high growth rates of the latter reflected, among other things, developments in some large countries, most importantly China. Without China, the rest of the developing countries grew at 2.8-3.0 percent p.a. These figures also reflect the rising share of high value commodities such as livestock products in the total value of production; in terms of quantities (whether measured in tons or calorie content), the growth rates have been lower (FAO, 2006 a).

[3] Based on growth figures on total agricultural demand from FAO 2006.

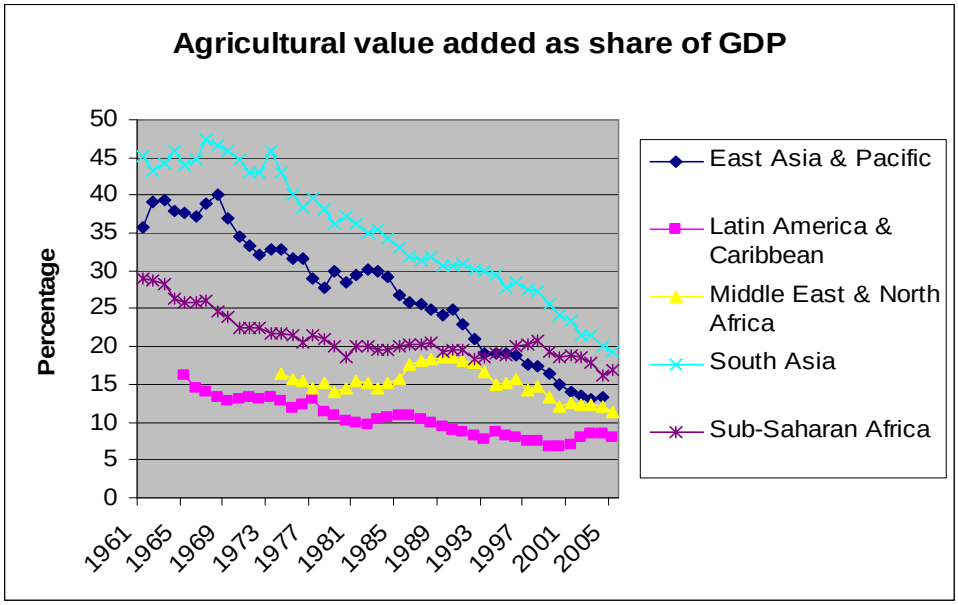
Figure 1. Total and per capita agricultural production.



Source: FAO, FAOSTAT

Globally, the share of agriculture in total GDP has fallen from 9 percent in the early 1970s to 4 percent in recent years (WDI 2006). This share is considerably higher in developing countries, but we see a falling trend even here (Figure 2).

Figure 2. Agricultural value added as share of GDP



Source: WDI 2006

The composition of agricultural production has changed considerably over the last 40 years as output of cereals, oil crops, sugar, horticulture, eggs and meat increased more than population growth rates since 1961, while production of pulses and roots

and tubers, crops that are important to the poor in many agriculture based countries, declined relative to total population.

Cereals production grew rapidly during the sixties and seventies, but has had a falling growth rate since then. Globally, the vegetable oil sector is the most rapidly expanding sector, fuelled by the growth of food and feed consumption and imports of the developing countries. Increasing demand for oil-crops for non-food uses is also a major factor for the optimism in the sector, as is the availability of ample expansion potential of land suitable for the major oil crops (FAO 2006 a).

In developing countries, egg and meat production grew even more rapidly than oil crops, and will probably continue to grow relatively more than population, due to the diversification of diets driven by rising incomes. Growth in the milk sector is expected to accelerate, mainly because of increased demand in developing countries.

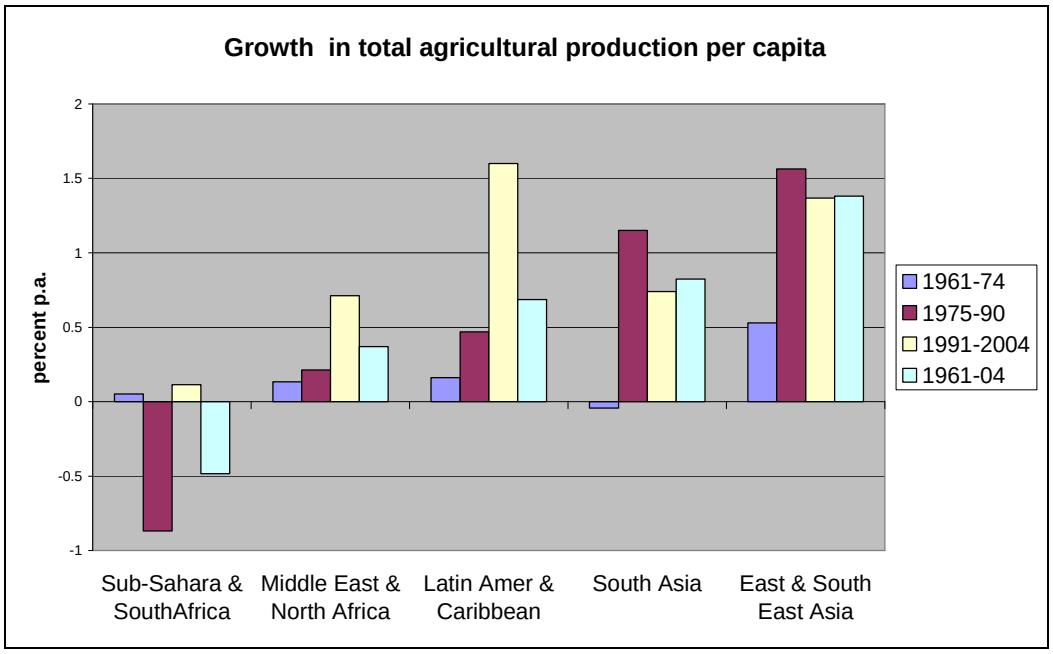
Sugar production growth has accelerated recently and it is expected that this sector will see continued growth in the future due to increased demand from developing countries (including China which has very low sugar-consumption per capita), and the potential for using sugar cane for production of biofuels (FAO 2006a).

2.1 Regional differences in performance, - Sub-Sahara Africa turning around?

Even though the value of total agricultural output per capita has had a yearly growth of 0.6 % p.a. since 1961, not all regions have followed the same trend. Sub-Saharan Africa remains the only region in which per capita agricultural output has not seen a sustained increase over the last four decades. Latin America and South Asia have had a small increase, while East Asia and the Pacific have increased agricultural production per capita by almost 80 percent over the last 45 years. We also find sharp contrasts not only between regions, but also between countries within regions (Figure 3) and even within countries[4].

[4] Such as the poor north-eastern states of Brazil vs. the richer south and central states. In India, for instance, yields of rice and wheat are more than twice as high in Punjab as in Bihar (Kumar 2006)

Figure 3. Growth rate in total agricultural production per capita in different regions.

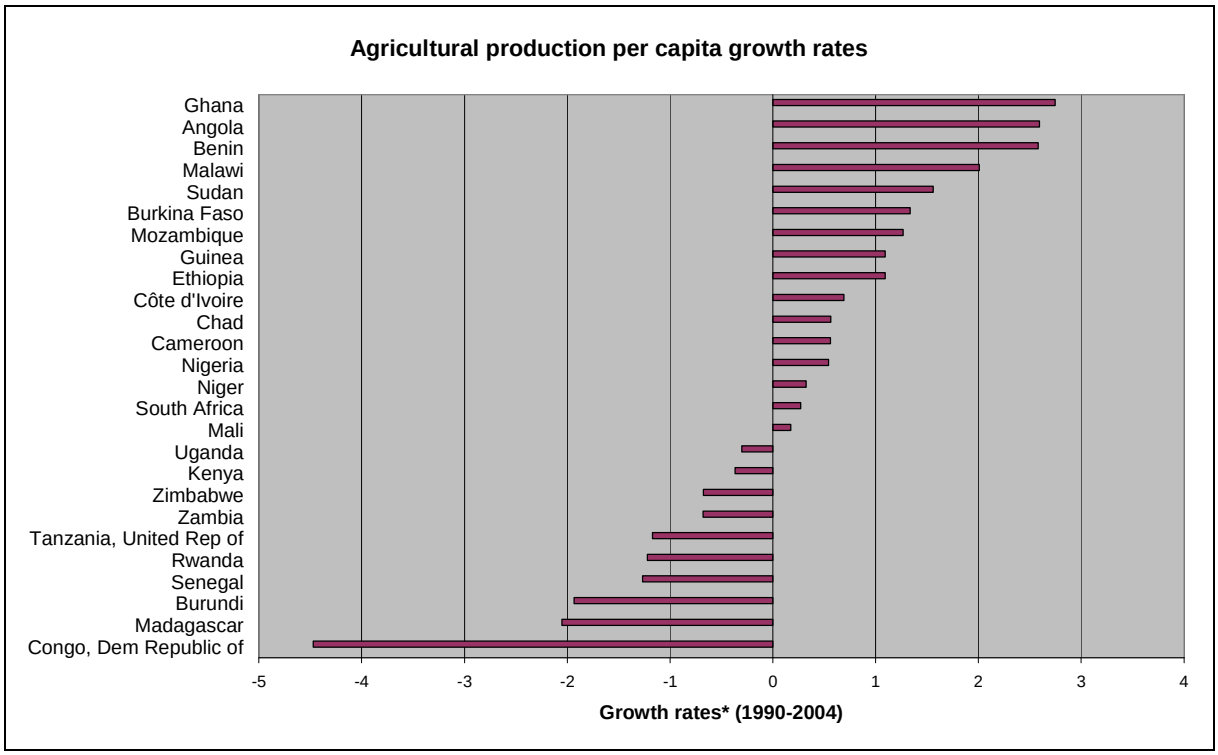


Source: FAO, FAOSTAT

The same trend is evident for food production per capita. All regions have kept up with population growth, except for sub-Saharan Africa where food production per capita has fallen over the last four decades. There is, however, some reason for optimism as both the total agricultural production growth rate and the food production growth rate have turned positive for Sub-Saharan Africa during the last 15 years.

Several African countries show a promising trend (Figure 4). Ghana, Angola, Benin and Malawi all had yearly per capita agricultural growth rates of 2 % or more over the last 15 years. Sudan, Burkina Faso, Mozambique, Guinea and Ethiopia had growth rates above 1%. In most of these countries growth in food production is the driving force behind the growth in total agricultural output, with food production per capita growth rates being at almost the same level or higher than agricultural growth rates. Only Burkina Faso, where cotton is an important cash crop, had a considerably lower food growth rate (0.8%). The African countries that performed well for per capita agricultural and food growth seemed to perform well in other economic sectors as well. All the countries with agricultural growth rates above one percent also had GDP growth rates between 1.2% and 4% (except for a 0.9% GDP growth rate in Angola).

Figure 4. Growth rate in agricultural production per capita in Africa, by country.



Source: FAO, FAOSTAT 2006.
* three year floating averages.

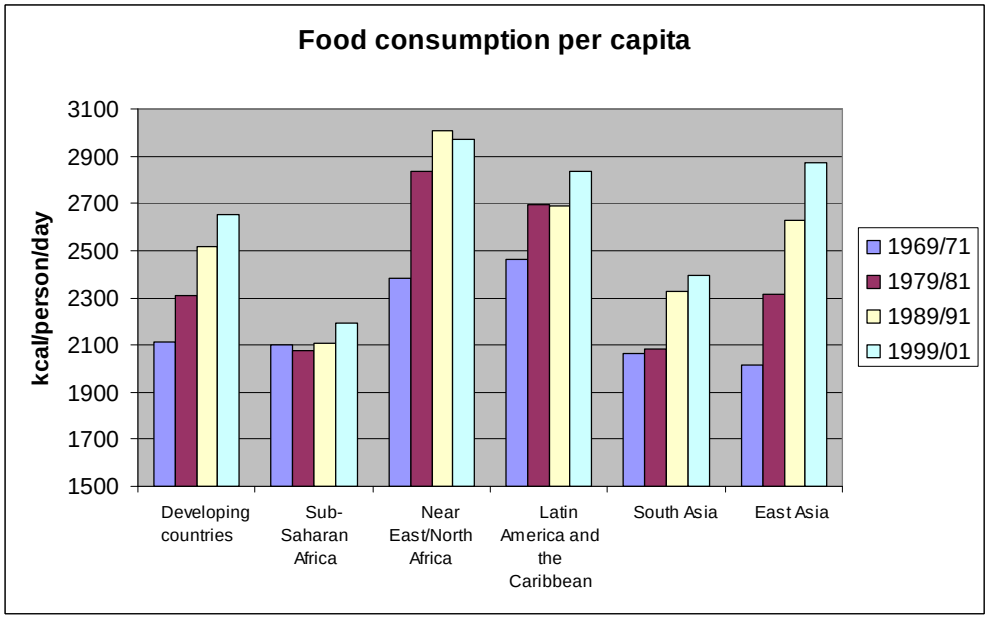
3 Increased food consumption

The world has made significant progress in raising food consumption per capita. It increased from an average of 2280 kcal/person/day in the early 1960s to 2800 kcal/person/day today (Figure 5). The gains in world average food consumption predominantly reflect those of developing countries, given that the industrial countries already had fairly high levels of per capita food consumption in the mid 1960s.

The overall progress of the developing countries has been decisively influenced by the significant gains made in East Asia. Increased production, but also a weaker link between production and consumption can explain this big increase in consumption. Global trade in food and feed crops has accelerated over the period (Galloway et al 2007).

Even in Sub-Saharan Africa, where food production and consumption are more closely linked than in the middle income countries in East Asia, consumption has seen a small increase even though per capita food production growth rates have been negative. This is due to increased food imports.

Figure 5. Food consumption per capita.



Source: FAO (2006a)

3.1 Diversification of food consumption in Asia and Latin America, status quo in Africa.

The growth in food consumption has been accompanied by significant structural change. Diets have shifted away from staples such as cereals, roots and tubers and pulses and towards more livestock products, vegetable oils and fruits and vegetables.

Income growth, relative price changes, urbanization and shifts in consumer preferences have altered dietary patterns in both the developed and developing countries. When people have more money to spend, they add more variety and more expensive and high-value foods to their diets.

But expenditures on foodstuffs and responses to improvements in income differ between developing and developed countries. In the latter, most consumers can already afford the foods they prefer. When their incomes rise, changes in their diets and food purchases are therefore relatively small.

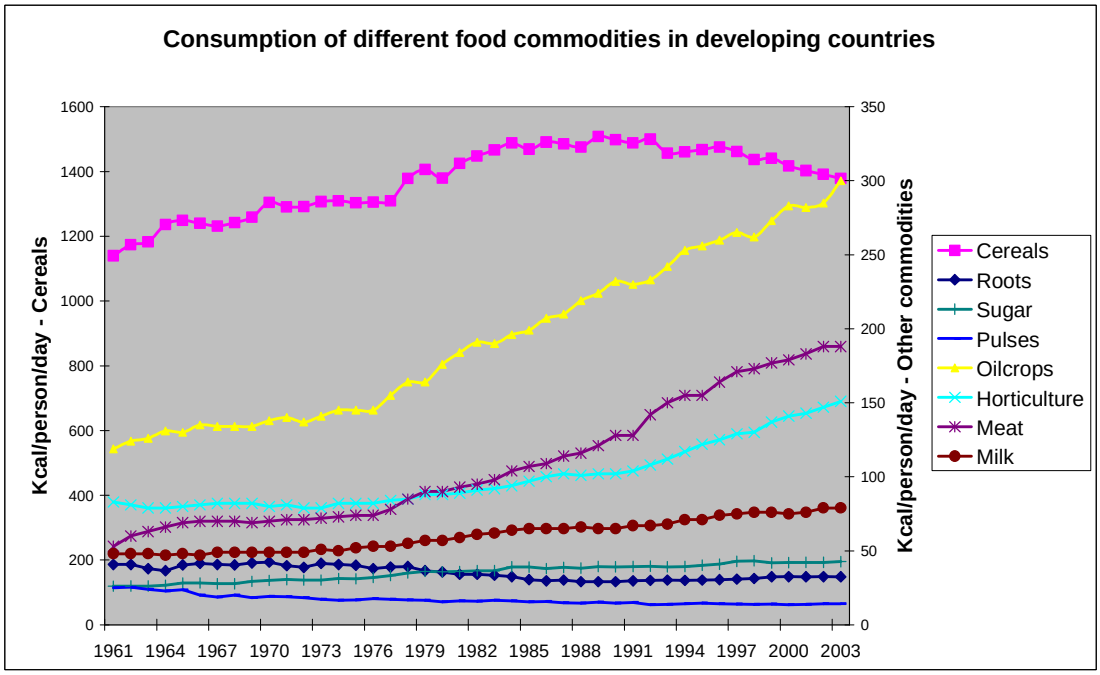
In developing countries on the other hand, rising incomes have an immediate and pronounced impact on diets, as people adjust their budgets to include higher-value food items (Figure 6). As wages increase, people are also willing to pay for more convenience, which frees up their time for income earning activities or leisure. They demand more processed foods with shorter preparation times. This is typically the case when more women participate in the labour market (Pingali, 2007 a; Popkin, 1999; Regmi and Dyck, 2001). Also, declining real food prices have allowed poor consumers access to improved diets at existing income levels.

Urbanization is another important factor influencing consumers' preferences. Urbanization is proceeding at a high pace, and urban dwellers are expected to outnumber rural populations by around 2007 (MEA 2005). Large urban markets create opportunities for establishment of large supermarket chains, and they attract

foreign investments and advertising from global corporations. Combined with trade liberalisation and declining transportation costs, non-traditional foods are becoming more accessible to urban populations (Pingali 2007 a).

Urban lifestyles often mean less time at home. As a consequence urban consumers eat more processed and convenience food. Bread, noodles and pasta are gaining popularity together with rice that is quick and simple to prepare compared to other cereals. Consumption of meat, fruits and vegetables is also increasing in urban populations (Regmi and Dyck 2001). Urban diets are found to be more diversified and contain more micronutrients and animal proteins, but with a considerably higher intake of refined carbohydrates and fats and lower intakes of fiber (MEA 2005, Popkin 2000).

Figure 6. Consumption of different food commodities in developing countries.



Source: FAOSTAT

While diets in Sub-Saharan Africa and Latin America have not changed considerably over the period, except for an increase in sugar consumption in Africa during the 1960s and 1970s, and a recent increase in meat consumption in Latin America, demand for high vale products is increasing rapidly in Asia due to rapid economic and income growth, urbanization and globalization. Asian diets are shifting away from staples and increasingly towards livestock products, fruits and vegetables, sugar and oils (Pingali 2007 a).

3.2 Food insecurity continues in many parts of the world.

The historical trend of increased food production and consumption per capita as a world average has resulted in a reduction of the *proportion*[5] of undernourished people

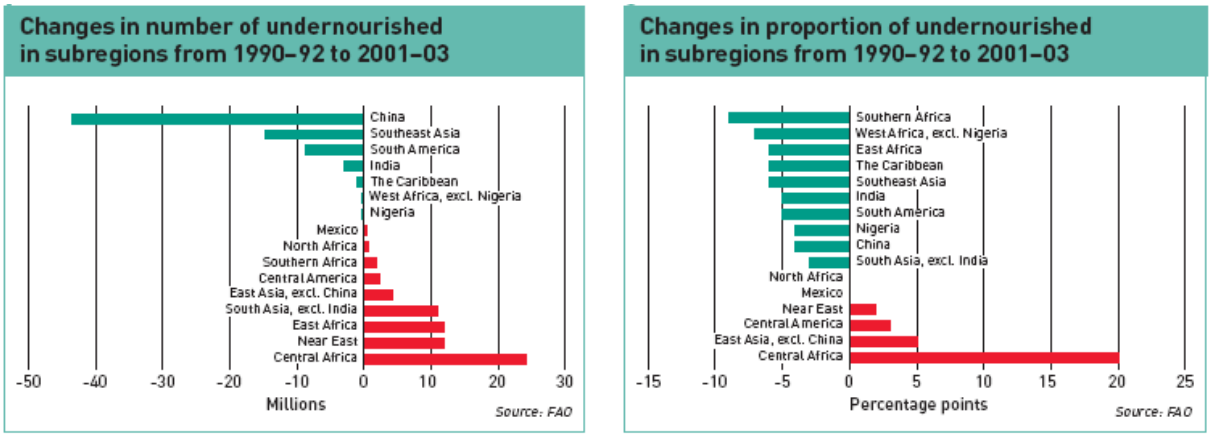
[5] One of the two targets of the first Millenium Development Goal is to halve, between 1990 and 2015, the proportion of people who suffer from hunger.

in the developing countries from 37 percent in 1969-71 to 17 percent in 2001-2003 (CFS 2001, FAO 2006c). Most of the reduction occurred in the first two decades of this period; indeed since the 1990-92 base period for the Millenium Development Goal, the proportion of undernourished has fallen only 3 percentage points. The number of undernourished declined from 960 million in 1969-71 to 820 million in 2001-2003, but almost the entire decline occurred before 1990-92 (CFS 2001, FAO 2006c).

Since 1990-92, the only significant progress towards reducing the *number* of undernourished people was concentrated in very few, but populous sub regions: China, Southeast Asia and South America (Figure 7). In India, on the other hand, the prevalence of hunger declined by 5 %, but the outcome in terms of reducing the number of undernourished was small, as a reduction in the first part of the decade was subsequently reversed. At the same time the number of undernourished increased in the rest of East Asia (excluding China) and even more in the rest of South Asia (excluding India) (FAO 2006c)

The Near East, North Africa, Central America, East Asia (excluding China) and Central Africa experienced an increase in both the *number* and *proportion* of undernourished since 1990-92 (FAO 2006c).

Figure 7. **Sub-regional changes in number and proportion of undernourished people between 1990-92 to 2001-03.**



Source: FAO 2006c

In sub-Sahara Africa, recent progress in reducing the prevalence of undernourishment is noteworthy. For the first time in several decades the share of undernourished people in the region's population declined significantly: from 35 % in 1990-92 to 32 % in 2001-03, after having reached 36 % in 1995-97. West-Africa and Nigeria saw a decline in both the *number* and *prevalence* of undernourishment. In Southern Africa and East Africa the prevalence of hungry people declined (although not the number). By contrast, Central Africa experienced a dramatic increase in both the number and prevalence of undernourishment (FAO 2006c).

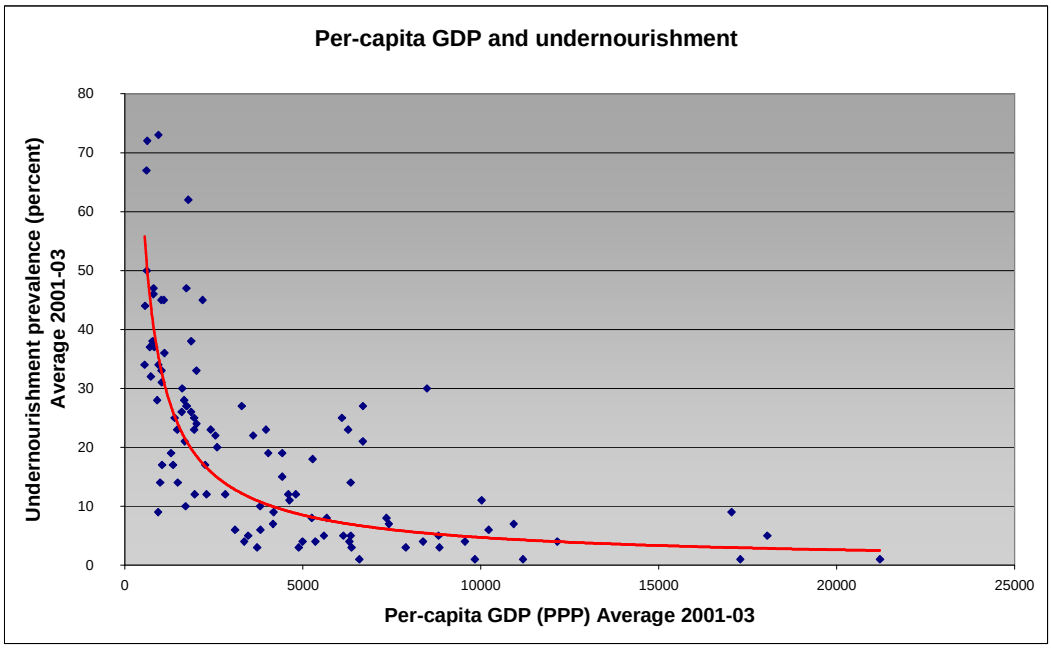
The decline in the share of undernourished people is an encouraging development. Still the task facing sub-Saharan Africa remains daunting. Sub-Sahara Africa accounts for 25 % of the undernourished people in the developing world, and it has the highest proportion (one-third) of people suffering from chronic hunger. In 14 countries in the

region, 35 percent or more of the population were chronically undernourished in 2001-03. The number of undernourished people increased from 169 million to 206 million, and only 15 of the 39 countries for which data are reported reduced the number of undernourished (FAO 2006c).

In addition to Ghana, which has already more than halved the *number* of undernourished people since 1990-92, Angola, Benin, Chad, Congo, Ethiopia, Guinea, Lesotho, Malawi, Mauritania, Mozambique and Namibia have also reduced the number of undernourished people.

There is a clear correlation between countries' income per capita and prevalence of undernourishment in the population (Figure 8). Ample evidence confirms that sustained economic growth leading to increased productivity and prosperity at the national level will result in reduced hunger. But cross-country studies of developing countries suggest that economic growth alone, in the absence of specific measures to combat hunger, may leave large numbers of hungry people behind for a long time, particularly in rural areas (FAO2005).

Figure 8. **Per-capita GDP and undernourishment**



Source: FAO, WDI

Numerous studies have provided evidence that the impact of economic growth on reducing hunger and poverty depends as much on the nature of the growth as on its scale and speed (Bourguignon & Morrison 1998, World Bank 2000, Ravallion & Datt 2001, FAO2005). Some 70 percent of the poor in developing countries live in rural areas and depend on agriculture for their livelihoods, either directly or indirectly. In the poorest countries agricultural growth is the driving force of the rural economy. Particularly in the most food-insecure countries, agriculture is crucial for income and employment generation. Agricultural growth is, therefore, a critical factor in hunger reduction.

3.3 Emerging obesity concerns in developing countries

The progress of raising and diversifying per capita food consumption has become a mixed blessing in several middle income developing countries. In raising dietary energy supplies to 3000 kcal/person/day, the related diet transition often includes a large increase in the consumption of refined carbohydrates and processed fats and oils (Popkin 2001). This diet transition, combined with a more sedentary lifestyle, results in rapidly growing rates of overweight, obesity and a number of diet related non-communicable diseases such as type 2 diabetes and hearth diseases in developing countries (Boutayeb & Boutayeb 2005, Popkin 2004, Prentice 2006). It is now common to find overweight/obesity and malnutrition side by side in developing countries (Boutayeb & Boutayeb 2005), even sometimes within the same households, with obese parents and malnourished children under the same roof (Doak *et al*, 2000).

Globally 1.6 billion adults are overweight and at least 400 million are obese (WHO 2006 a). Two out of three overweight and obese people now live in low and middle income countries, the vast majority in emerging markets and transition economies (WHO 2006 b). Health problems related to obesity-related non-communicable diseases tend to appear side by side with health problems related to undernutrition, and these countries are confronted with a "double burden of malnutrition" resulting in novel challenges and strains in developing countries' health systems.

3.4 Spotlight on consumption of livestock products

Total meat production in developing countries tripled from 47 million tons to 143 million tons between 1980 and 2002 (Steinfeld and Chilonda 2005), and although the pace of growth is slowing down, meat demand is expected increase by more than 50 % by 2030 (FAO 2006 a). Satisfying the increasing demands for animal food products, while at the same time sustaining the natural resource base, and coping with climate change and vulnerability, is one of the major challenges facing world agriculture today.

Table 1. Changes in consumption of animal products

	Developing countries				Developed countries			
	1970	1980	1990	2003	1970	1980	1990	2003
Annual per capita meat consumption (kg)	11	14	19	29	65	75	82	80
Annual per capita milk consumption (kg)	28	34	38	48	188	194	201	202
Total meat consumption (million MT)	29	47	74	143	70	88	103	107
Total milk consumption (million MT)	74	112	152	240	203	227	253	268

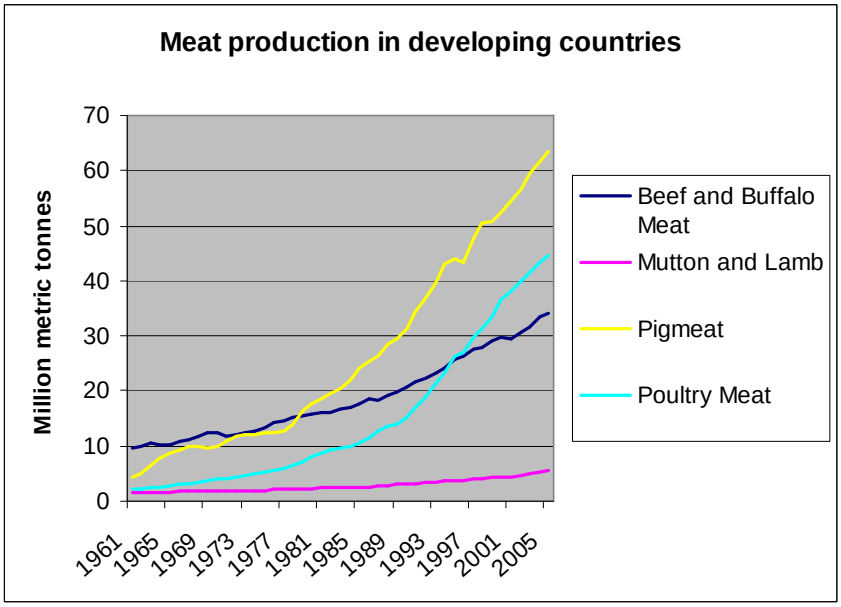
Source: FAO, FAOSTAT 2007

Globally, livestock production is the world's largest user of land, and accounts for almost 40 percent of total value of agricultural production. In industrial countries this share is more than half. In developing countries, where it accounts for one third, its

share is rising quickly as a result of growth in incomes and changes in lifestyles and dietary habits (Bruinsma, 2003).

Until recently, a large proportion of livestock in developing countries was not kept for food, but for providing draught power and manure and as capital assets that was only disposed of in times of emergency. Livestock was an integral part of agricultural systems, distributed among many owners and raised close to their feed supplies. This is changing rapidly. Almost all of the growth in livestock production is now occurring in industrial systems, where meat production is no longer tied to a local land base for feed inputs or to supply animal power or manure for crop production (Naylor *et al* 2005).

Figure 9. Meat production in developing countries.



Source FAO, FAOSTAT

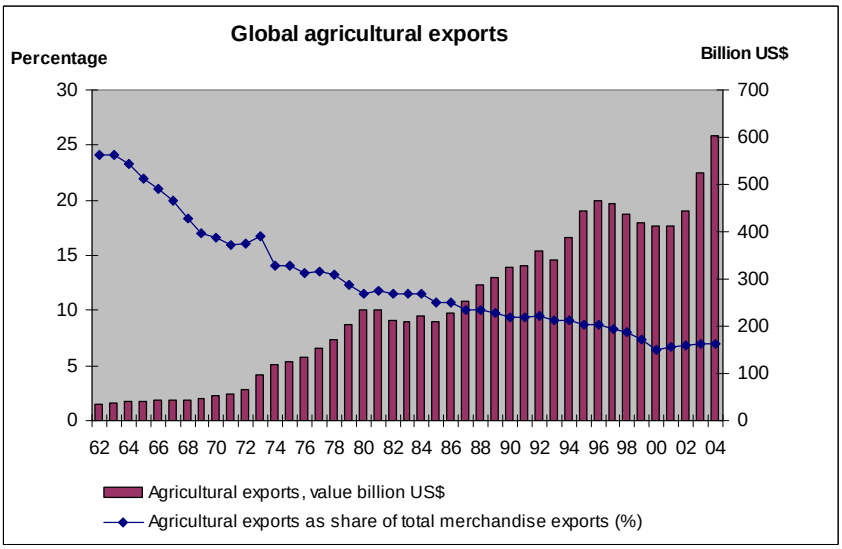
Another challenge is the potential conflict between devoting land to feed production instead of food production. Today there is a 4:1 ratio of land devoted to animal food relative to direct human food (Galloway *et al* 2006). This ratio also includes livestock's use of less productive land for grazing. Livestock production account for about 33 percent of arable land. But as the industrial livestock production increases, so will demand for arable land for the production of animal feed.

4 Trends and changing terms of agricultural trade[6]

4.1 Trade

Since the early 1960s the value of agricultural exports has increased by tenfold, while the share of agricultural trade in total merchandise trade has followed a long-term downward trend from above 20 % in the early sixties to less than 10 percent in recent years (Figure 10).

Figure 10. Global agricultural exports

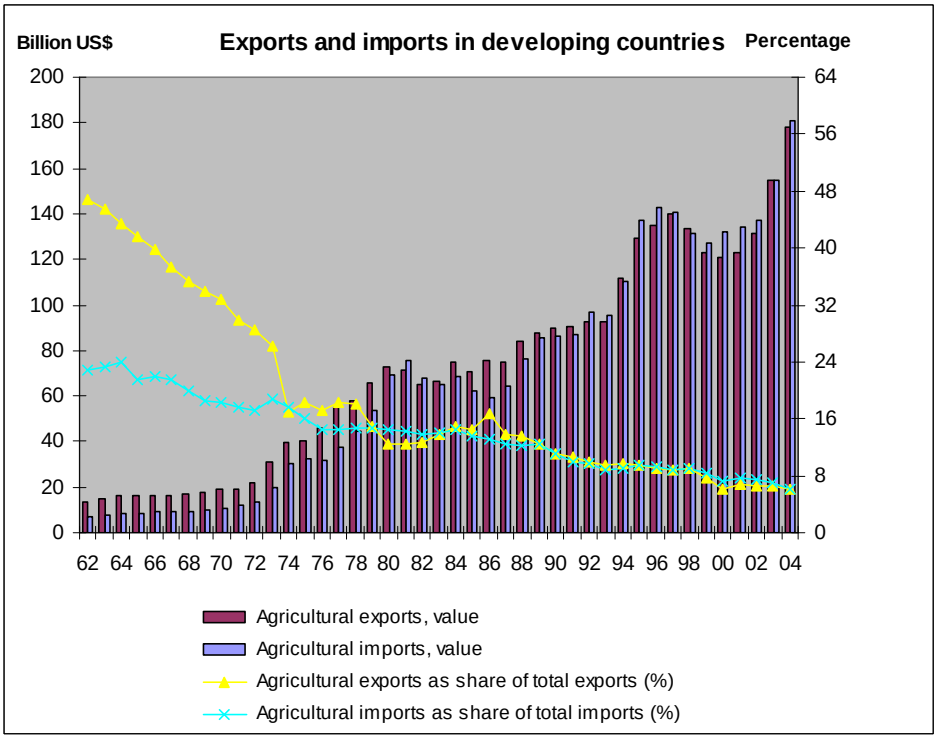


Source: FAO (2006d)

Over this period the net flow of agricultural commodities between developed and developing countries has reversed direction (Figure 11). In the early 1960s, developing countries had an overall agricultural trade surplus of almost US$ 7 billion per year. By the end of the 1980s, however, this surplus had disappeared. During most of the 1990s and early 2000s, developing countries were net importers of agricultural products. Without Brazil, the deficit of the rest of the developing world would have been considerably bigger. It would have grown from US$ 20 billion in 2000 to US$ 27 billion in 2004 (FAO 2006a).

[6] This section is based on FAO 2004a

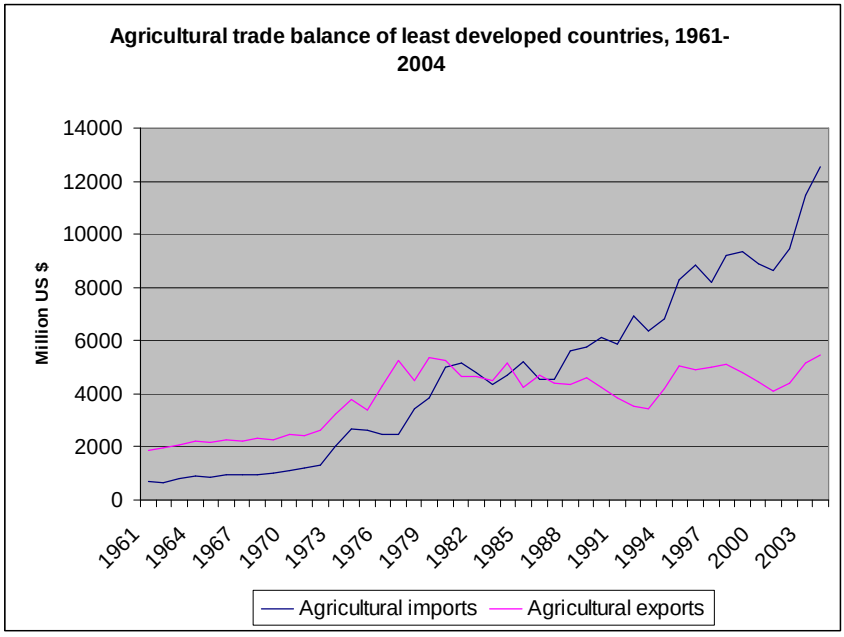
Figure 11. Agricultural exports and imports in developing countries.



Source: FAO (2006d)

The change has been even more pronounced for the LDCs, which over the same period have changed from being net exporters to significant net importers of agricultural commodities. By the end of the 1990s, imports by the LDCs were more than double their exports.

Figure 12. Agricultural trade balance of least developed countries.



Source: FAO, FAOSTAT

Cereal foodstuffs once dominated international agricultural trade. Now, however, the share of cereals in total agricultural imports has fallen below 50 percent in developing countries and below one-third in developed countries. While the share of cereal imports has declined, both developed and developing countries are importing greater quantities of higher-value and processed foods, particularly edible oils, livestock products and fruits and vegetables.

4.2 Prices

Agricultural commodity prices over the past 40 years reveal some striking features:

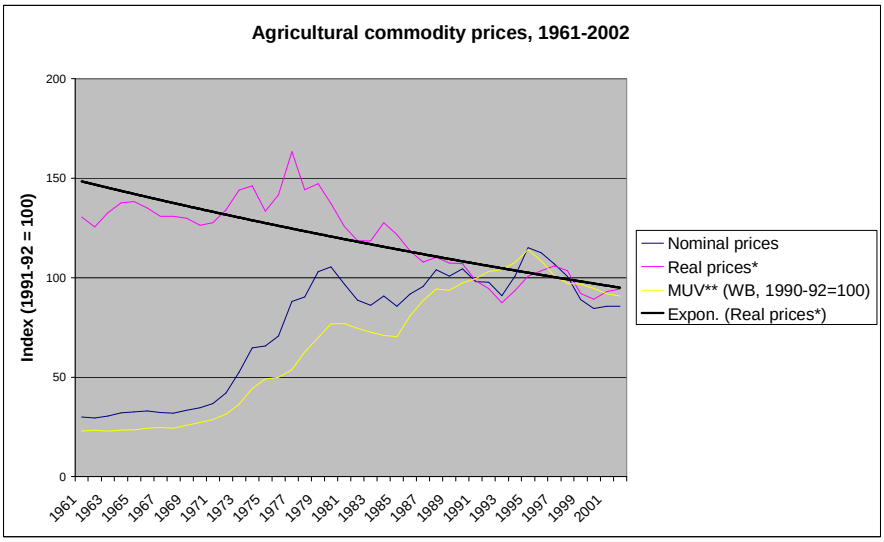
- Real prices of agricultural commodities relative to prices of all manufactured goods have declined significantly, even as nominal prices have risen;
- Real prices have fluctuated considerably around the long-term downward trend;
- Both the fluctuations and the long-term decline have been less pronounced since the mid-1980s.

Several factors have contributed to the long-term decline of almost 2 percent per year. Technological advances have reduced costs and made it possible, at given prices, to expand production at a rate that has outstripped both population growth and increases in demand spurred by rising incomes.

Prices of some commodities have also been driven lower by oversupply, fuelled by intense global competition in production, reduced transportation costs and new technologies that have increased productivity and introduced synthetic alternatives to some commodities. In some cases, the appearance of major new producers, such as the rapid increase in coffee production in Vietnam, has also affected the market balance.

Subsidies to producers and for export in some developed countries have also contributed to pushing down world prices for many agricultural products grown in temperate zones, reducing the export earnings of developing countries that export commodities such as cotton, sugar and rice.

Figure 13. Agricultural commodity prices.

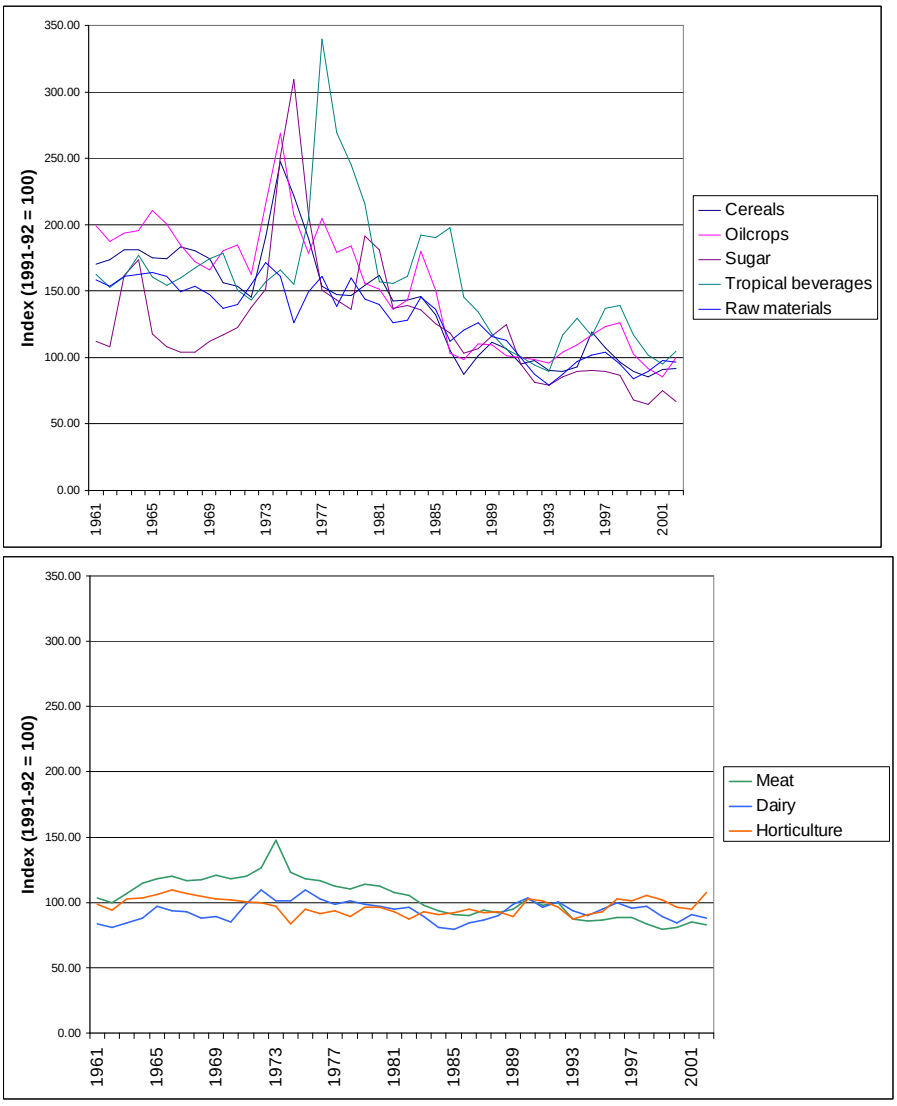


* Real prices deflated by export unit values of all merchandise exports
** MUV = Manufactures export unit value
Source: FAO (2004a)

Prior to the mid-1980s, real commodity prices fluctuated widely while the overall trend declined steeply. Since that time, both the fluctuations and the trend have flattened out considerable. A number of global factors helped slow the rise in nominal prices for all traded goods, including trade policy reforms and increased trade in manufactured goods, whose prices have tended to fall more quickly as a result of technological advances and high productivity growth. Furthermore, trade liberalization has permitted a wider range of countries to participate in world commodity markets, reducing the relative importance of the supply situation in any one country, while technological advances have reduced the vulnerability of some crops to climatic influences.

Even though real prices for all agricultural commodities have declined over the past 40 years, the rate of decline has varied from one commodity to another. Traditional commodities like raw materials, tropical beverages, oil crops and cereals have experienced most variation and the steepest decline. The fall in real prices has been least severe for non-traditional agricultural products like meat, dairy and horticultural products.

Figure 14. Real prices for traditional and non-traditional agricultural commodities, 1961-2002.



*Agricultural commodity prices on world markets deflated by export unit values of all merchandise exports.
Source: FAO (2004a)

4.3 Trade diversification

Some developing countries have managed to take advantage of these trends by shifting production and trade into the non-traditional higher-value sectors. It has mainly been the more advanced and prosperous developing countries that have managed to do this. Developing countries other than the LDCs have more than doubled the share of horticultural, meat and dairy products in their agricultural exports, while they reduced the share of tropical beverages and raw materials in their agricultural exports from 55 percent in the early 1960s to around 30 percent in 1999-2001.

An analysis of the FAOSTAT data (Hallam *et al*, 2004) indicates that trade in some non-traditional agricultural exports, including fruits, vegetables and selected speciality and processed products (excluding trade in bananas and citrus) is currently worth

more than US $ 30 billion annually. Developing countries held a 56 percent share of world trade in non-traditional fruit and vegetables in 2001. In the same year, developing countries also accounted for two-thirds of trade in selected speciality products, such as chillies, ginger and garlic.

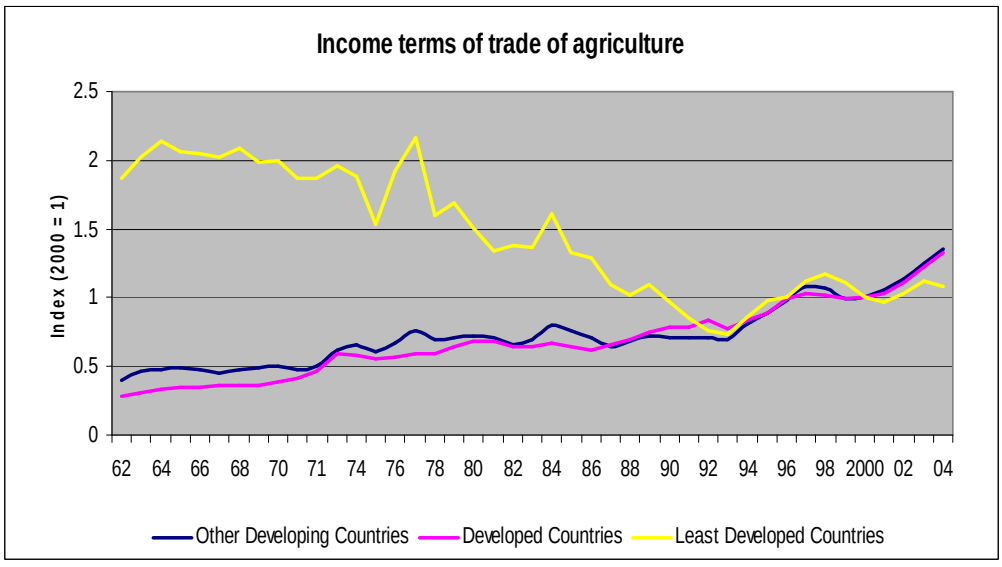
Across a broad range of these products, developing countries have been gaining market share at the expense of the developed countries. This is especially the case of trade in vegetables and speciality products, in which developing countries have taken the lion's share of the very substantial growth in global trade during the last decade.

This non-traditional agricultural export market is, however, dominated by just a handful of countries. Some of these, such as Mexico, Chile, Argentina, Brazil and Costa Rica are leading developing country exporters of more than one product. Other countries are dominant in the market for only one product: for example; Kenya for green beans, Malaysia for minor tropical fruits, Thailand for minor fresh fruits and Zimbabwe for green peas. A large number of countries have only a very limited participation in the market for non-traditional products (Hallam *et al*, 2004).

LDCs account for only 0.5 percent of world fruit trade and only 0.8 percent of world vegetable trade. On the other hand, they increased their dependence on traditional export products such as raw materials and tropical beverages for their agricultural export earnings from 59 percent to 72 percent during the last forty years.

For LDCs, export earnings failed to increase, and rising import prices further eroded their purchasing power. Real agricultural export earnings of LDCs fell by more than 30 percent over the last two decades, and by half over the last 40 years.

Figure 15: **Income terms of trade for agriculture**



Source: FAO, FAOSTAT

5 Sources of agricultural growth

The past four decades have seen solid growth in agricultural productivity. This productivity increase has been particularly strong in developing countries, and especially for cereals such as rice in Asia, wheat in irrigated and favourable production environments worldwide, and maize in Mesoamerica and selected parts of Africa and Asia (Pingali and Heisey, 2001). Other crops have also seen productivity increases.

Agricultural growth occurs if i) the amount of arable land increases, or ii) the cropping intensity increases, or iii) output per unit of input (i.e. workers, land or water) increases, or iv) the composition of output changes towards higher valued products with a constant value of inputs. The relative importance of these factors depends on the situation faced by a particular country. A country like the United States, which has 1.4 hectares of agricultural land per head, can continue to rely on land as a source of agricultural growth in a manner that is not open to a country like India, which has only 0.2 hectares of agricultural land per head. For the latter, growth has to come primarily from sources that economise on land and water, the two main constraints. This in turn implies that cropping intensity must increase or yields have to grow, i.e. there has to be an increase in productivity.

5.1 The closing of the land frontier

Output growth is the result of growth in area harvested and yield growth. Yield is a function of soil quality, weather conditions, labour use per hectare, type of seed used, fertilizer use per acre, herbicide and pesticide use, the availability of irrigation, the availability of tractors, as well as inputs that are difficult to measure, such as the farmer's ability and capacity for work. Agricultural production has increased in most areas of the world, but to what degree did this growth arise out of area expansion or yield growth?

Expansion of harvested area can occur either because more land is cleared for cultivation or because the land is used more intensely. Cropping intensity increases for instance when you go from one to two or three harvests on the same plot of land each year, or when a farmer transfers from shifting cultivation to permanent agriculture. Two or more harvests per year is only possible if the growing periods are relatively short and if there is an assured supply of water. As population density begins to increase from low levels, the first response will likely be to clear more land for agriculture, i.e. the arable land area should increase first, without much impact on yield. As density continues to increase, this option becomes increasingly unrealistic and there is a tendency for cropping intensity to increase and for yields to rise.

In the subsequent analysis of productivity growth we will use an index of *crop* production[7]. Table 2 show growth rates of crop production, total crop land (area under arable and permanent crops), cropping intensity and yields by world region. It should be noted that "historical data for arable land for many countries are particularly unreliable" (Bruinsma 2003, Chapter 4, p 125).

[7] This measure is different from the indices of *agricultural* production and *food* production used in the previous sub-sections as that includes livestock products, whereas the index of crop production used here covers the output of 34 crops (listed in Appendix A).

Table 2. Growth rates

		1961-75	1976-90	1991-05
East Asia and the Pacific				
	Production	3.2	3.8	3.8
	Total crop land	0.1	2.0	1.2
	Cropping intensity	0.4	-1.3	-0.3
	Yield	2.7	3.1	2.9
Latin America and the Caribbean				
	Production	2.9	2.7	3.1
	Total crop land	1.6	0.6	0.6
	Cropping intensity	0.3	0.5	0.6
	Yield	1.0	1.6	1.9
Middle East and North Africa				
	Production	2.3	2.4	2.3
	Total crop land	0.5	0.5	0.5
	Cropping intensity	1.0	0.1	-0.3
	Yield	0.8	1.8	2.1
South Asia				
	Production	2.3	3.0	1.8
	Total crop land	0.4	0.1	0.0
	Cropping intensity	0.2	0.3	0.0
	Yield	1.7	2.6	1.8
Sub Saharan Africa				
	Production	2.6	2.4	2.9
	Total crop land	0.6	0.6	0.9
	Cropping intensity	0.7	1.1	1.0
	Yield	1.3	0.7	1.0

Source: FAOSTAT

To a surprising extent land was still being cleared for cultivation in the 1990s in many world regions, particularly in Latin America & Caribbean and sub-Saharan Africa, regions of relatively low population density. The increase in total crop land in East Asia and the Pacific is surprising. South Asia, a densely populated sub-region with good land records, shows little or no tendency for the arable area to increase.

The only area that consistently showed increases in both area expansion and cropping intensity was sub-Saharan Africa. The increase in cropping intensity can partly be explained by a transition from shifting cultivation to annual cropping in many areas of the continent (Binswanger and Pingali 1988). The increase in cropping intensity might, however, also be an indication that rural population densities in many areas in sub-Saharan Africa are not as low as they seem once they are adjusted for land quality (*op cit*).

Rural population densities were over 250 people per sq km of harvested area by the end of the 20th century in all developing world regions except Latin America & Caribbean. The general conclusion is that area expansion has ceased to be a feasible source of crop production growth by the end of the 20th century, except in those world regions, especially Latin America & Caribbean and parts of sub-Saharan Africa, where rural population densities are still low.

5.2 Are crop yields picking up the slack?

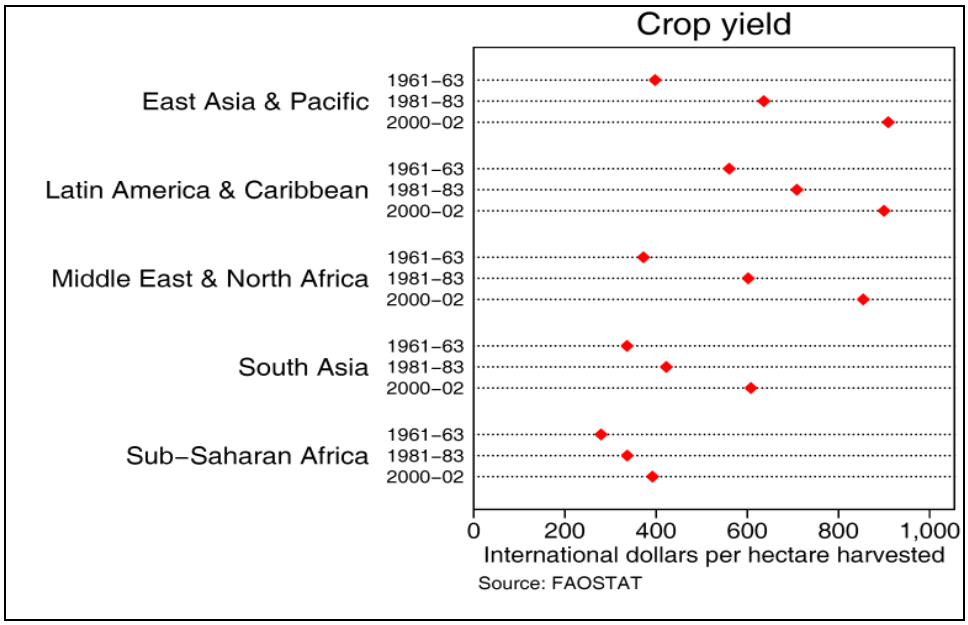
If the land frontier is now closed in most regions[8], the obvious sources of further growth in crop production are land productivity, i.e. yield growth, labour productivity and/or total factor productivity.

Turning first to yield growth, we find consistent patterns of strong to very strong yield growth in most world regions, with the exception of the sub-Saharan Africa region (Table 2).

But is there a tendency for yield growth to increase over time with the closing of the land frontier? This seems to be the case in South Asia and the Middle East and North Africa. But the contribution of area expansion to crop production growth continued to be impressive in the period 1991-2005 in other regions, especially in the sub-Saharan Africa (Table 2).

Yield increases have been impressive in East Asia and the Pacific and also considerable in Middle East and North Africa, Latin America and Caribbean and South Asia. Sub-Saharan Africa started out with the lowest yields in 1961, and has since then had the lowest yield growth rates of all the continents (Table 2 and Figure 16). Yields in Sub-Saharan Africa are further behind today, than ever before.

Figure 16. Regional crop yields in 1961-63, 1981-83 and 2000-02.



5.3 What is causing the yield growth?

Yield is a function of *inter alia* agricultural labour per hectare, type of seeds used, fertilizer application per hectare, farm machinery per hectare and the availability of irrigation. In the following sub-sections, we examine changes in these variables and discuss their impact on crop yield growth.

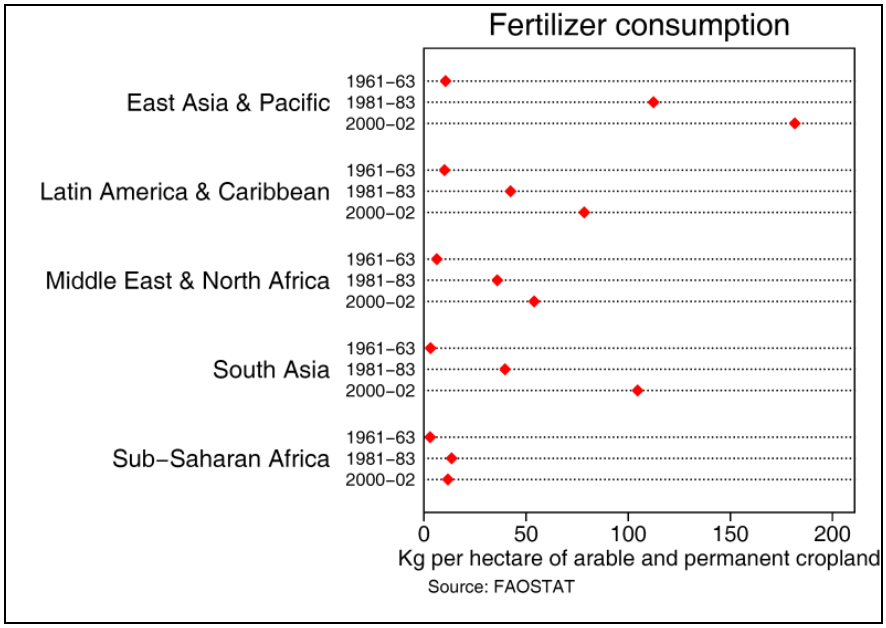
[8] A good case could be made out that opportunities for area expansion through increases in cropping intensity are by no means exhausted.

The transition towards high land and labour productivities is conditioned both by the extent of land scarcity and the level of economic development. Increases in land productivity is a result of intensification of agricultural production and the adoption of high yielding technologies, especially modern varieties (MVs) and fertilizers. The move from low-yield, land extensive cultivation systems to land-intensive, double and triple-crop systems is most profitable in those areas in which the land frontier has been exhausted and where export markets are available and accessible (Pingali & Heisey 2001).

5.3.1 Fertilizers

In 1961, developing countries consumed only 12% of the world total consumption of fertilizers. Forty years later developing countries consumed 64% of total fertilizer nutrients. Application rates were still higher in developed countries than in developing countries, but only by about 20 to 25% on average (Heisey & Norton 2007)

Figure 17. Regional fertilizer consumption in 1961-63, 1981-83 and 2000-02.



Fertilizer consumption grew at very high rates in the 1960s and 1970s, but this growth is now levelling off and is close to zero in all the developing world regions. It should be noted, of course, that this levelling off is occurring at very different intensities of fertilizer use (see Figure 18), ranging from under 10 kg per hectare of arable land in sub-Saharan Africa to almost 200 kg per hectare in East Asia & Pacific in 2000-02. This has very different implications for crop output levels.

5.3.2 Modern Varieties

High yielding crop varieties (MVs) of rice and wheat were first released to farmers in Latin America and Asia in the mid 1960s. They were rapidly adopted in tropical and subtropical regions with reliable rainfall or good irrigation systems. Since then high yielding crop varieties (MVs) of several crops have been adopted by farmers all over the developing world.

Diffusion of the different crops has varied from region to region. Farmers in Asia and Latin America were the early adopters, while the MVs released during the 1960s and 70s were not suitable for African conditions (except for wheat). But after research targeted African conditions specifically, more suitable varieties have become available for African farmers from the 1980s (Evenson and Gollin 2003).

Evenson and Gollin (2003) analyse the production impact of MVs over the past 40 years[9]. One of their striking findings is that the gains from MVs were larger in the 1980s and 1990s than in the preceding two decades, despite popular believes that the Green Revolution was effectively over by this time (see table 3). They suggest that the Green Revolution should not be understood as a one-time jump in production, occurring in the late 1960s, but rather as a long-term increase in the trend growth rate of productivity.

Table 3. MV contributions to yield growth (growth rate)

	1961-1980	**1981-2000**
Asia	0.682	0.968
Latin America	0.463	0.772
Middle East and North Africa	0.173	0.783
Sub-Saharan Africa	0.097	0.471
All developing countries	0.523	0.857

Source: Evenson and Gollin 2003

For all developing countries they found that MVs accounted for 21% of the growth in yields and about 17 % of production growth in the early period. In the later period the MV contribution to yield and production growth was considerably higher, accounting for 50% of yield growth and 40% of production growth for all developing countries. This indicates that production growth has become more dependent on MVs in the later period. (Evenson and Gollin 2003).

5.3.3 Irrigation

Worldwide, irrigated land has increased from 50 million hectares in 1900 to 267 million hectares today, with much of the increase in developing countries, which currently have 75 % of all irrigated land (Schoengold and Zilberman 2007). More than 60% of the value of Asian food crops comes from irrigated land and irrigation was the source of more than 50% of the increase in global food production during the 1965-1985 period (*op cit*).

Irrigation tends to be more important in densely populated areas. Thus irrigation percentages are high, around 40% in South Asia and 30 % in East Asia & Pacific. Sub-Saharan Africa has very low percentages, generally below 5% of arable and permanent cropland. Only 26% of the potential irrigated land in Africa is irrigated today, 17% in Latin America and 64% in Asia (Schoengold & Zilberman 2007). Thus there is significant potential for future expansion of irrigated acreage in other developing regions than Asia. Limited supply of fresh water is an important concern in this respect (see chapter 6.5).

[9] They use data on food crop production (total cereals, total roots and tubers and total pulses) from FAO.

5.3.4 Labour productivity

Labour productivity growth rates seem to have increased, with a strong growth after 1980, in East Asia & Pacific, Middle East & North Africa and Latin America & Caribbean. In sub-Saharan Africa and South Asia, however, labour productivity appears to have grown very slowly. The table below summarises the situation with regard to both land and labour productivity, averaged over the period 2000-2002. The results are in accordance with expectations. Densely populated, poor countries such as Bangladesh tend to have low labour productivity and high land productivity, whereas the situation is reversed in sparsely populated countries such as Iraq or Saudi Arabia. Many of the poorest countries in the world are found in the left, bottom corner with both low land and low labour productivity, while most of the countries with both high labour and land productivity are middle income countries with well developed markets and infrastructure.

Table 4. Land and labour productivities in crop production, developing countries and countries in transition, Average 2000-2002

Land productivity	**High**	Bangladesh, India, Nepal, Sri Lanka, Rwanda	China, Indonesia, Philippines, Viet Nam, Guatemala, Jamaica, Colombia, Iran, Turkey, Egypt	South Korea, Argentina, Brazil, Chile, Ecuador, Jordan, Lebanon, Mauritius
	Moderate	Haiti, Kenya, Tanzania, Uganda, Malawi, Guinea, Liberia, Sierra Leone	Pakistan, El Salvador, Mexico, Bolivia, Benin Ghana, Nigeria	Malaysia, Cuba, Uruguay, Venezuela, Syria
	Low	Cambodia, Afghanistan, Yemen, Cent African Rep, Congo Dem Rep, Ethiopia, Botswana, Zambia, Zimbabwe, Burkina Faso, Gambia, Niger, Senegal, Togo	Nicaragua, Algeria, Morocco, Tunisia, Cameroon, Gabon,	Iraq, Saudi Arabia, Libya, South Africa
		Low	**Moderate**	**High**
		Labour productivity		

1. *Source*: FAOSTAT.
2. *Note*: Land productivity is defined as output (in international dollars) divided by units of land (hectares).
   Labour productivity is defined as output (in international dollars) divided by economically active population in agriculture.
   The classifications low, medium and high correspond to terciles of productivity for land and labour.

5.4 Growth in Total Factor Productivity

Historically, changes in agricultural TFP have been the main force driving growth in agricultural output and farm income in countries that have modernized their economies (Rozelle *et al* 2003). Factors that can account for improvements in TFP include changes in technology, institutional reforms, infrastructure development, improvements to human capital and others. A partial productivity measure such as yield may increase over time because of some fundamental change in the production process, or because of increased use of inputs such as labour, fertilizer or water. TFP trends over time can help clear up the ambiguities about sources of yield growth (Pingali & Heisey 2001). In essence, TFP growth measures the difference between aggregate output and aggregate inputs growth.

Figure 18 and Figure 19 below are scatterplots showing the relationship between growth in agricultural TFP and growth in agricultural output, in the periods from 1961-1980 and from 1981-2000 respectively.

Figure 18. Agricultural production growth and TFP growth, 1961-80.

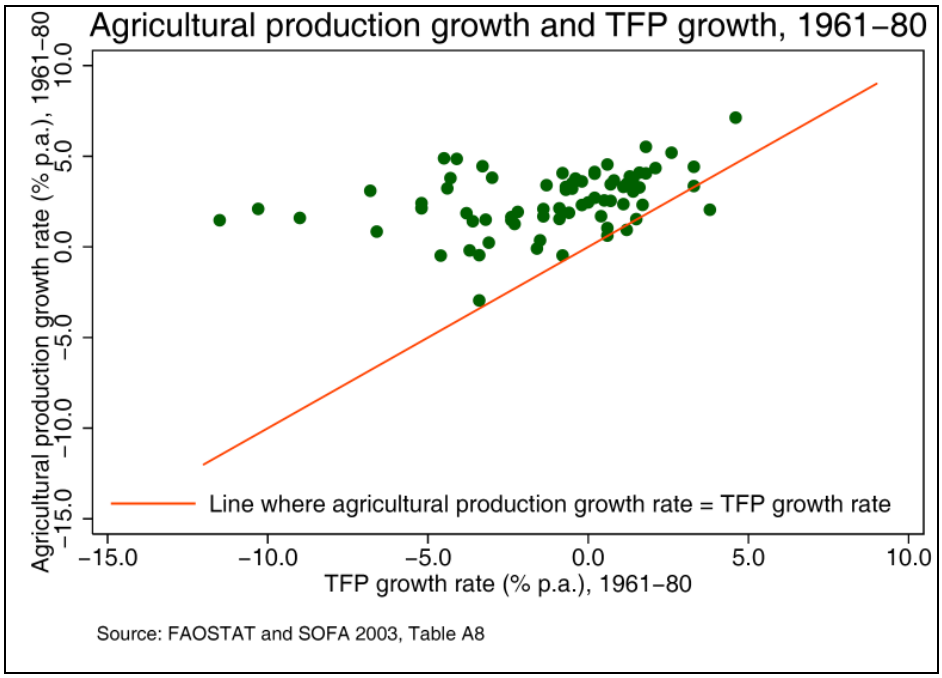
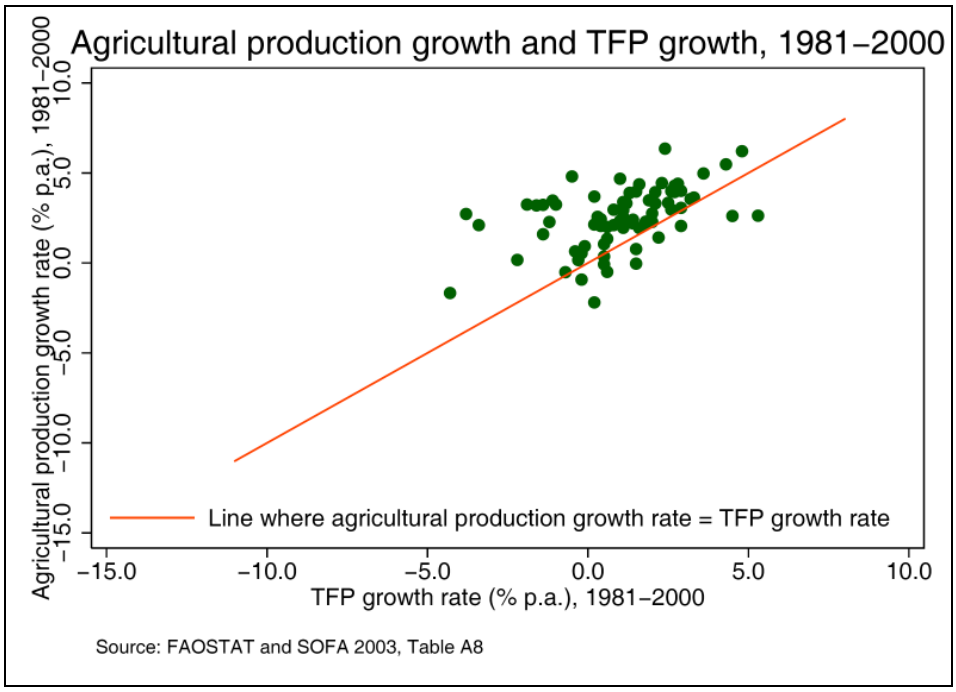


Figure 19. Agricultural production growth and TFP growth, 1981-00.



These graphs show that agricultural production growth is positively related to growth in agricultural TFP. A large number of countries had either negative or negligible TFP growth in the period from 1961-1980, indicating that input growth accounted for most of the agricultural growth in this period. In the later period the vast majority of countries had positive agricultural TFP growth combined with positive agricultural production growth rates. This result agrees with the Evenson and Gollin's (2005) findings that modern varieties contributed more to yield growth in the decades after 1980 than in the previous 20 years.

In the earlier period, almost all countries lay above the 45 degree line, i.e. the agricultural production growth rate was higher than the TFP growth rate for these countries. This implies that production inputs were also growing at positive rates. However, in the later period, there were 10 countries for which the TFP growth rate was not only positive, but greater than the agricultural production growth rate. This implies that in these countries, productive inputs were actually growing at negative rates. This would have led to a negative agricultural production growth rate, if TFP growth had not outweighed the decline in productive inputs.

Table 5. TFP growth rates

	Total factor productivity change	
	1961-81	**1981-2000**
Asia and the Pacific	-3.5	1.9
Latin America and the Caribbean	-1.2	0.4
Near East and North Africa	0.6	2.4
Sub Saharan Africa	-3.7	1.9
Developing countries	*-2.6*	*1.7*

Source: FAO 2004b

Several studies using data from periods between 1961 and the early to mid 1990s report a widening gap between developed and developing countries due to technological regression in developing countries while developed countries showed technological progress (Krüger 2003, Trueblood & Coggins 2003, Arnade 1998, Fulgitini & Perrin 1993,1997, 1998, 1999). Newer findings, using data from the period 1980 to 2000, however, show little evidence of this technological regression (Coelli & Rao 2005, FAO 2004b).

Developing countries have increased their average growth rate from -2.6% during the 1960s and 1970s, to 1.7% in the 1980s and 1990s. Asia and Sub-Saharan Africa, the two continents performing the worst during the early period, are now showing solid TFP growth rates of almost two percent per year. Coelli & Rao (2005) present TFP growth rates for the 93 top agricultural producer countries in the world over the 1980-2000 period. Their findings show an overall annual TFP growth of 2.1%, a 2.9% growth rate in Asia and 1.3% in Africa.

Using individual country data Coelli & Rao (2005) found that those countries that were well below the frontier in 1980 (with technical efficiency coefficients of 0.6 or below) had a TFP growth rate of 3.6% during the later period. This was in contrast to a low 1.2% growth for those countries that were at the frontier in 1980. These encouraging results indicate a degree of catch-up in productivity levels between high-performing and low-performing countries.

6 Opportunities and challenges in the future.

6.1 Population growth

Global population growth has been the major driving force for growth in world food demand and production. The population will continue to grow, but longer term projections suggest that population growth may slow down by the middle of this century. World population is expected to increase from the current 6.7 billion to 9.2 billion by 2050 (UN 2007). From 2050, world population will be increasing by 30 million per year.

Almost all of this increase is expected to take place in developing countries, and especially in the group of the 50 least developed countries. These countries may still have inadequate consumption levels in 2050 and therefore there is significant scope for further increases in demand for food even when population growth slows down.

6.2 Growth in agricultural production slows down[10].

World agriculture is expected to fall to 1.5 percent p.a. in the next two and a half decades and on to 0.9 percent p.a. in the succeeding 20 years to 2050, compared with 2.1 percent per year since 1961. This slowdown reflects the lower population growth

[10] Based on FAO 2006 a) World Agriculture: towards 2030/2050

and the gradual achievement of medium-high levels of per capita consumption in a number of countries.

All the major commodity sectors (except for the milk sector) are expected to take part in the deceleration of agricultural growth. The cereals sector has already been in such downward trend for some time now, and is expected to continue to have the lowest growth rate of the major commodity sectors during the next 50 years.

6.3 Food security[11]

Historical trends towards increased food consumption per capita as a world average and particularly in the developing countries will, according to FAO scenarios, continue in the near future, but at a slower rate than in the past as more and more countries approach medium-high levels. The average of the developing countries may rise from today's 2650 kcal per person per day to 3070 kcal by 2050. By the middle of the century more than 90 percent of the world population may live in countries with more than 2700 kcal per day, up from 51 percent at present and only 4 percent three decades ago. As in the past, the great improvements in China and a few other populous countries will continue to carry a significant weight in these improvements.

However, not all countries are likely to achieve appropriate food consumption levels. This is especially the case for countries that already have high rates of undernourishment, high population growth rates, poor prospects for rapid economic growth and often meagre agricultural resources. Today 32 countries are in this category with an average undernourishment rate of 42 percent. The population of these poor countries is expected to increase from the current 580 million people to 1.39 billion by 2050, and food consumption will under fairly optimistic assumptions increase from the current 2000 kcal/person/day to 2450 kcal in the next 30 years. This is still not enough for good nutrition in several of these countries. Hence the conclusion that reducing undernourishment may be a very slow process in these countries.

Despite the slow pace of progress in reducing the occurrence of undernourishment, the FAO projections do imply considerable overall improvements. In the developing countries the numbers well-fed could increase from 3.9 billion in 1999/01 (83 % of the population) to 6.2 billion (93 %) in 2030 and to 7.2 billion (96 %) by 2050. The problem of undernourishment will tend to become smaller in terms of both absolute numbers affected and, even more, in terms of the proportion of the population.

6.4 Increased energy prices[12]

As the availability of fossil fuels declines, the only renewable carbon resource large enough to substitute for or replace fossil resources for the production of fuels and electricity is biomass (MEA 2005). Recent high energy prices are now creating new markets for products which can be used as biomass feedstocks for the production of biofuels as substitutes for petroleum-based fuels. Brazil, after a period of shrinkage during the 1990s when oil prices were low, has now reverted to using some 50 percent

[11] Based on FAO 2006 a.
[12] Based on FAO (2006) World Agriculture: towards 2030/2050

of its sugar cane output to produce fuel ethanol, both for domestic use and export. Ethanol in Brazil is considered to be competitive vis-à-vis traditional fossil fuels at oil prices of US$ 35-40 per barrel. In the USA a growing share of maize is used to produce fuel ethanol (in this case with subsidies).

EU has a target of a 5.75 percent market share of biofuels in the petrol and diesel market by 2010. The use of vegetable oils to produce biodiesel is expanding in certain EU countries (again with subsidies). The latest projections of the European Commision foresee that 1.5 million tonnes of grain and some 10 millions of oilseeds may be used to produce bioenergy in 2012.

There is also growing interest in countries with real or potentially abundant production potential of suitable feedstocks (like palm oil for biodiesel in Malaysia and Indonesia, cassava and sugar cane for ethanol in Thailand) for producing biofuels, both for domestic use and export. Africa, with its significant sugar cane production potential is often cited as a region that could profit from Brazil's experience and technology, though obstacles to realizing it (infrastructure, institutional etc) should not be underestimated.

The competitiveness of biofuels may be further enhanced if the savings of greenhouse gas emissions resulting from substituting ethanol for gasoline were to be monetized in the form of tradable carbon credits (Certified Emission Reductions of greenhouse gases) through the Clean Development Mechanism under the provisions of the Kyoto Protocol.

If world agriculture is to become a major source of feedstocks for the biofuel industry, this might have implications for food security if feedstocks become a competitor to food, and for the environment if further deforestation takes place from the eventual expansion of land under the feedstock crops.

6.5 Water shortages

It takes 1,000 litres of water to grow a kilo of wheat, between 2,000 and 5,000 litres to grow one kilo of rice, and 16,000 litres to grow the feed it takes to make one kg of beef (Pearce 2006, MEA 2005). Agriculture accounts for 70 percent of all water use in the world and as much as 95 percent in many developing countries, almost all of this is for irrigating crops (MEA 2005, FAO2007). Per capita use of water has decreased from about 700 to 600 cubic meters per year since 1980 (MEA 2005), and water productivity in agriculture increased by at least 100 percent between 1961 and 2001 (FAO 2003), but total water use is still increasing and is expected to continue to increase due to population growth, urban expansion and increasing industrialisation.

Today, more than 1.2 billion people live in areas of physical water scarcity (Comprehensive Assessment of Water Management in Agriculture 2007) and by 2025 over 3 billion people are likely to experience water stress (UNDP HDR 2006). The gap between available water supply and water demand is increasing in many parts of the world, limiting future expansion of irrigation. In areas where water supply is already limited, water scarcity is likely to be the most serious constraint on development, especially in drought-prone areas (MEA 2005).

In some water basins the water tables have been falling at an alarming rate. In large areas of India and China ground water levels are falling by one to three meters a year (WB 2006). This can lead to irreversible land subsidence, salt-water intrusion and pollution of the water resource in addition to increased pumping costs. This presents an important risk to world food production, as 10 percent of the world's food is produced in areas experiencing groundwater depletion (WB 2006).

Areas that are already relatively dry, such as the Mediterranean basin and parts of Southern Africa and South America will likely, due to climate change, experience further decreases in water availability. Increases in the frequency of droughts and floods due to climate change are projected to affect local production negatively, especially in subsistence sectors at low latitudes. Other regions, such as South Asia and parts of Northern Europe are likely to experience increases in water availability (IPCC 2007 b, Stern 2006).

If today's food production and environmental trends continue, we will probably have to face crises in many parts of the world (Comprehensive Assessment of Water Management in Agriculture 2007). To avoid this we need to act to improve water use in agriculture. The hope lies in closing the gap in agricultural productivity in parts of the world through better water management and changes in production techniques, including the use of new drought resistant crops.

6.6 Climate change.

Climate change is a serious and urgent issue. The earth has already warmed by 0.7°C since 1900, and based on current trends, average global temperatures could rise by 2–3 °C within the next 50 years (Stern 2007) (or 2-4 °C by the end of the century according to IPCC (2007 a)).

Food production is particularly sensitive to climate change, since crop yields depend in large part on climate conditions such as temperature and rainfall patterns. There are still large uncertainties as to when, how and where climate change will affect agriculture production and food security. But recent research (i.e. Stern 2007 and IPCC 2007 a and b) has suggested that the impacts will derive primarily from:

- **Higher temperatures**. It is *virtually certain*[13] that temperatures over most land areas will increase. We will have fewer cold days and nights, and more frequent hot days and nights. This might lead to increased yields and larger agricultural areas in colder environments where the planting season will become longer and more favorable for crop production. But in warmer environments, and especially in arid and semi-arid areas higher temperatures and increased evaporation will lead to decreased yields.
- **More frequent heat waves**. We will *very likely*[13] experience more frequent warm spells and heat waves. Increased heat stress will lead to reduced yields in warmer regions. Heat waves will also cause more frequent fires.

[13] Description of likelihood of occurrence/outcome in IPCC documents:

Virtually certain	means	> 99% probability
Very likely	means	90 to 99% probability
Likely	means	66 to 90% probability

- **Droughts**. Areas affected by droughts and frequencies of droughts will *likely*[13] increase. As a result we will experience more land degradation, lower yields, crop damage and failure, and increased livestock deaths.
- **Heavy precipitation events**. The frequency of heavy precipitation events will *very likely*[13] increase over most areas. This will cause increased soil erosion, damage to crops, and inability to cultivate land due to water logging of soils and possible floods.
- **Tropical cyclones**. It is *likely*[13] that we will encounter more frequent disruptions in food production due to severe extreme events such as tropical typhones and hurricanes.
- **High sea levels**. Increased incidence of extreme high sea levels is *likely*[13]. As a result agricultural production in coastal and low land areas (such as highly populated areas of Bangladesh) will be threatened by saltwater intrusion of irrigation water.
- **Pests and diseases**. Higher average temperatures and fewer cold waves and frost days may foster larger pest populations and could extend the range of some pests and disease vectors, and favor the more rapid buildup of their populations to damaging levels. Even though no attempt has been made to quantify losses, they could be appreciable in terms of lower yields and higher production costs (Bruinsma 2003).

It is generally agreed that agricultural impacts will be more adverse in tropical areas than in temperate areas (Stern 2007, IPCC 2007, Parry *et al* 2004, Parry *et al* 2005, Fischer *et al* 2005), and that climate change effects will likely widen the gap between developed and developing countries. Low levels of warming in temperate areas (US, Europe, Australia and some parts of China) may improve the conditions for crop growth by extending the growing season and/or opening up new areas for agriculture. But further warming will have increasingly negative impacts, as damaging temperature thresholds are reached more often and as water shortages limit crop growth in semi-arid regions such as Australia, Southern Europe and Western USA (Stern 2007, IPCC 2007 a).

The impact of climate change on agriculture depends crucially on the size of the "carbon fertilization" effect (Stern 2007). Since carbon dioxide is a basic building block for plant growth, rising concentration in the atmosphere may enhance the initial benefits of warming and even offset reductions in yield due to heat and water stress. Much effort has been put into modeling the links between climate change and crop growth to project future changes in crop yields and food supply across the globe (Parry *et al* 2005, Fischer *et al* 2005). These models, and projections by the IPCC, suggest that reduced crop yields due to increased temperatures and decreased soil moisture will be offset by the direct fertilization effect of rising carbon dioxide concentration.

Research based on the full realization of the carbon fertilization effect suggests that total crop yields may even rise when averaged across the globe, even though most scenarios exerted a slight to moderate (0 to – 5%) negative impact on simulated world crop yields (Parry *et al* 2004, Parry *et al* 2005). These studies were based on information about crop responses to elevated carbon dioxide obtained from studies in greenhouses and laboratory controlled-environment chambers. However, newer analysis from crops grown in more realistic field conditions suggests that the carbon

fertilization effect is likely to be less than half that typically included in the crop models (Long *et al* 2006, Long *et al* 2005). When a weak carbon fertilization effect is used in the models, global cereal production declines by 5 % for a 2 °C increase in temperature and 10 % for a 4 °C increase (Stern 2007).

The effects of climate change on agriculture will also, of course, depend on the degree of adaptation, which again will be determined by income levels, market structure, farming type, etc (Stern 2006).

6.6.1 Impacts on food security.

The impacts of climate change will not be evenly distributed. "The poorest countries and people will suffer earliest and most" (Stern 2007). Since crop productivity is expected to decrease at lower latitudes, even for small local temperature increases (1-2 °C), the risk of hunger will also increase (IPCC 2007 b). The impacts will be strongest across Africa and Western Asia, where models show that yields of the most common crops may fall by 25-35 % under the weak carbon fertilization scenario or 15-20% under the strong carbon fertilization scenario once temperature rises by 3-4 °C (Stern 2007).

The projected number of people affected by climate change depends to a large degree upon the development pathway. In a pathway characterized by relatively low per capita income and large population growth, the projected number of people affected is considerably greater than under pathways with higher per capita income and lower population growth (Parry *et al* 2005, IPCC 2007 b). This difference is largely explained by differences in vulnerability, and not by differences in changes of climate.

7 Conclusions

Total agricultural output expanded by almost 170 percent globally since 1961, an average increase of 2.2% per year, always keeping ahead of global population growth rates. Much of this growth originated in developing countries (3.4 – 3.8 percent p.a.). But many of the least developed countries, particularly in sub-Saharan Africa, continue to experience low agricultural productivity, rising food deficits and high levels of hunger and poverty. The recent success in accelerating growth in some Sub-Saharan African countries gives hope for the future. The growth in these poor countries must be sustained, and extended to the neighbouring countries that have not yet participated in this growth.

The world made significant progress in raising food consumption per capita. In developing countries consumption increased from an average of 2100 kcal/person/day in 1970 to almost 2700 kcal/person/day today. The proportion of hungry people was reduced from 37% to 17% over the same period. But there are still more than 850 million undernourished people worldwide. In sub-Saharan Africa, the worst hit continent, over one third of the population is chronically undernourished.

The composition of agricultural production and consumption has changed considerably over the last 45 years. Growth in per capita cereal consumption

stagnated, while income growth and urbanization led to increased demand for livestock, oil crops and horticultural products. Meat production tripled between 1980 and today, and livestock production now accounts for almost 40 percent of the total value of agricultural production.

Real prices for agricultural commodities declined by approximately two percent per year since 1961, but the rate of decline varied. Traditional commodities such as raw materials, tropical beverages, oil crops and cereals experienced the steepest decline. The fall in prices was least severe for non-traditional commodities such as horticultural and animal products. Some developing countries managed to take advantage of these trends by shifting production and trade into higher-value non-traditional products. The least developed countries, however, increased their dependence on traditional export crops. Over the last four decades, their agricultural exports earnings fell by more than 40 percent, and they have changed from being net exporters to significant net importers of agricultural commodities.

Historically, area expansion was an important source of crop production growth. However, further opportunities for area expansion are now exhausted except in Latin America & Caribbean and some parts of sub-Saharan Africa where rural population densities are still low. Increases in cropping intensity may offer a solution to the problem of how to expand area despite high rural population densities. This will require expansion of irrigation, for which there is still some scope, particularly in Latin America and Sub-Saharan Africa.

Except for Sub-Saharan Africa where area expansion has continued to be a substantial source of growth, *yield growth* has been the major source of increase in crop production over the last 45 years. Countries with high population densities tend to be the ones with high land productivity and vice versa. Many middle income countries with well developed markets and infrastructure have both high labour and land productivity.

The use of inputs such as fertilizer, modern varieties, tractors and irrigation are other determinants of yield growth. While modern varieties increasingly seem to play a more important role in yield growth, growth in the use of the other inputs appears to be levelling off, at very low levels in Africa.

Research on Total Factor Productivity (TFP) is pointing in the same direction. Output growth during the 1960s and 1970s was mainly a result of increased input use, and TFP growth rates were negative for most developing regions. It is encouraging to note that TFP growth rates have become positive in the 1981-2000 period. Even Asia and Sub-Saharan Africa were showing solid TFP growth rates for this period. Increased growth in TFP might offer the only feasible solution to the problem of ensuring continued productivity growth. This will require investments in research and development as well as institutional reforms and infrastructure development.

World agriculture faces many future challenges. One major challenge is to accelerate production growth in poor agriculture based countries, especially in Sub-Saharan Africa. Additional challenges will include satisfying increasing global demands for food, including that for animal products, sustaining the natural resource base (soil, water, air and biodiversity), coping with water shortages, climate change and

vulnerability, and navigating the potential conflict between devoting land to animal food and biofuels relative to direct human food.

References:

Arnade, C. (1998). Using a Programming Approach to Measure International Agricultural Efficiency and Productivity. *Journal of Agricultural Economics*. Vol 49, 67-84.

Binswanger, H and P Pingali (1988). Technological Priorities for Farming in sub-Saharan Africa. *World Bank Research Observer*, Vol3 (1), Jan. 81-98

Bourguignon, F., C. Morrison (1998). Inequality and development: the role of dualism. *Journal of Development Economics*. Vol 57 (2), 233-257

Boutayeb, A. & S. Boutayeb (2005). The Burden of Non Communicable Diseases in Developing Countries. *International Journal for Equity in Health*, 4:2.

Bruinsma (2003). *World agriculture: towards 2015/2030*, FAO, Rome.

CFS (2001). *Assessment of the World Food Security Situation*. Committee on World Food Security. Rome, 28. May – 1. June.

Coelli, T. J. & P. Rao (2005). Total factor productivity growth in agricolture: a Malmquist index analysis of 93 countries, 1980-2000. *Agricultural Economics*. Vol 32 (1s), 115-134.

Comprehensive Assessment of Water Management in Agriculture (2007). Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. London: Earthscan, and Colombo: International Water Management Institute

Doak, C. M., L.S. Adair, C. Monteiro & B.M. Popkin (2000). Overwheight and Underweight Coexist within Households in Brazil, China and Russia. *The Journal of Nutrition*. Vol. 130., 2965-2971.

Evenson, R.E. & D. Gollin (2003). Assessing the Impact of the Green Revolution, 1960 to 2000. *Science*. Review. Vol 300, May. 758-762.

FAO (2003). *Unlocking the Water Potential of Agriculture*. Rome

FAO (2004 a) *The State of Agricultural Commodity Markets 2004*. Rome.

FAO (2004 b) *The State of Food and Agriculture*. 2003-2004. Rome

FAO (2005) *The State of Food Insecurity in the World 2005*. Eradicating world hunger – key to achieving the Millenium Development Goals. Rome.

FAO (2006a) *World agriculture: towards 2030/2050*. Rome

FAO (2006b) *Livestock's long shadow: Environmental issues and options*. Rome

FAO (2006c) *The State of Food Insecurity in the World. Eradicating world hunger – taking stock ten years after the World Food Summit*. Rome.

FAO (2006d). *The State of Food and Agriculture*. Rome

FAO (2007) *The State of Food and Agriculture 2007* Paying farmers for environmental services. Rome. Forthcoming.

Fischer, G., M. Shah, F.N. Tubiello & H. van Velhuizen (2005). Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990-2080. *Philosophical Transactions of the Royal Society B.* Vol. 360. 2067-2083.

Fulgitini, L. & R. Perrin (1993). Prices and Productivity in Agriculture. *Review of Economics and Statistics*. Vol 75, 471-482.

Fulgitini, L.E. & R.K. Perrin (1997). LDC Agricolture: Nonparametric Malmquist Productivity Indexes. *Journal of Development Economics*. Vol 53, 373-390.

Fulgitini, L.E. & R.K. Perrin (1998). Agricultural productivity in developing countries. *Agricultural Economics*. Vol 19. 45-51.

Fulgitini, L.E. & R.K. Perrin (1999). Agricultural Productivity in Developing Countries. *Contemporary Economic Policy*. Vol 17, 469-475.

Galloway, J, M. Burke, E. Bradford, R. Naylor, W. Falcon, A.K. Chapagain, J. Gaskell, E. McCullough, H. Mooney, K. Oleson, H. Steinfeld, T. Wassenaar, V. Smil, (2007). International Trade in Meat: The tip of the pork. Ambio. In Press.

Hallam, D., P. Liu, G. Lavers, P. Pilkauskas, G. Rapsomanikis, J. Claro (2004). The market for non-traditional agricultural exports. *FAO commodities and trade technical paper* (3).

Heisey P.W. & G.W. Norton (2007). Fertilizers and other Farm Chemicals. In Evenson, R. and P. Pingali (Eds): *Handbook of Agricultural Economics,* Vol. 3, Chapter 53.

IPCC (2007 a). Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2007 b). Summary for Policymakers. In:. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report*.

Kumar, P. (2006). Economic Reforms and Agricultural Economy. A Comparative Analysis of Punjab and Bihar. In; *Agriculture Summit 2006*. Ministry of Agriculture, Gov. of India and Federation of Indian Chambers of Commerce and Industry.

Krüger, J.J. (2003). The global trends of total factor productivity: evidence from the nonparametric Malmquist index approach. *Oxford Economic Papers*. Vol 55. 265-286.

Long, S.P., E.A. Ainsworth, A.D.B. Leakey & P.B. Morgan (2005). Global food insecurity. Treatment of major food crops with elevated carbon dioxide or ozone under large-scale fully open-air conditions suggests recent models may have overestimated future yields. *Philosophical Transactions of the Royal Society B.* Vol. 360. 2011-2020.

Long, S. P., E.A. Ainsworth, A.D.B. Leakey, J. Nösberger & D.R. Ort (2006). Food for Thought: Lower-Than-Expected Crop Yield Stimulation with Rising CO_2 Concentrations. *Science*. Vol 312. 1918-1921.

MEA (2005). *Millenium Ecosystems Assessment. Ecosystems and Human Well-Being*. Volume 1. Current State and Trends. Washington.

Naylor, R., H. Steinfeld, W. Falcon, J. Galloway, V. Smil, E. Bradford, J. Alder, H. Mooney (2005). Losing the Links Between Livestock and Land. *Science*. Vol. 310. 1621-1622.

Parry, M., C. Rosenzweig, A. Iglesias, M. Livermore, G. Fischer (2004). Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change*. Vol 14. 53-67.

Parry, M., C. Rosenzweig & M. Livermore (2005). Climate change, global food supply and risk of hunger. *Philosophical Transactions of the Royal Society. B.* Vol. 360. 2125-2138.

Pingali, P. & P.W. Heisey (2001). Cereal-Crop Productivity in Developing Countries. In Alston, J.M., P.G. Parday & M.J. Taylor (eds.) *Agricultural Science Policy. Changing Global Agendas.* The John Hopkins University Press, Baltimore and London.

Pingali, P. (2007 a). Westernization of Asian diets and the transformation of food systems: Implications for research and policy. *Food Policy*, Volume 32, Issue 3. 281-298.

Pingali, P (2007 b). Agricultural Mechanization: Adoption Patterns and Economic Impact. In Evenson, R and P Pingali (Eds): *Handbook of Agricultural Economics, Vol. 3*, Chapter 54

Popkin B. (1999). Urbanization, lifestyle changes and the nutrition transition. *World Development* 27 (11), 1905-16

Popkin B. (2000). Urbanization and the Nutrition Transition. Policy Brief 7 of 10. Focus 3. In: *Achieving Urban Food and Nutrition Security in the Developing World*. J. Garret and M. Ruel (eds.), International Food Policy Research Insitute, Washington, DC.

Popkin, B.M. (2001). The Nutrition Transition and Obesity in the Developing World. *The Journal of Nutrition*. Vol: 131.

Popkin, B.M. (2004). The Nutrition Transition: An Overview of World Patterns of Change. *Nutrition Reviews*, Vol. 62, No. 7. S140-S143.

Prentice, A.M (2006) The Emerging Epidemic of Obesity in Developing Countries. *International Journal of Epidemiology*. Vol. 35. 93-99.

Ravallion, M. & G. Datt (2002). Why has economic growth been more pro-poor in some states of India than others? Journal of Development Economics. Vol 68. No. 2. 381-400.

Regmi A., & J. Dyck (2001). Effects of urbanization on global food demand. In: Regmi A. (Ed.), *Changing Structures of Global Food Consumption and Trade*. ERS WRS 01-1. Economic Research Service, United States Department of Agriculture, Washington, DC.

Rozelle, S., S. Jin, J. Huang & R. Hu (2003). The Impact of Investments in Agricultural Research on Total Factor Productivity in China. In Evenson, R.E. & D. Gollin (eds.): *Crop Variety Improvement and its Effect on Productivity*. CABI Publishing, Wallingford, UK.

Schoengold, K. & D. Zilberman (2007). The Economics of Water, Irrigation, and Development. In Evenson, R and P Pingali (Eds): *Handbook of Agricultural Economics*, Vol. 3, Chapter 58.

Steinfeld, H. and P. Chilonda (2005). Old players, new players. *Livestock Report 2006*. FAO

Stern, N. (2007). *The Economics of Climate Change. The Stern review*. Cambridge University Press, Cambridge, UK.

Trueblood, M.A. & J. Coggins (2003). *Intercountry Agricultural Efficiency and Productivity: A Malmquist Index Approach*. World Bank: Washington, DC. Mimeo.

UN (2004). World Urbanization Prospects: The 2003 Revision. [-get the 2006 report when it is released later this year]

UN (2007). *World Population Prospects: the 2006 revision*: Highlights. United Nations, New York.

United Nations Development Program (2006). *Human Development Report 2006. Beyond Scarcity: Power, Poverty and the Global Water Crisis*. New York: United Nations.

WHO (2006 a). *Obesity and Overweight*. Fact Sheet no. 311. September.

WHO (2006 b). *Implementing the Global Strategy on Diet, Physical Activity and Health*. Global Programming Note 2006-2007.

World Bank (2000). *World Development Report: Attacking Poverty*. New York.

World Bank (2006): *Reengaging in Agricultural Water Management. Challenges and Options*. Washington, D.C.: World Bank.

Appendix A: List of crops included in the crop production index

1. Wheat
2. Rice
3. Maize
4. Barley
5. Millet
6. Sorghum
7. Other cereals
8. Potatoes
9. Sweet potatoes
10. Cassava
11. Other roots
12. Plantains
13. Beet
14. Sugarcane
15. Pulses
16. Vegetables
17. Bananas
18. Citrus
19. Fruits
20. Oilcrops
21. Rapeseed
22. Palm oil
23. Soybeans
24. Groundnuts
25. Sunflower seed
26. Sesame
27. Coconut
28. Cocoa
29. Coffee
30. Teas
31. Tobacco
32. Seed cotton
33. Fibres
34. Rubber
35. Fodder