Chapter 8

Capital requirements for agriculture in developing countries to 2050

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This chapter reports on ongoing work at FAO to estimate investment requirements in developing countries' agriculture. Estimates cover most capital items, but do not single out areas for public involvement of either domestic or foreign funding sources. Neither has any attempt been made to gauge the incremental investment needs required to attain certain development goals, such as Millennium Development Goal (MDG) 1 or the target set by the World Food Summit. This means that important investment areas such as agricultural research or rural infrastructure are excluded, but they are covered in other work (Schmidhuber and Bruinsma, 2011). An item of major concern to public investment – ensuring access to food for the most needy, such as through social safety nets[1] – is also not dealt with here.

The estimates presented in this chapter embody a broad range of capital items needed to achieve the 2030 and 2050 crop and livestock production levels in developing countries that are foreseen in the baseline outlook of the latest FAO perspective study (FAO, 2006b). The majority of these capital items relate to primary agriculture. In addition, a number of the activities covered relate to downstream industries of primary agriculture, notably various forms of processing, storage and marketing.

Total investment requirements are made up of net additions to and replacement of obsolete capital stocks. Traditionally, the lion's share of capital needs has been covered by private farmers and by entrepreneurs in the related upstream and downstream industries (including capital outlays in non-monetized forms). Some capital items, such as irrigation development, rural infrastructure and agricultural research, require public intervention, but this chapter makes no effort to measure

1. Accounting for more than a fifth of the incremental annual public investment estimated in the FAO (2003) Anti-Hunger Programme.

the needed or desired level of public sector engagement. This can vary widely across capital items and countries, and any quantitative assessment would need to start from a detailed and disaggregated basis.

Methodology and measurement

Imputed versus actual

The basic goal of this assessment was to gauge the amount of capital that will be required to produce the total amounts of crops and livestock products projected in FAO's long-term outlook to 2030 and 2050, such as the hectares of land to be developed, irrigated and put under permanent crops; the numbers of tractors, combines, implements or hand tools to be acquired; and the increases in livestock herds, sheds, etc. All investments are imputed estimates, and not necessarily actual investments. Capital stocks too are imputed and not necessarily actual, as are capital stocks, i.e., net investments and depreciation.

Box 8.1 - Past FAO estimates of investment requirements

The 1981 publication *Agriculture: towards 2000* (FAO, 1981) estimated the average annual gross investment for the 20-year period 1980 to 2000 for 90 developing countries (excluding China) at USD 69 billion in 1975 dollars: USD 47 billion for investment in primary agriculture, about a third of which is for investment in replacement; and USD 22 billion for investment in supporting capital stock. Separate estimates are given for (net) investment in forestry and fisheries. These investment estimates refer to total investment required – the sum of private and public investment.

The 1988 study *World agriculture: towards 2000* (Alexandratos, 1988) is an update of the 1981 study and follows the same methodology. For 93 developing countries (excluding China) the estimate of average annual gross investment for the 17-year period 1982/1984 to 2000 amounts to USD 88 billion in 1980 dollars. Investments in primary agriculture are estimated at USD 50 billion (nearly 60 percent for investment in replacement), and investment in supporting capital stock at USD 38 billion. No estimates are given for investment in forestry and fisheries.

The investment estimates in the technical background document for the 1996 World Food Summit (FAO, 1996) are based on the study by Alexandratos (1995). These estimates refer to the group of 93 developing countries and the investment needed to achieve the production projections in this latter publication (i.e., the World Food Summit target is not considered and 637 million people are left undernourished in 2010). The estimate for average annual gross investment for 1993 to 2013, in 1993 dollars, is USD 129 billion, of which USD 86 billion is in primary agriculture (USD 61 billion for replacement) and USD 43 billion in support (or post-production) investment. To this are added USD 37 billion of investments in public support services (mainly technology generation and transfer) and rural infrastructure, two categories that were not covered in earlier studies. The total then amounts to USD 166 billion, of which about three-quarters (USD 125 billion) is private and one-quarter (USD 41 billion) public investment.

The next FAO exercise, giving investment estimates of a slightly different nature, was FAO, 1999 (which is also reported in FAO, 2001). These estimates are an update of the 1995 estimates (for developing countries only), but refer to what is needed to reach the World Food Summit target of halving the number of undernourished people by 2015. They estimate an average annual gross investment for 2000 to 2015, in 1995 dollars, of USD 140 billion, of which USD 93 billion is in primary agriculture (USD 66 billion for replacement) and USD 47 billion in support (or post-production) investment. To this are added USD 40 billion of investments in public support services and rural infrastructure. The total amounts to USD 180 billion.

The latest FAO publication giving investment estimates (FAO, 2003) refers to what is needed to reach the World Food Summit target in 2015. These estimates cover only investment incremental to expected future public investment. Average annual investment for 2003 to 2015, in 2002 dollars, is USD 23.8 billion, of which USD 2.3 billion is for productivity improvements, USD 7.4 billion for natural resource development, USD 7.8 billion for rural infrastructure, USD 1.1 billion for knowledge generation, and USD 5.2 billion for ensuring access to food.

These imputed investments and capital stocks can differ from actual investments and capital stocks for a number of reasons. For instance, if farmers work with excessively depreciated capital stocks (old tractors, tillers, threshers, sheds, etc.), actual capital stocks would be lower than the imputed ones, and vice versa. Conversely, some investments may not entirely or always translate into monetary expenditures. For instance, when a farmer builds a storage facility for cereal crops or a shed for grazing animals, these activities may not be fully reflected in the actual value of the capital stocks; they are, however, part of the imputed capital as they absorb resources with positive opportunity costs and reflect a shift away from consumption into investment.

As a consequence, the estimated investment numbers and capital stocks may not always correspond to those from other sources, such as national accounts. Although this means that deviations from actual capital stocks are unavoidable in the short run, imputed and actual capital stocks and investment requirements should converge in the longer run, at the latest after one full depreciation period of the item with the longest life span. The outlook to 2050 should thus be sufficiently long to ensure convergence. At any rate, the advantage of the calculation of imputed capital stocks is that the results are comparable across countries and over time.

Investment areas and unit costs

To derive capital needs from production projections, changes in agricultural outputs are linked to 26 different capital items. For each capital item, specific unit costs and a specific lifetime, and thus depreciation period, are chosen. The imputed values are obtained by multiplying the physical quantities (hectares, numbers, etc. in the base year and in 2030 and 2050) with an average unit cost expressed in constant 2009 United States dollars. Although the calculations are undertaken on the basis of 93 individual developing countries, specificity for unit costs and depreciation periods is limited to regional averages. Of the 26 capital items, 14 relate to primary agriculture (including some non-conventional ones, such as establishment of permanent crops, herd increases and working capital) and 12 to the agricultural downstream sector (see Box 8.2 for a list of the capital items).

Investment in agricultural downstream activities covers storage, processing and marketing of agricultural products. These are included for the sake of completeness, although they may not always be entirely attributable to agriculture and agricultural development. Investments related to manufacturing and distribution of agricultural inputs such as fertilizer are not included, and expenditures on agricultural research could not be estimated as part of the investment requirements. For all investment items – in both the primary and the downstream sectors – unit costs are identified. Obviously, the absolute levels of investment requirements are contingent on factors such as the assumed unit costs, the capital (input) absorbed per unit of agricultural activity, or the assumed life span of a capital item.[2]

Depreciation and gross investment

Additions to capital stocks between the base year (2005/2007) and 2030 and 2050 amount to the cumulative net investment requirements over the projection period. Requirements for replacement investment are then derived for the capital goods that must be replaced periodically. For each capital item, a specific lifetime is identified. For example, permanent crops are assumed to have a life span of 25 years, and tractors one of 15 years. For many capital items, replacement investments exceed net investments. Estimates for replacement investment are added to the net requirements, to obtain estimates of gross investment (see Box 8.3 for a summary explanation).

Country coverage

Capital stock and investment calculations are performed for the 93 developing countries covered in the FAO 2006 study (see list of countries in Annex 8.1; note that Central Asian countries in transition are not included).

2. Investments in physical units are generally more robust than those in monetary terms, as it is difficult to assemble appropriate unit value costs for the various investment items.

Box 8.2 - Capital items included

Crop production:

Development of arable land under crops
Soil and water conservation
Flood control
Expansion and improvement of irrigation
Establishment of permanent crops: citrus, other fruits, oil-palm, coconuts, cocoa, coffee, tea and rubber
Mechanization: tractors and equipment
Other power sources and equipment: increase in number of draft animals, equipment for draft animals, hand tools
Working capital: 50 percent of the increase in the cost of fertilizer and seed

Livestock production:

Increase in livestock numbers: cattle and buffaloes, sheep and goats, pigs, poultry
Housing and equipment for commercial production of pigs and poultry
Development of grazing land

Downstream support services:

Investment in milk production and processing
Investment in meat production and processing
Dry storage: cereals, pulses, oilseeds, cocoa, coffee, tea, tobacco and sugar
Cold storage: bananas, fruits and vegetables, livestock products
Rural marketing facilities
Assembly and wholesale markets for fruits and vegetables
Milling of cereals
Processing of oilseeds, sugar crops, fruits and vegetables
Ginning of seed cotton
Other processing

Endogeneity and technology shifts

The projections of future investment needs are linked to and derived from the projections of 40 individual agricultural production activities, assuming certain technologies and/or complete technology packages (frontiers). Over an outlook horizon of more than 40 years, investment requirements will not be defined by only a given, current state of technology, but will encompass shifts to new frontiers. Depending on factors such as the farm size or opportunity costs of farm labour, farmers will shift to new technology levels. Although important, these shifts have not been explicitly taken into account. Instead, links have been established indirectly by associating output levels (e.g., crop yields) with a certain package of input requirements; in many cases, this is done in a step-wise linear manner that is meant to emulate the shifts in technology (for a description of this approach, see Bruinsma *et al.*, 1983). To make assumptions more transparent, and these technology shifts more explicit, future revisions will therefore attempt to include such frontier shifts directly, with links to changes in the overall level of development and/or farm size.

Box 8.3 - Derivation of investment requirement estimates

The projections to 2050 cover 40 agricultural production activities (34 relating to crop production and six to livestock production) in 93 developing countries. Each activity draws on certain amounts of current inputs and capital stock services.

For each of the 26 capital items distinguished, the value of capital stock CS is calculated for each year covered in the model (t = 2005/2007, 2010, 2015, 2030 and 2050), multiplying the physical quantity Q (hectares, numbers, etc.) with an average unit cost P, expressed in 2009 United States dollars.

For each capital item, the net investment in any year is defined as the net increase in the value of capital stock over that year, or as the growth of capital stock g times capital stock CS at the beginning of the year. The growth rate is estimated as the annual growth of capital stock over the period preceding the year in question (except for the base year):

$$I_t^n = g_t \cdot CS_t \qquad (1)$$

Replacement investment in any year t is equal to the gross annual investment of L years earlier, where L is the economic life of the capital good in question. Gross annual investment is defined as the sum of net annual investment and replacement investment in the same year:

$$I_t^g = I_t^n + I_{t-L}^g \qquad (2)$$

Equation (2) can be approximated as:

$$I_t^g = \frac{I_t^n}{1 \quad (1+g_t)^{-L}} \qquad (3)$$

Cumulative net investment over any of the periods distinguished in the model (2005/2007 to 2010, 2010 to 2015, 2015 to 2030, and 2030 to 2050) is defined (and calculated) as the net increase in capital stock over that period:

$$CI_t^n = CS_t - CS_{t-1} \qquad (4)$$

Cumulative gross investment is defined (and calculated) in a manner similar to annual gross investment:

$$CI_t^g = \frac{CI_t^n}{1-(1+g_t)^{-L}} \qquad (5)$$

Total annual and cumulative net and gross investments are simply derived by adding up the 26 capital items.

Public and/or private

No distinction is made regarding the potential source of the required capital. The amounts therefore include all potential sources: private and public, and of both foreign and domestic provenance. The way capital stocks are currently financed suggests that the largest part of total investments comes from private domestic sources, and the selection of capital items in this assessment suggests that private sources (domestic and foreign) would be the prime source of capital, at least if it is assumed that public investments should be limited to activities where public goods are produced (hunger and poverty reduction, environmental sustainability, social cohesion, etc.). The public sector can play a role either in funding these investments directly or by helping link, pool and promote private flows. Typically, such investments include the creation and maintenance of infrastructure, large-scale irrigation schemes, or research and development (R&D) of new crop varieties and animal breeds. Depending on the level of public engagement, these investments can help attract further private flows (crowding in) or, if too massive, replace private engagement (crowding out). Private-public partnerships would aim to maximize the former and minimize the latter.

The results

Projected capital stocks and investment needs

Provisional results regarding investment requirements for primary agriculture and its downstream industries in developing countries show that the total over the 44-year period 2005/2007 to 2050 could amount to almost USD 9.2 trillion (2009 dollars), 46 percent of which will be for primary agriculture and the remainder for support services (Table 8.1). Within primary agriculture, almost a third (31 percent) of all capital needs will stem from projected mechanization needs, and almost a quarter (23 percent) from further expansion and improvement of irrigation.

Broken down by type of investment, 60 percent, or USD 5.5 trillion, will be needed to replace existing capital stocks, the other 40 percent, or USD 3.6 trillion, will be growth investments, and thus net additions to the existing capital stock. A detailed account of sector-specific investment projections is available in Annex 8.2.

The share of investments in primary agriculture is expected to fall in all regions, again at considerably different rates. Investments in downstream activities are expected to rise in all regions. Perhaps surprisingly at first sight, the fastest growth in downstream activities is expected for sub-Saharan Africa, albeit from a relatively low absolute level. This region's food system is the least mature, and growth reflects a gradual move away from a heavy reliance on primary production only. East Asia, by contrast, already has the most mature system, with higher levels of grain, sugar, meat and milk processing, so exhibits the smallest non-primary growth, but at much higher absolute levels (Figure 8.1).

Table 8.1
Cumulative investment from 2005/2007 to 2050 (billion 2009 USD)

	Net	Depreciation	Gross
Total for 93 developing countries	3 636	5 538	9 174
Total in primary production	1 427	2 809	4 236
Crop production	864	2 641	3 505
Land development, soil conservation and flood control	139	22	161
Expansion and improvement of irrigation	158	803	960
Establishment of permanent crops	84	411	495
Mechanization	356	956	1 312
Other power sources and equipment	33	449	482
Working capital	94	0	94
Livestock production	562	168	731
Herd increases	413	0	413
Meat and milk production	149	168	317
Total in downstream support services	2 209	2 729	4 938
Cold and dry storage	277	520	797
Rural and wholesale market facilities	410	548	959
First-stage processing	1 522	1 661	3 182

Source: Authors' calculations.

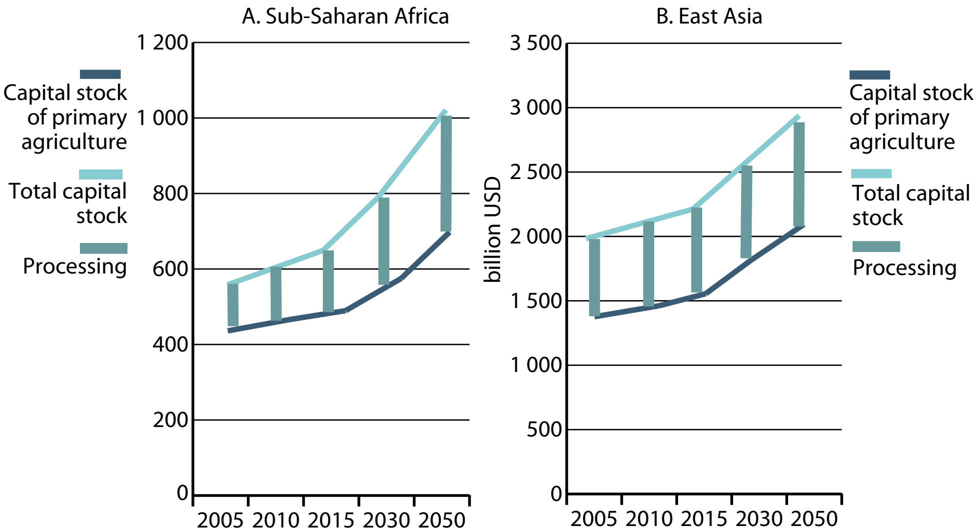
Table 8.2
Growth rates of agricultural production (percentages per annum)

Region	1961–2007	1981–2007	1991–2007	2005/2007–2030	2030–2050	2005/2007–2050
Developing countries	3.5	3.6	3.5	1.8	1.1	1.5
excluding China and India	3.0	3.0	3.1	2.1	1.4	1.8
Sub-Saharan Africa	2.6	3.3	3.1	2.7	1.9	2.3
Near East and North Africa	3.0	2.7	2.5	2.1	1.3	1.7
Latin America and Caribbean	3.0	3.0	3.4	2.1	1.2	1.7
South Asia	2.8	2.8	2.4	2.0	1.3	1.6
East Asia	4.3	4.5	4.3	1.3	0.6	1.0

Source: Authors' calculations.

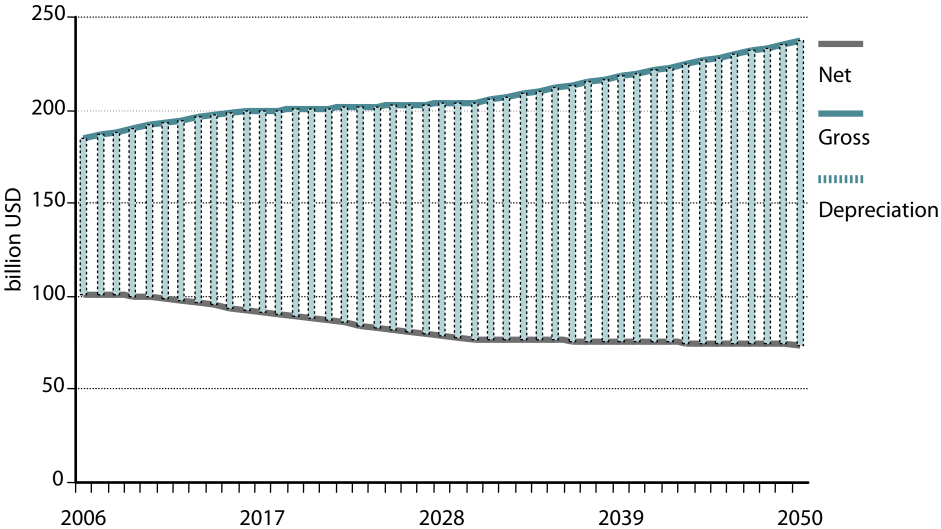
A striking feature of the outlook is that the annual net additions to capital stock (growth investments) exhibit a noticeable decline over time and result in a slowdown in the annual net capital requirement. Growth investments account for an average of 40 percent of total investments, 55 percent at the beginning of the projection period and merely 30 percent towards 2050 (Figure 8.2). For the aggregate of developing countries as a whole, this reflects a number of factors.

Figure 8.1
Capital stocks in primary agriculture and downstream industries, sub-Saharan Africa and East Asia



Source: Authors' calculations.

Figure 8.2
Total annual (public and private) investment requirements in developing countries



Source: Authors' calculations.

First, a declining incremental production need (Table 8.2), driven by declining population growth and growing satiation levels of per capita consumption of food and fibre, also drives down incremental investment needs. For developing countries as a whole, overall agricultural production grew at a rate of 3.5 percent per year over the last 46 years, and is expected to grow at less than half that rate over the next 44 years. Second, while the decline in production dynamics supports the projected slowdown in capital needs, there will be a countervailing shift towards more capital-intensive forms of production and a growing replacement of labour by capital. This explains the more moderate decline in incremental capital needs than is suggested by the expected levelling of output growth. And third is the impact of a change in the overall efficiency of input use, or total factor productivity (TFP). This is derived as the residual element of output growth that cannot be explained by growing input use, i.e., by either changes in labour or changes in capital and land. Although no TFP accounting is available for the past, future TFP growth is expected to be moderately positive for developing countries as a whole, albeit at rates that vary considerably across regions.

For the aggregate of all developing countries, the relative importance of these factors (from 2005 to 2050) renders the following shares of (net) change: capital, + 71 percent; agricultural labour, - 16 percent; land use, + 25 percent; and TFP, + 20 percent.[3] This suggests a moderate decline in the role of labour inputs and an equally moderate replacement of labour with capital. Obviously, the aggregate hides vastly divergent developments in the various regions; for instance, there is a much larger substitution of capital for labour in Latin America (capital, + 62 percent; labour, - 73 percent; land, + 49 percent; and TFP, + 62 percent) and no such shift at all in sub-Saharan Africa (capital, + 48 percent; labour, + 59 percent; land, + 28 percent; and TFP, - 35 percent). Put colloquially, sub-Saharan Africa would continue to grow by "transpiration", while Latin America could grow further by efficiency gains or "inspiration".

A breakdown by region suggests that Asia would account for the largest part of global investment needs (57 percent); China and India alone account for some 40 percent. Latin America would absorb about 20 percent of capital needs, and sub-Saharan Africa and the Near East and North Africa for the remaining 23 percent (Table 8.3). Asia's high share reflects the region's large agricultural base, its high overall output and its relatively capital-intensive forms of agricultural production (irrigation, mechanization, terracing, etc.). However, growth rates for Asia would be more modest. This is in stark contrast to sub-Saharan Africa, where the overall level of investment requirements is expected to be relatively modest – reflecting

3. The underlying growth accounting approach applied here assumes a uniform, constant real wage across all income strata.

the region's generally labour-intensive, capital-saving forms of production – while growth rates are projected to be higher, reflecting a very gradual shift to a more capital-intensive form of agriculture and moderately rising per capita production levels driven by a doubling of the region's population and consumer base.

Table 8.3
Cumulative investment from 2005/2007 to 2050

Region	Net	Depreciation	Gross: Crop production	Gross: Livestock production	Gross: Support services	Gross: Total	Share
	(billion 2009 USD)						(%)
93 developing countries	3 636	5 538	3 505	731	4 938	9 174	100
excluding China and India	2 427	3 169	2 184	384	3 029	5 596	61
Sub-Saharan Africa	479	462	319	83	539	940	10
Latin America and Caribbean	842	962	528	127	1 149	1 804	20
Near East and North Africa	451	742	619	45	529	1 193	13
South Asia	843	1 444	1 024	123	1 139	2 286	25
East Asia	1 022	1 928	1 015	353	1 582	2 950	32

Source: Authors' calculations.

Broken down into annual instalments over the 44-year outlook period, the total gross needs of USD 9.2 trillion amount to annual capital requirements of nearly USD 210 billion. A larger share of the net investment requirements will occur in the early years and decades of the outlook, reflecting (among other factors) higher incremental investment needs in these years. Thereafter the slowdown in production growth will be reflected in a levelling-off of incremental investment needs. This "front-loading" effect could have important policy implications and lend itself to important policy messages.

As indicated, this chapter does not provide an assessment of public versus private financing from either domestic or foreign sources. If current private and public shares were to be applied to the projections, 70 percent, or USD 150 billion, of the USD 210 billion would come from private sources, and the remaining 30 percent, or USD 60 billion, would have to be provided by public sources, both foreign (official development assistance [ODA]) and domestic.

Performance indicators for agricultural production, capital stocks, labour and land

How much will be produced, and by whom?

In 2005, East Asia alone accounted for nearly half the developing world's agricultural output. Measured in international commodity prices,[4] USD 554 billion dollars came from East Asia, followed by Latin America and South Asia, each producing an annual agricultural output of USD 210 to 215 billion, with the Near East and North Africa producing only USD 95 billion, and sub-Saharan Africa only USD 98 billion (Table 8.4).

Table 8.4
Gross value of agricultural production

Region	2005	2030	2050	2050/2005
	(billion 2004/2006 international dollars)			*(ratio)*
Developing countries	1 172	1 784	2 207	1.88
Sub-Saharan Africa	98	182	263	2.69
Latin America and Caribbean	210	343	436	2.08
Near East and North Africa	95	155	200	2.11
South Asia	216	356	459	2.12
East Asia	554	748	848	1.53

Source: Authors' calculations.

A look at the long-term growth path to 2050 suggests a dynamic that is quite different from current rates and levels. Sub-Saharan Africa, currently the region with about the lowest agricultural output, is expected to show the fastest growth, and could nearly triple its production to USD 263 billion by 2050. In contrast, East Asia, currently the largest producer, may see an increase of only 53 percent (Table 8.4). This reflects the fact that sub-Saharan Africa has to meet the food needs for the largest population increase of all regions, and may do so from its own agricultural production base. East Asia is expected to see only a very modest overall growth in its population to 2050, falling to zero growth between 2030 and 2050. Moreover, the region has already attained relatively high per capita consumption levels (2 870 kcal per day in 2000), which are expected to rise only moderately to levels somewhat above 3 200 kcal per day. Like sub-Saharan Africa, it may feed its population from its own agricultural resources, with self-sufficiency declining only very moderately. The only region that is expected to step up production significantly beyond its own needs is Latin America, with self-sufficiency rates projected to rise from 118 to 130 percent; Latin America will thus cover the moderately growing deficits of all other regions.

4. International commodity prices are used to avoid the use of exchange rates to obtain country aggregates, and to facilitate international comparative analysis of productivity. These international prices, expressed in "international dollars", are derived using a Geary-Khamis formula for the agriculture sector. This method assigns a single price to each commodity. For example, 1 tonne of wheat has the same price, regardless of the country where it was produced.

To meet these production increases, the various regions will have to put more money into agriculture and mobilize more capital, land and labour. The amounts of additional resources the various regions will commit and the roles that incremental capital, land and labour will play are discussed in the next subsection. The starting point for this analysis is the expected output per person, which serves as the basis for discussion of how efficiently land, labour and capital will be used. This discussion is based on an outlook for labour and capital intensity of production, and explores the scope and limits of agriculture in creating incomes and helping reduce poverty.

Output per person

From a developmental perspective, the most important indicator[5] is probably the evolution of agricultural output per person employed in agriculture – the agricultural gross value of production per capita (AGVP/PC). It is a first proxy for how much revenue people employed in agriculture generate and how revenues will evolve over the long run to 2050. It also provides hints as to how large a contribution agriculture will make to overall poverty reduction, and how rapidly the agricultural transformation is likely to evolve.

Table 8.5
Gross value of production per agricultural labourer

	2005	2030	2050	2050/2005
Region	*(billion 2004/2006 international dollars)*			*(ratio)*
Developing countries	882	1 319	1 844	2.09
Sub-Saharan Africa	475	587	700	1.47
Latin America and Caribbean	4 993	10 405	18 173	3.64
Near East and North Africa	1 827	3 157	4 888	2.68
South Asia	575	836	1 230	2.14
East Asia	845	1 398	2 221	2.63

Source: Authors' calculations.

A first inspection of the levels and trends of output per labourer across regions reveals vast divergences (Table 8.5). In 2005, by far the highest level of agricultural output per person was attained in Latin America, and despite these high initial levels no slowdown in growth per agricultural labourer is expected for the region. On the contrary, agricultural output per person is projected to rise faster than in any other region, nearly quadrupling to USD 18 173 per person by 2050. At the other end of the spectrum, in sub-Saharan Africa, output per agricultural labourer

5. Ideally, performance should be measured as gross margins (returns on variable costs) or net margins (returns on total costs) of production; however this would require a complete accounting for the variable and fixed costs of production.

is the lowest today and will remain the lowest by far over the next decades. The gap between sub-Saharan Africa and all other regions is even expected to widen, as AGVP/PC is expected to grow by less then 50 percent in 45 years.

This raises questions as to what drives these divergent regional trends and what the different paths mean for poverty reduction through agriculture. The first question can only be answered by analysing the trends in the underlying variables. The two factors involved are trends in the overall value of output and trends in the evolution of the agricultural labour force.

Table 8.6
Aggregate self-sufficiency rates (percentages)

Region	2005	2050
Developing countries	99	99
Sub-Saharan Africa	97	95
Latin America and Caribbean	118	130
Near East and North Africa	79	78
South Asia	99	98
East Asia	94	91

Source: Authors' calculations.

Growth in overall agricultural output will be highest in sub-Saharan Africa. As discussed, this reflects high growth in consumption and the fact that much of the added need is expected to be met by domestic production. Self-sufficiency is expected to decline only moderately, from 97 percent in 2005 to 95 percent in 2050 (Table 8.6). Output may also rise in Latin America, albeit less rapidly and predominantly for export markets, to make up for the slightly rising deficits of other regions. This means that the difference in the growth of output per worker is almost entirely due to changes in the agricultural labour force. The agricultural labour force of sub-Saharan Africa is projected to nearly double by 2050, while it will fall by nearly half in Latin America, to 24 million (Table 8.7).

The mere numerical description of these trends does not allow any inferences to be drawn on the desirability of the associated development paths. However, it can be concluded that even the near tripling of agricultural output in sub-Saharan Africa will not make a significant difference in revenues per person working in agriculture. When combined with the outlook for capital stocks (Table 8.8) and land available per labourer (Table 8.9.), it can also be concluded that too many people will remain dependent on a labour-intensive, capital-saving form of small-scale agriculture.[6] The poverty reduction potential of this form of agriculture remains limited because too many farmers will have too few revenues to share.

6. The capital stock available per worker will not increase in sub-Saharan Africa, while it will triple in Latin America (Table 8.8).

This is not to suggest that poverty reduction efforts and strategies should ignore small-scale agriculture. On the contrary, as more than 70 percent of the poor reside in rural areas and most depend on small-scale agriculture, poverty reduction strategies should start from and fully embrace small-scale farmers (UNDP, 2005). However, while a smallholder structure is the starting point for poverty reduction, it cannot be an objective in its own right, particularly in sub-Saharan Africa. For one thing, the expected growth in this region's domestic food markets is too limited to engender improved incomes for a growing number of farmers; for another, agricultural export markets would remain elusive for an undercapitalized form of small-scale agriculture. If market potential is limited to food needs, new markets (e.g., energy markets), new non-market income possibilities (payments for carbon offsets, climate change mitigation programmes, payment schemes for environmental services), or strategies for a complete exit from agriculture need to be found to generate income possibilities for the region's young and rapidly growing labour force.

Table 8.7
Agricultural labour force

	2005	2030	2050	2050/2005
Region		*(million people)*		*(ratio)*
Developing countries	1 330	1 353	1 197	0.90
Sub-Saharan Africa	206	310	376	1.83
Latin America and Caribbean	42	33	24	0.58
Near East and North Africa	52	49	41	0.79
South Asia	376	426	373	0.99
East Asia	655	535	382	0.58

Source: FAO Statistics Division.

The poverty reduction potential will also not be significant in Latin America's large-scale agriculture, at least not in absolute terms. Too few people in the agriculture sector today are in need of being brought out of poverty in the future. Those remaining in agriculture will produce enough agricultural output to make a living from it. In tandem with this rising output per person, Latin America will continue to pursue its current export orientation. The overall rate of self-sufficiency is expected to rise from 118 to 130 percent by 2050 (Table 8.6). The region will continue and even expand its role as the world's agricultural powerhouse, making up for the less dynamic growth in other regions.

An alternative way of attaining higher incomes and ensuring livelihoods, although not explored in this chapter, would be to raise revenues not covered by agricultural production. Options would include revenues raised from the provision of environmental services, particularly contributions to greenhouse gas abatement and the entry into the carbon market. It is important to note that agriculture, which accounts for more than 30 percent of greenhouse gas emissions (including through deforestation), is not only one of the main sources of emissions, but also has significant potential for climate change mitigation. Funds raised from these alternative sources could help farmers adopt carbon-saving production technologies, reducing the carbon footprints of traditional technologies while increasing the productivity and profitability of agricultural production. Promising options include a shift to no-tillage and conservation agriculture, more efficient milk and ruminant meat production systems (FAO, 2006a), or a transition from paddy to upland rice production.

Another income source could be increased production of agricultural feedstocks for the energy market. The energy market is so large that such production would not be subject to demand constraints and would allow more farmers to draw revenues from otherwise increasingly saturated markets. For small-scale farmers, bioenergy could help overcome the on-farm power constraint, the factor that often limits agricultural productivity growth the most. For larger-scale farmers, bioenergy offers new potential to produce for a market that is, in essence, characterized by perfectly elastic demand and that will absorb any incremental production, as long as agricultural feedstocks are competitive as inputs into the energy market – i.e., as long as energy prices are above parity prices in the energy market. This necessitates high energy prices. The perfectly elastic demand also means that food prices would be determined by energy prices and that poor food consumers could be priced out of food markets by less elastic energy consumers.

The success of such diversification into new agricultural activities will be contingent on whether or not smallholder agriculture has a comparative advantage for these new markets. Typically, smallholder agriculture is labour-intensive, capital-saving and, particularly, deficient in expertise. In contrast, many of the emerging income options require expertise and capital, and seldom require unskilled labour. Tapping into carbon offset schemes under the Clean Development Mechanism (CDM), for instance, is mostly limited to large projects and large farmers, and a large share of these CDM projects have been granted to large holdings or agricultural industries in Latin America. The administrative hurdles of such schemes are too onerous for smallholders to meet. Commercial bioenergy production is also highly expertise- and capital-intensive; for instance, Brazilian ethanol production has become more profitable as it becomes more labour-saving. The discrepancy between the factor needs and factor endowments of smallholders means that they are unlikely to have a comparative advantage for these alternative income sources; in fact, their factor endowment is precisely the opposite of the factor requirements needed for such activities.

Options for overcoming a lack of capital and expertise exist. One would be to improve or establish the institutional setting that allows a pooling of smallholder resources, to create enough human and financial capital to overcome the resource limits. Cooperatives can play an important role in pooling resources; public investments can support and foster these efforts. There are numerous examples of successful resource pooling, particularly for new bioenergy projects. In Thailand, for instance, 4 000 farmers pooled their resources in a cooperative for setting up a cassava-based bioethanol project in the Chok Chai district of Nakhon Ratchasima; through the country's Agricultural Cooperative Federation they even established a joint venture with a USA-based energy company, to overcome remaining capital constraints and attract the necessary expertise to operate a large-scale ethanol plant.

These examples suggest that the comparative disadvantages of small-scale farming in new market opportunities could be overcome, and that the new markets could be tapped by small-scale operators if their resources are pooled. In turn, this would require a strengthening of rural institutions, and thus public investments. The greatest needs, but also the greatest potentials, for institutional improvements lie in sub-Saharan Africa.

Why will outcomes be so different?

An important factor that helps explain differences in the output per worker is the capital stock available per labourer. Taking the two extreme cases of Latin America and sub-Saharan Africa, the estimates summarized in Table 8.8 suggest that a farm worker in the former region has, on average, ten times as much capital available than a farm worker in the latter. Behind the abstract aggregate of capital per farmer are a large range of tools and equipment that make agriculture in Latin America so much more productive than in Africa. These tools include more and better mechanization, tractors, tillers and combines, irrigation, storage and processing plants, and other elements of an efficient downstream sector. Although not included in the estimates, Latin American farmers also have far more support capital in better infrastructure, research institutions, roads and electricity. Equally important is the reliability of these supplies, rendering fewer off-hours because of interruptions in electricity supplies or irrigation water availability. For instance, rural roads per hectare amount to 0.017 km in Latin America compared with 0.007 km – less than half – in sub-Saharan Africa. Rural electricity supplies per worker are 50 times higher in Latin America than sub-Saharan Africa.

The outlook to 2050 suggests that the interregional differences in capital stocks per worker are likely to become more pronounced. Capital stocks per worker will roughly double in East Asia, South Asia and the Near East and North

Africa, while they will triple in Latin America and completely stagnate in sub-Saharan Africa. This means that by 2050 a worker in Latin America will have 28 times as much capital available as a worker in sub-Saharan Africa. These huge differences in capital intensity are at the heart of differences in the current output per worker and the divergent growth paths the two regions are expected to take.

Table 8.8
Capital stock per worker

	2005	2030	2050	2050/2005
Region	*('000 2009 USD/person)*			*(ratio)*
Developing countries	4.28	5.72	7.68	1.79
Sub-Saharan Africa	2.78	2.62	2.77	1.00
Latin America and Caribbean	25.24	45.70	77.77	3.08
Near East and North Africa	11.61	17.33	25.41	2.19
South Asia	3.88	4.59	6.10	1.57
East Asia	3.06	4.87	7.67	2.51

Source: Authors' calculations.

As discussed, critical elements in the divergent developments of labour productivity across regions include the diversity of developments in the agricultural labour force. Latin America, for instance, will almost halve its labour force, while sub-Saharan Africa will nearly double its. The importance of this effect can be seen when agricultural output is related to land rather than labour (Table 8.9).

Table 8.9.
Harvested land per worker

	2005	2030	2050	2050/2005
Region	*(ha/person)*			*(ratio)*
Developing countries	0.69	0.75	0.90	1.30
Sub-Saharan Africa	0.86	0.68	0.63	0.73
Latin America and Caribbean	3.47	5.53	8.62	2.49
Near East and North Africa	1.41	1.50	1.87	1.33
South Asia	0.60	0.56	0.65	1.08
East Asia	0.45	0.57	0.81	1.80

Source: Authors' calculations.

Output per hectare in Latin America is only 2.5 times higher than it is in sub-Saharan Africa, and somewhat lower than it is in East Asia. However, by 2050, a worker in Latin America will be cropping twice as much land, while arable land available per labourer will shrink in sub-Saharan Africa. This again raises the question of how sustainable the outlook is for sub-Saharan Africa, if agriculture continues to be based on a farming system in which a limited resource base has to be shared among a rising number of resource users. Even if the basis of the argument is largely arithmetical, small-scale agriculture is unlikely to provide much revenue generation and poverty reduction. Another question that arises is whether agricultural development in sub-Saharan Africa needs to be combined with exit strategies, to ensure that fewer people are left in the sector and that they have enough resources to generate sufficient income.

What bang for the buck? Incremental capital output ratios and investment rates in primary agriculture

In an increasingly globalized world, private investors, development planners and policy-makers are interested in identifying investment opportunities in agriculture at home and abroad. A broad and easy-to-calculate indicator that helps address this issue is the incremental capital output ratio (ICOR). High ICORs suggest that increases in agricultural output require high investments, and vice versa.

Table 8.10
Average ICORs and investment rates in primary agriculture, 2005/2007 to 2050 (percentages)

Region	Investment as share of AGVP	Inputs as share of AGVP[a]	Investment as share of agricultural GDP	ICOR
Developing countries	6.7	27	9.2	6.3
excluding China and India	7.5	27	10.3	5.8
Sub-Saharan Africa	6.2	11	6.9	3.1
Latin America and Caribbean	5.7	29	8.0	4.8
Near East and North Africa	11.4	40	19.0	11.1
South Asia	9.0	28	12.5	7.2
East Asia	5.2	28	7.2	7.4

[a] From Alexandratos, 1988.

Comparison of the ICORs across regions (Table 8.10) suggests that changes in agricultural capital stocks are expected to render fairly different levels of agricultural output across the main developing regions. By far the highest ICORs (averaging more than 11) are projected for the Near East and North Africa, while by far the lowest (averaging just over 3) are expected for sub-Saharan Africa. In both regions, the expected ICORs are consistent with current factor endowments and expected factor returns. High ICORs for the Near East and North Africa reflect the high level of capital intensity that this region has already attained, leaving it with few options for stepping up production through an easy expansion of cropland or irrigation water use. In fact, the Near East and North Africa has virtually exhausted its agricultural land base and is also approaching the limits of its renewable water resources. This makes further increases in production a capital-intensive endeavour and ultimately implies low returns on future additions to the existing capital stock. Extreme examples include agricultural production systems that use groundwater mining or water supplies from energy-intensive desalinization plants; ICORs are particularly high where investments have been geared towards low-value outputs such as cereals and other food staples. The unit production costs of such farming systems often exceed international commodity prices by multiples, and can only be sustained with exorbitantly high subsidies.

From a planning and policy perspective, this suggests that further expansion of production in the Near East and North Africa has to be weighed against alternatives such as increased imports of agricultural goods or investments in foreign capital stocks and cropland. While the region has focused on imports for a long time, it has recently also pursued the option of securing domestic supplies through foreign direct investment in other regions.

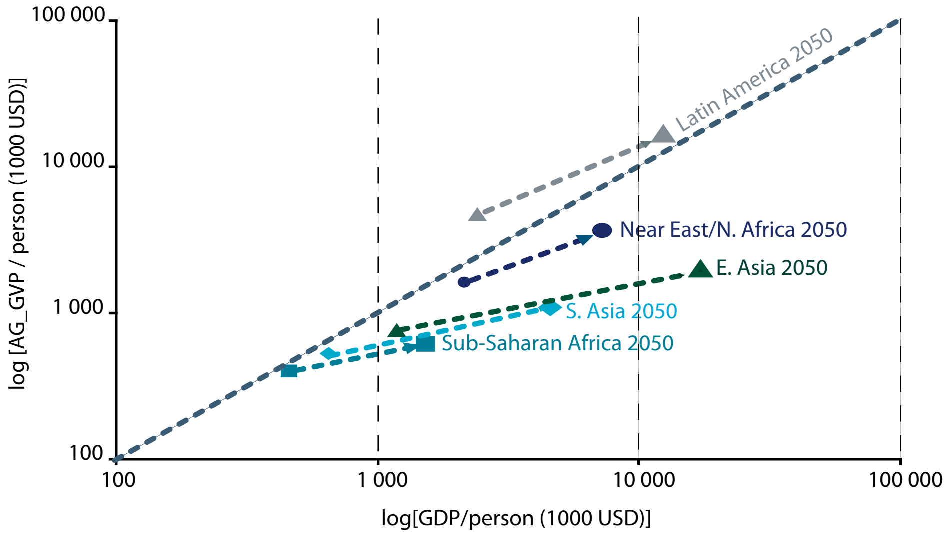
Inspection of the ICORs in other regions (Table 8.10) helps explain why many of these new investments are currently directed to sub-Saharan Africa. The low ICORs of just over 3 suggest that incremental capital invested in sub-Saharan African agriculture will render nearly four times as much as investments in the Near East and North Africa. This is consistent with African agriculture's abundant land and labour combined with a shortage of the capital (both working and fixed) needed to make the existing land and labour base more productive.

How will farm revenues perform compared with non-agricultural incomes?

As outlined in the previous subsection, the trends in future farm revenues exhibit vast differences across regions, and people dependent on agriculture in the various regions will see vastly different growth potentials for their agricultural incomes. A crucial question regards whether or not the projected revenue paths for agriculture are more or less favourable than those outside agriculture, or – more precisely – whether they are more or less favourable than those of the average income earner (agricultural and non-agricultural combined).

The agricultural and non-agricultural income trajectories are compared in Figure 8.3, which depicts three important features of the projected income trajectories for the various regions. First, the horizontal extension of the paths captures the projected income growth for each region. It suggests that East Asia's income growth per person is expected to be much higher than that in any other region; for example, it is expected to be three times that of sub-Saharan Africa, and the overall picture suggests a continuation of the growth patterns seen over the last three decades. Income growth is also projected to be high in South Asia, followed by Latin America and the Near East and North Africa. The second feature is captured by the slope of the trajectories. The steeper the slope, the higher the agricultural growth prospects relative to overall growth. A slope steeper than the 45° diagonal denotes that agriculture outperforms the average for the region. Clearly, this is not expected in any of the regions; instead, trajectories are flat for all regions, and move further away from the 45° diagonal as 2050 approaches. This unequal growth is particularly pronounced for all regional aggregates of sub-Saharan Africa and Asia. The third feature stems from the location of a trajectory above or below the diagonal; this denotes whether agricultural incomes are above or below average incomes, for both the starting and the end years. As can be seen immediately from Figure 8.3, the only region where agricultural incomes are above average incomes is Latin America, while the reverse is the case for all other regions. Even for Latin America, it should be noted that the vertical axis depicts AGVP rather than agricultural GDP, i.e., agricultural incomes are overstated by the amount of working capital employed. Given the relatively advanced stage of agriculture in Latin America, the effect of income overestimation could be considerable; taking this into account, it is probable that agricultural incomes are not above average incomes in any region, in either the base year or 2050.

Figure 8.3
Regional income trajectories: agricultural versus non-agricultural, 2005 to 2050



Source: Authors' calculations.

In summary, this means that the projected income trajectories suggest a largely negative outlook for agriculture. In no region will agricultural labourers be able to accomplish the same income growth as their peers outside agriculture. The only exception is Latin America, where farm revenues are slightly higher than average incomes, and growth rates in farm revenues, on average, just match those of the region's economy. The outlook also suggests a growing divergence between agricultural and non-agricultural incomes, and thus probably an even stronger concentration of poverty in rural areas. The results are likely to understate the true agricultural versus non-agricultural income gap for two reasons. First, agricultural income growth is compared with average income growth; where agriculture accounts for a large share of the total economy, the difference between agricultural and non-agricultural incomes is likely to be larger than it appears in the results. Second, the population projections for agriculture refer to the agricultural labour force, which is a subset of the overall agricultural population; if agricultural incomes were divided over the larger agricultural population, this would widen further the gap with non-agricultural incomes.

It must be emphasized that these results are only preliminary; they need to be vetted and confirmed with projections for agricultural GDP, rather than just those for AGVP. The growing divergence may also bring to the fore a possible shortcoming of the underlying partial equilibrium approach. Past developments show that considerable, and even growing, rural/urban income differences can persist over extended periods, but a growing income divergence over more than four decades may become untenable, and suggests that hitherto exogenous assumptions, such as the projections for agricultural labour force or even general population projections, may need to be endogenized. Rising income gaps would ultimately raise the pressure to leave rural areas (push), and attract cheap labour to more remunerative urban areas and non-farm environments (pull).

The prospect of a widening income gap between farm and non-farm incomes has also given rise to new initiatives for providing support to developing country farmers. FAO is currently examining various possibilities of such support measures; the decisive criterion for these measures is that they help farmers to catch up with the average incomes in an economy or region, without introducing new or augmenting existing measures that distort international competition, resource allocation and trade. The scope, options and limits of such measures were discussed at the Summit on World Food Security in November 2009.

Summary and conclusions

Cumulative gross investment requirements for developing countries' agriculture add up to a total of nearly USD 9.2 trillion over the 44 years from 2005/2007 to 2050. This amount would be necessary to remain consistent with FAO's long-term outlook for global agriculture (FAO, 2006b).

Broken down by type of investment, more than USD 5.5 trillion, or 60 percent of the total, will be required to replace the existing capital stock (or the new capital items that are added and subsequently depreciate over the 44 years to 2050); the rest, about USD 3.6 trillion, will be added to the existing capital stock to increase (nearly double) output and raise productivity. Broken down by activity, primary agriculture will account for about USD 4.2 trillion of the total, while the remaining USD 4.9 trillion will be absorbed by downstream needs (processing, transportation, storage, etc.). Within primary agriculture, mechanization will account for the single biggest investment item (31 percent), followed by expansion and improvement of irrigation (23 percent). The cumulative investments result in yearly averages of about USD 210 billion gross and USD 83 billion net. All estimates, gross and net, cumulative and annual, are in constant 2009 dollars.

A striking feature of the outlook is that annual net additions to the capital stock (growth investments) exhibit a noticeable decline over time, resulting in a slowdown in growth of the annual net capital requirement. These net investments account for 55 percent of the total at the beginning of the projection period, and for merely 30 percent towards 2050. The change in net investments reflects a number of factors. First, incremental production will need to decline alongside declining incremental needs. Partly offsetting this decline is a shift towards more capital-intensive forms of production, with a growing replacement of labour by capital. A third factor, again supporting the decline in net capital needs, is the somewhat higher overall efficiency of input use in the future.

Growth accounting results suggest that overall growth will be characterized by increasing substitution of labour with capital, and moderate TFP growth. However, there are marked regional differences; for instance, in Latin America growth will be capital- and productivity-based, with negative labour contributions, while in sub-Saharan Africa it will be heavily labour- and moderately capital-based, with limited efficiency gains.

The analysis of performance indicators suggests that there are marked regional differences in agriculture's capacity to generate incomes and reduce poverty. For instance, projections for the gross value of production suggest that revenues generated by an agricultural labourer in sub-Saharan Africa will rise by only 50 percent over the next four decades. The expected growth in food markets will not suffice to lift revenues significantly.

The analysis of expected revenues, capital stocks and land available per labourer suggests that too many people in sub-Saharan Africa will remain dependent on a labour-intensive, capital-saving form of small-scale agriculture, in which too many farmers will have to share too few resources and revenues. The poverty reduction potential in the projected revenue/capital stock trajectory in sub-Saharan Africa will thus be limited.

This raises questions regarding the alternative income sources that could be tapped. Emerging options include new opportunities arising from higher energy prices and the production of bioenergy feedstocks; income opportunities from the provision of environmental services; or a greater export orientation of production. All three growth options call for an expertise- and capital-intensive form of agriculture, and thus run counter to the factor endowment that characterizes Africa's smallholder structure. One option for overcoming these constraints would be to increase investments in resource-pooling institutions.

The available capital stock per worker was identified as an important explanatory variable for interregional differences in performance. A farmer in Latin America has on average ten times as much capital available as a farmer in sub-Saharan Africa. Behind the abstract aggregate of capital per farmer are a large range of tools and equipment that make agriculture in Latin America far more productive than in Africa. These include more and better mechanization, tractors, tillers and combines, irrigation, storage and processing plants, and other elements of an efficient downstream sector.

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Annex 8.1

Countries included in the analysis

Sub-Saharan Afirca

Angola	Democratic Republic of the Congo	Madagascar	Sierra Leone
Benin	Eritrea	Malawi	Somalia
Botswana	Ethiopia	Mali	Sudan
Burkina Faso	Gabon	Mauritania	Swaziland
Burundi	Gambia	Mauritius	Togo
Cameroon	Ghana	Mozambique	Uganda
Central African Republic	Guinea	Niger	United Republic of Tanzania
Chad	Kenya	Nigeria	Zambia
Congo	Lesotho	Rwanda	Zimbabwe
Côte d'Ivoire	Liberia	Senegal	

Latin America and the Caribbean

Argentina	Ecuador	Mexico	Suriname
Brazil	El Salvador	Nicaragua	Trinidad and Tobago
Chile	Guatemala	Panama	Uruguay
Colombia	Guyana	Paraguay	Venezuela
Costa Rica	Haiti	Peru	
Cuba	Honduras	Plurinational State of Bolivia	
Dominican Republic	Jamaica		

Near East and North Africa

Afghanistan	Islamic Republic of Iran	Libyan Arab Jamahiriya	Syrian Arab Republic
Algeria	Jordan	Morocco	Tunisia
Egypt	Lebanon	Saudi Arabia	Turkey
Iraq			Yemen

South Asia

Bangladesh	Nepal	Sri Lanka
India	Pakistan	

East Asia

Cambodia	Indonesia	Myanmar	Viet Nam
China	Lao People's Democratic Republic	Philippines	
Democratic People's Republic of Korea	Malaysia	Republic of Korea	
		Thailand	

Cumulative investment requirements for 2005/2007 to 2050, by region (billion 2009 USD)

	Sub-Saharan Africa			Latin America/ Caribbean			Near East/North Africa			South Asia			East Asia		
	Net	Depre-ciation	Gross	Net	Depre-ciation	Gross	Net	Depre-ciation	Gross	Net	Depre-ciation	Gross	Net	Depre-ciation	Gross
Total	479	462	940	842	962	1 804	451	742	1 193	843	1 444	2 286	1 022	1 928	2 950
Total investment in primary production	177	225	401	290	365	655	194	470	664	340	808	1 147	427	941	1 368
Crop production	101	218	319	183	345	528	151	468	619	223	801	1 024	206	809	1 015
Land development, soil conservation and flood control	45	3	48	44	4	48	5	1	7	21	5	25	25	9	33
Expansion and improvement of irrigation	14	31	45	28	69	96	52	215	267	28	236	265	36	251	288
Establishment of permanent crops	4	41	45	4	47	51	2	15	17	16	52	68	58	256	314
Mechanization	22	37	59	85	207	292	77	224	300	115	304	420	57	184	241
Other power sources and equipment	10	105	115	0	19	19	1	13	14	17	204	220	6	108	114
Working capital	6	0	6	22	0	22	15	0	15	26	0	26	25	0	25
Livestock production	76	7	83	107	20	127	42	3	45	117	6	123	220	133	353
Herd increases	67	0	67	85	0	85	37	0	37	96	0	96	128	0	128
Meat and milk production	9	7	15	22	20	42	5	3	8	21	6	27	93	133	225
Total investment in downstream support services	302	237	539	552	597	1 149	257	272	529	503	636	1 139	595	987	1 582
Cold and dry storage	41	37	78	96	88	184	20	46	66	55	109	164	65	240	305
Rural and wholesale market facilities	87	72	159	60	61	121	68	68	136	100	163	263	96	184	280
First-stage processing	174	129	302	396	447	844	169	158	326	348	364	712	435	563	998

Source: Authors.