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Documents

Integrated Assessment of Soil Degradation and Economic Growth in Ghana

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1 Introduction[1]

A decade of economic reforms has lifted the economy of Ghana to an average annual economic growth of 5 per cent. This is encouraging for an African country south of Sahara, but the average poor person will still remain below the poverty line for another 20 years if this growth rate prevails (World Bank, 1992). For the extremely poor it would take half a century to cross the poverty line. Hence, current policies aim at an acceleration of economic growth.

Ghana is endowed with rich natural resources, but current production technologies contain potential conflicts with conditions for sustainability in several economic activities. The most serious environmental problems in Ghana are soil degradation, deforestation and pollution from mining industries. An accelerated growth could challenge the resource base seriously unless emphasis is laid on technological improvement. Economic reforms to date have stimulated certain activities, like small scale mining relying so far on a seriously polluting production technology. Fortunately, reforms affect production technologies in other respects also. Rising farm gate prices might open up for introduction of more sustainable cultivation methods and reduced rates of soil nutrients extraction. On the other hand, a reduction of fertilizer subsidies as part of the reform may work opposite, keeping up the current soil mining. Also the actual wage level and pattern of growth may direct different degrees of pressure on resources, affecting population movements as well as choices of technologies which are more or less kind to the environment. A particular concern is with migration to the Western region where the forest reserves are located on soils fragile to farming.

The agricultural sector is generating a little less than 40 per cent of GDP, 60 per cent of export earnings and 70 per cent of employment in Ghana (World Bank, 1992). Even if mining industries and urban sectors grow considerably, a take off for the whole economy might still rely heavily on the achievements in the agricultural sectors. Agricultural surplus might be an important source of initial capital for investment in secondary activities. Also, agriculture more indirectly affects the dynamics of the growth process: Since poverty predominantly is a rural phenomenon in Ghana (World Bank, 1992), the role of agricultural growth becomes particular important to poverty alleviation by directly affecting the poorest, improve health via better nutrition and increase labour productivity and the susceptibility in a learning/modernization process. These effects are certainly of considerable importance, although this paper only deals with the narrow national account measures of growth. All in all an environmental drag on the productivity of food and export crops production might challenge the sustainability of economic growth in Ghana.

The agriculture in Ghana is dominated by low input - low output technology. As frequently is the consequence, nutrients are mined and the productivity of soil is being reduced, which in turn increases the land area necessary for subsistence cultivation or answering external demand. The agricultural frontier moves into forested areas and eats into forest capital representing sources of income for Ghana over a potentially infinite time horizon. Hence, the nutrients account of current soil management is crucial to development in several respects.

It is hard to tell what the net effect of all the interactions between environment and economy will be for Ghana. This analyses is focusing on land degradation and indirectly also the pressure on forest reserves. The paper presents a model for dealing with some central interactions between economy and soil degradation which are not explicitly reckoned with in general economic policy formation. Even when such environmental problems are taken into account, there are few quantitative

[1] This study has been funded by the Environment department, World Bank , Washington D.C.

assessments of how various degrees of environmental stress affects the growth capacity of the economy and vice versa.

A key to economywide modeling of environmental impacts associated with production activities is that environmental degradation is associated with too much or too little use of certain inputs in production or consumption. Therefore it is clearly an advantage to describe markets and production in appropriate disaggregated terms to reflect the various technologies as good as possible. However, the economywide approach sets limits to the feasible level of modeling. As a consequence, models should focus on certain central environmental issues where economic policy has considerable impact and interactions between the economy and environment is fairly robust.

A key variable in our approach is fertilizer use, which has a significant potential for rising yields immediately and to some extent also in future years due to recycling of plant residues and increased protection against soil loss. Efforts to compensate for the decline of soil productivity in Ghana by adding fertilizer or improve management practice has so far not been successful (World Bank, 1992). Fertilizer consumption declined from 40 000 tons in 1988 to 23 000 tons in 1991 after removal of fertilizer subsidies. Chemical fertilizer may be a convenient medium to apply to stimulate production and soil productivity when the introduction of improved soil management practices is time demanding. Within a market framework, enhancing fertilizer demand may serve as a beneficial second best policy which does not necessarily lead to inefficient allocation, excess use and water pollution, since the initial consumption is generally very low.

By means of an integrated economy-environment model for Ghana we trace the soil productivity effect on economic growth. Likewise, the model framework provide facilities for studying the impact of economic policy on the economy, including the feedback from the state of soil resources. The economic core model is a fairly straight forward CGE model with a 19 industries times 16 goods input/output matrix calibrated to the Ghana National Account in 1992. (However, we had to rely on several additional data sources to be able to establish a Social Accounting Matrix for Ghana, see Appendix 3). This model is supported by an integrated tropical soil productivity module (Aune and Lal, 1995) which trace the impact of cultivation and management on the productivity of soil. Among the 19 production activities of the CGE model, 4 are agricultural sectors. The soil module returns a soil productivity indicator into production functions of the respective crops in the CGE model. The demand for agricultural land corresponding to the production level and soil productivity is calculated, indicating the pressure on forest reserves.

The model framework provides the opportunity for looking into how improvement or decline in agricultural productivity affect other production activities like for instance the manufacturing of food, transportation and hotels and restaurant services, directly or indirectly through income generation and consumer demand. Since Ghana is a considerable exporter as well as importer of food products, changes in domestic supply or demand may also influence on the trade balance. In the next stage this may have consequences for exports and imports of other products depending on the restrictions set on the trade balance.

The study treats the Western Region separately to deal with the regional characteristics in the growth process. First, there is a particular high growth potential in Western Region mining due to rich mineral resources. Immigration due to employment opportunities may intensify pressure on land and forest reserves. The Western Region contains the last remaining moist tropical rain forests in Ghana.

This paper is organized as follows: section 2 briefly presents the overall structure of the CGE model. Section 3 deals with the special features of the agricultural sector, and the module which is linking cultivation practice to soil productivity feeding back into the economy. Section 4 contains some remarks on migration between the Western region and the rest of the country, while section 5 reports on some illustrative simulation exercises. Section 6 concludes. Several appendices describe the simulation results, model and data sources in more detail: Appendix 1 consists of a set of tables with some main results from the simulations presented in section 5. The model equations and the variables and parameters of the model is presented in Appendix 2. Appendix 3 contain the Social Accounting Matrix (SAM) developed for this work, while Appendix 4 discusses the data sources and the data manipulations done in order to arrive at the SAM. Appendix 5 present the soil productivity model, and, finally, Appendix 6 describes how the soil model is integrated in the economic core model.

2 The economic core model

In this study we will apply a fairly standard static general equilibrium model similar to models presented in for instance de Melo et al. (1982) and Robinson (1989). Central assumptions are that producers maximize profit and consumers maximize utility. Hence, we assume rational economic behaviour in a smoothly functioning market economy. This may sound misfit in relation to a poor developing agricultural economy. However, economic reforms in developing countries during the last decade have strengthened markets considerably, and removed structural obstacles to some extent, making our analytical approach more appropriate.

However, several non-market features still usually affects the behaviour of smallholders, such as availability of rural credits, availability of roads and the efficiency of distributional networks. Hardly any firm information is available about the actual strength of these various constraints. However, one source of information tends to rule out the shortcoming of rural credit systems as an effective limit to price response to fertilizer. According to World Bank (1992), smallholders in Ghana are not likely to demand credits in the short term even if a rural credit system were available. This supports the assumption that prices, technology and preferences are dominant factors in the smallholder behaviour.

Infrastructure elements may still possibly remain as a barrier to the adaptation to market incentives. As already mentioned, the input of fertilizer was reduced from 40 000 tons in 1988 to 23 000 tons in 1991. Hence, we may assume that present physical infrastructure may have the potential for significantly increasing the current fertilizer distribution capacity. The institutional capacity in distribution remains as a possible bottleneck.

Production takes place in 19 sectors, see table 1. The production technology is assumed to be Cobb Douglas, with constant returns to scale in the total factors. In all sectors except the four agricultural sectors, input factors are labour and capital while intermediates and energy are treated as shadow factors. There is one type of labour and two types of capital goods; construction and other capital goods. The elasticities in the production functions are determined by the cost shares in the base year. In all sectors, intermediate inputs and energy demand is proportional to output levels. The intermediate aggregates are based upon an input/output matrix (Appendix 3). Two energy inputs are specified in the input/output matrix; electricity and a composite of fossil fuels.

Production in the agricultural sectors is modeled somewhat differently, assuming use of the input factors labour, fertilizer and land, i.e. no real capital is included in the production function since mechanization generally is not yet on the agenda of the smallholders who dominate the agriculture in Ghana. A land variable is representing the cost and productivity of land as a scarce factor. The land rent is set exogenously equal to 1/3 of the profit, which is typical for all agricultural crops in Ghana, including cocoa (Schreiber, 1994). Investments in perennial plants and soil preparation (negligible according to national account numbers) is lumped together with the labour input cost.

Table 1. Sector list

Abbreviation	Sector	Abbreviation	Sector
cocw	Cocoa, Western region	wood	Production of furniture
cocr	Cocoa, other regions	meta	Production of metals
agrw	Other agriculture, Western region	manu	Other manufacturing
agrr	Other agriculture, other regions	cons	Construction
forw	Forestry, Western region	elec	Electricity production
forr	Forestry, other regions	wate	Water
fish	Fishing	serv	Private services
minw	Mining, Western region	gove	Government services
minr	Mining, other regions	tran	Transport, comm.
food	Production of food		

Total domestic production is allocated to domestic demand and exports according to a CES Armington aggregate subject to the changes in the relative product prices in the world market and the domestic market. Similarly, domestic demand is directed towards domestic production and import, subject to changes in relative import prices and domestic prices.

Total savings (private and public) determine the level of gross investments. Gross capital formation is allocated to manufacturing sectors and services by fixed coefficients determined in the base year. Thus, future sectoral capital accumulation is determined by gross investments and sectoral depreciation rates. In the public sector, income taxes, excise duties, commodity taxes, foreign transfers minus net private transfers equals governmental expenditures, i.e. salaries and intermediates.

The macro aggregates for this preliminary version of the Ghana model is based upon the national accounts for the year 1992 as published in Quarterly Digest of Statistics, June 1993. No updated input/output matrix was available for Ghana (a matrix from 1972 existed), hence the input structure has been constructed from various data sources. The production technology and input/output matrix is extrapolated from the Ghana Industrial Census 1987 to correspond with the National Account (NA) figures of Gross Domestic Production (GDP) for 1992. The industrial census covers manufacturing, electricity and water. Gross production in Mining and Cocoa is adjusted to match total exports in the trade statistics. The main source for calculating the size of the service industries and Construction is the NA. Separate data gathering has been conducted to characterize other sectors. Sources of information are the Ghana Statistical Service (GSS), the Ministry of Forestry and several printed sources, see Appendix 4. For the agricultural sectors, data origin from the Ministry of Agriculture and COCOBOD - the cocoa marketing board. Agricultural marketing is included in the agricultural production activities, except for transport services which are covered by the transport sector.

Data on private consumption are calculated on the basis of the Ghana Living Standard Survey II as presented in Poverty profile of Ghana (Boateng et al. year not identified).

Based on these sources we have established a Social Accounting Matrix (SAM) for Ghana. The quality of the data is generally weak. The business unit register for the industrial census is not updated and data on private services are fairly uncertain. However, within the SAM framework we have roughly tested the consistency of information in a systematic way and relevant adjustments are made, i.e. even if the data sources have different quality in the details they are all adjusted to fit into an accounting framework. Although this SAM and CGE are mainly intended for illustrative purposes, they may be useful as a background for the ongoing process of statistical work in Ghana. Currently, work on a SAM for Ghana is being carried out at GSS and at ISSER in cooperation with Free University, Amsterdam. Hence, the potential for data improvement is considerable in the near future. In particular the availability of Ghana Living Standard Survey III will provide crucial improvements as to private consumption and production in households.

The model equations are presented in Appendix 2, while the social accounting matrix is presented in Appendix 3. Appendix 4 discusses the data sources and manipulations in more detail.

3 Agriculture

While total annual economic growth in Ghana has been approximately 5 per cent the last few years, agriculture has been growing slower at an annual rate of 2 per cent (World Bank, 1992). With a population growth of 3 per cent, the discouraging result so far is a 1 per cent annual per capita income decline among the agricultural population, although revised statistical information may outdate this observation. It remains to be seen whether rural sector growth is underestimated, but facing tough terms of trade, the productivity of the sector will be crucial to growth and poverty alleviation.

Agriculture generates approximately 36 per cent of GDP according to our SAM, and employs more than half of the working population. Smallholders dominate both within food crops and export crops as generally is the case when land is available and there is no landless rural labour class. The technology is low-input and low-output, i.e. labour and land intensive in genuine economic terms. There is a general security of land tenure owing to the right to agricultural land associated with membership of a tribe (Asenso-Okyere et al., 1993). The exception is stranger farmers who are not members of the local tribe and face uncertainty of tenures. In some areas, in particular in southern areas where tree crops are cultivated, property markets have developed.

The status of land tenure security will certainly be affected by the population growth and the economic development. Although land is available right now, population growth may create conflict or stimulate more formal property markets. If productivity of land is increasing, there is a danger of land grabbing and creation of a poor landless rural class. However, a rapid growth in urban sectors or mining may alleviate the pressure on agricultural land, by attracting labour from rural activities. Growth in industry and services are expected to be high in the strategy for accelerated growth. Growth rates may reach 12 and 9 per cent respectively by year 2000 (Government of Ghana, 1993). Hence, there is a potential relief of land demand, slowing down the institutional changes related to land ownership. It is not within the scope or capability of this study to deal with impacts of land tenure. However, the estimates of land degradation will indicate the strength of agricultural demand for land.

The most important export crop is cocoa. Cocoa generated 20 per cent of export earnings in 1992. Although world prices have been declining the last years, farmgate prices have increased due to currency depreciations, and the production has been increasing. Reduced marketing costs have also benefited cocoa producers, receiving an increasing share of export prices (except around 1993/1994 due to a jump in inflation rates). Cocoa is traditionally grown in Central, Ashanti and Brong-Ahofo

Regions, but the last couple of decades the Western region (WR) has taken over as the leading producer region.

In food crops, volume has increased in spite of lower prices. Among food crops, tubers is the most important crop with roughly 50 per cent of gross production.

In the model, agriculture is represented by the two activities; "Cocoa" and "Other agriculture", both activities going on in the two regions; Western region and Other regions.

Producer behaviour is of the Cobb Douglas type, assuming constant return to scale:

$$X_i = ad_i \cdot L_i^{\alpha_i} \cdot F_i^{\beta_i} \cdot KL_i^{1-\alpha_i-\beta_i}. \qquad (1)$$

X_i is the output of crop i being generated by labour L_i, fertilizer F_i, and land KL_i. The land variable is an indicator of the amount of homogenous agricultural land used in cultivation. In all crops, the rent $(P_{KL}KL_i)$ allocated to land owners typically equals one third of the profit;

$$P_{KL}\,KL_i = \frac{1}{3}(P_i X_i - wL_i - P_F F_i)\,. \qquad (2)$$

Here, P_i is the price net of the cost of intermediates, w is the wage rate and P_F is the price of fertilizer. Profit maximisation under the constraints (1) and (2) determines the labour and fertilizer demand

$$L_i = \alpha\,\frac{P_i X_i}{W} \qquad (3)$$

$$F_i = \beta\,\frac{P_i X_i}{P_F} \qquad (4)$$

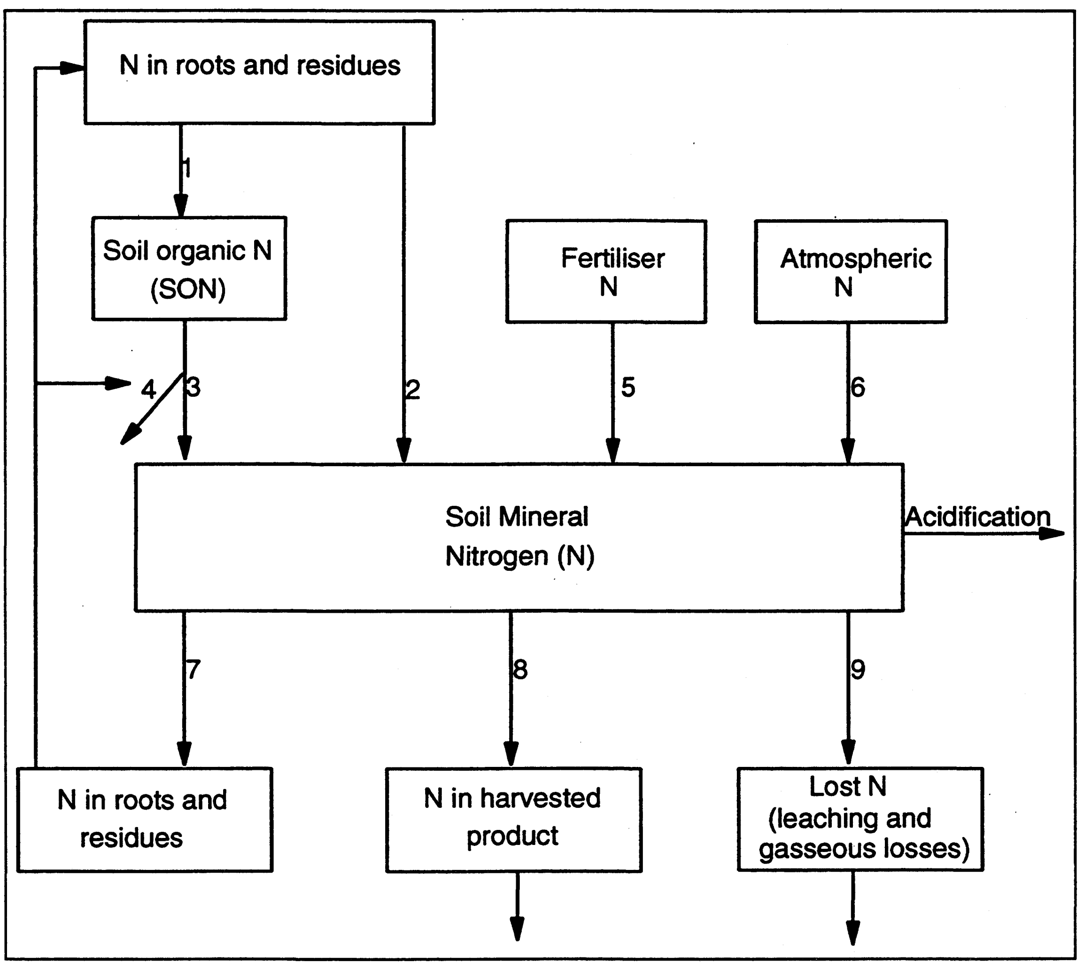
which together with (2) determines the total demand of input factors and consequently the output level for given market prices. The price P_{KL} of homogenous land is assumed to be constant in this study.

Crops affect the soil differently, both with regard to nutrients withdrawal and regarding the protection crops offer against soil erosion. The nutrient mining in Ghanaian agriculture might be considerable, since hardly any nutrients in crop removal are replaced by chemical fertilizer. To assess the impact of cultivation practices on soil quality, we apply a model for calculating the impact of cultivation on soil productivity. The nutrients mining and nutrients loss via soil erosion feeds back into the producer environment as reduced productivity of soil. The purpose of introducing this soil productivity module is to bring in explicitly the environmental drag on the agricultural sector in Ghana, and also to assess the area of land which will be cultivated to answer the demand for food and export crops along a path of accelerated growth. The demand for land is of particular interest since the expansion might conflict with potential high value rain forest reserves. However, the demand for homogenous land *(KL)* must be translated to actual land use, taking into account the rate of soil fertility loss on marginal land.

3.1 Soil model

In this section we describe the modeling of the link between agricultural activity and soil productivity. The focus is on nitrogen as the limiting factor for productivity which is the case for most food crops. For cocoa, phosphorus is the limiting factor. The two corresponding formal model versions are presented in Appendix 5. Below we describe the nitrogen model briefly in verbal terms. The model is developed by Aune and Lal (1995) with the purpose to overcome the general lack of data on tropical soil degradation due to cultivation practices. A model approach facilitates analysis of sustainable cultivation both on micro and macro levels.

Figure 1. The nitrogen cycle



The figure shows the main elements in the nitrogen cycle of an agricultural production system, and indicates the connection with soil erosion and acidification processes. There are four sources of mineralized soil nitrogen (indicated by 2,3,5 and 6 in the figure). First, there is the recycled nitrogen from roots and plant residues (2 and 3). This supply enters the soil mineral stock in two different ways. One part consists of recycled nitrogen immediately mineralized (2), while the other part is stored as organic nitrogen and released (mineralized) within 2-4 years (3 in the figure). Hence, there is a considerable time lag in the recycling. The characteristics of the crop and management procedures determines the share of plant nitrogen which is recycled.

The soil organic nitrogen is exposed to water and wind. Hence, some is lost through erosion on the way to being released and available for plant uptake (4 in the figure). A high yield (output per ha) provides a better vegetation cover and protects against soil loss. Thus there is an important link between productivity and soil erosion.

Chemical fertilizer is mineralized nitrogen which is ready for immediate uptake by plants (5). In the model it is assumed full efficiency in chemical fertilizer uptake. This depends on the timing of fertilizer application. When, as in Ghana, the level of fertilizer use is low and the farmer carries the full fertilizer cost, there is good reasons to believe that timing of fertilizer application with the growth period is reasonably good.

Also the atmosphere provide nitrogen to plants (6). Some plants do absorb nitrogen directly from the air, while the wet and dry deposition of nitrogen on the ground benefit all crops.

The stock of soil mineral nitrogen is depleted by harvesting products (8). Some nitrogen is fed back into the nitrogen cycle via roots and stover, etc. (7). In addition, there is a loss through leaching and gaseous emissions (9). There is also a link between nitrogen fertilizer and acidification, when nitrogen is converted to nitrate. If nitrate fertilizer is applied, this effect is avoided.

4 Migration

Spatially differentiated development must be expected in a dynamic growth process, since there are regionally differences in natural resource endowments and infrastructure development, to mention just a few of the relevant aspects. In Ghana, there is particular concern about the capacity of the Western Region to absorb the foreseen pressure on forests and land from an accelerated economic growth.

The Western Region has a growing mining sector which, including the informal activities, is expected to grow at an annual rate of more than 10 per cent in the coming years. Also, the region imports agricultural labour for treecrop and food production. The Western Region now generates almost 50 per cent of the total cocoa production in Ghana.

In the model we have specified four main economic activities in the Western Region: mining, forestry, cocoa and other agriculture. These activities produce outputs which are imperfect substitutes for their counterparts produced in the rest of Ghana. They apply the same production technologies, except for mining which is modeled with a separate input-output structure. The output from the Western Region sectors are aggregated with output in the rest of the country to form the total domestic supply.

The model describes the sectoral demand of labour, and assumes (so far) the same wage level across sectors and regions. Simulation results concerning labour demand certainly must be judged on this background. It should also be considered that labour might be a scarce factor in Ghana - there is no landless class - and that large increases in labour demand may be unrealistic and dampened by rising real wages.

Since the model simulates labour demand in each region (the Western Region and the rest of the country) we may track some of the dominant forces in the migration pattern between the different parts of the country. Characteristics of the labour market in Ghana indicates that this approach might be a useful tool. According to World Bank (1992), there is limited outright unemployment in Ghana, and the market for urban and rural (informal) labour allocates resources fairly well over both seasons and regions. The main reallocation of workers has been toward the cocoa producing Western Region. The Greater Accra Region has even been loosing workers.

Of course there are important factors affecting migration which this model does not deal with. External shocks like the historical incidence of swollen shoot virus disease in traditional cocoa areas (Central, Ashanti and Brong-Ahofo regions) is perhaps a typical example. Another concern is the impact of infrastructure development. In the northern areas of Ghana there is available land for agriculture, but these areas are less accessible due to lack of infrastructure. This has strengthened the pressure on Western Region where infrastructure is provided for mining, etc. A slack in infrastructure constraints would thus affect the migration flows.

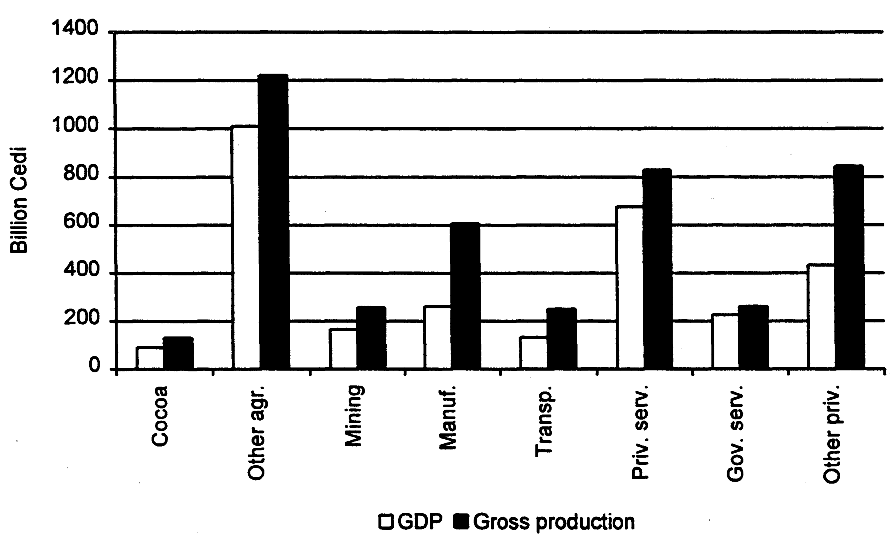
In this paper we have very limited ambitions. We only want to shed light on some of the pure economic forces providing migration incentives. Although sector by region demand for labour may be a strong indicator of net migration, gross migration flows might be bigger than indicated by clearing labour markets (World Bank, 1992). A caution to have in mind is that available and improved infrastructure related to expanding mining activities may attract more labour than directly demanded, being a magnet to people in a composite role as job-seeker and as potential settler for subsistence food production. An ongoing study of migration in Ghana (Tutu et al., 1994) might shed light on the actual mechanisms which can be incorporated in the model framework at a later stage.

5 Some illustrative model simulations

5.1 The economy in the base year 1992

As already mentioned, agriculture is the most important part of the Ghanaian economy, as Cocoa and Other Agriculture constitutes 36 per cent of total GDP, see figure 2. Other important industries are Private Services (which is probably overestimated in the NA) and Other Private industries which is composed of Forestry, Fisheries, Electricity, Water, Fuels and Construction. Even though Ghana is a developing country, over 8 per cent of GDP is generated by the Manufacturing industries, mostly in production of food and metals (aluminium).

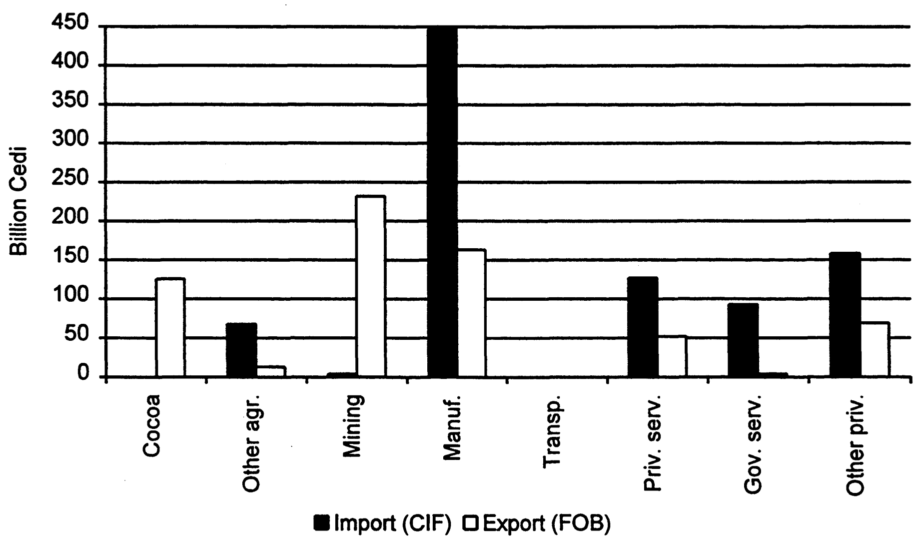
Figure 2. GDP and gross production in 1992



Ghana is a relatively small country with an open economy. The export volume in 1992 represented approximately 20 per cent of GDP, while import constituted above 30 per cent. The Cocoa and Mining industries are the cornerstones on the export side (55 per cent of total export), and Ghana have to rely on these exports to pay for imports of petroleum and most of the manufactured products. Ghana is one of the leading cocoa exporters in the world, however the export of other agricultural products is minor. Exports of Manufactured goods are high, with a considerable metal component. Export of logs is also an important export commodity.

Most of the machinery and vehicles is imported and this gives rise to Manufacturing's high share of the imports (50 per cent). The import of Other Private industries mostly consists of petrol and petroleum products. Services imported from abroad mostly covers wages paid to foreigners working in Ghana for either private companies or the government.

Figure 3. Exports and imports in 1992



The Ghanaian economy was in deep crisis in 1983, but it has been growing since the introduction of the Economic Recovery Program in 1983 and its renewal in 1987. The real capital stock was growing by 6.2 per cent in the base year 1992. In particular the Mining industry is growing rapidly, see figure 4. Investments in the mining industry include both mining on new sites and modernization of the production technology on the old ones. Net capital growth is also substantial in the service sectors and in Other Private industries. Cocoa and Other Agriculture hardly use any real capital in the production, and there are no significant investments in those industries.

Figure 4. Investments in 1992

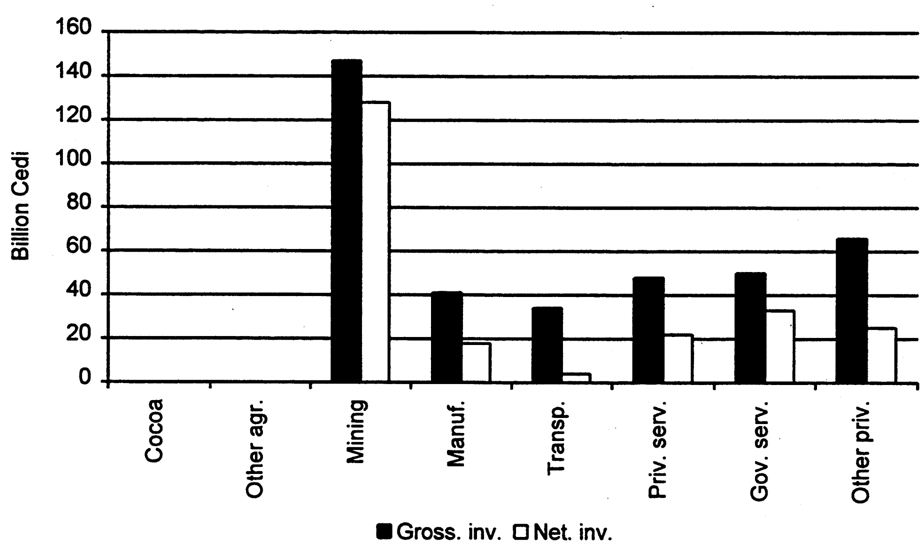
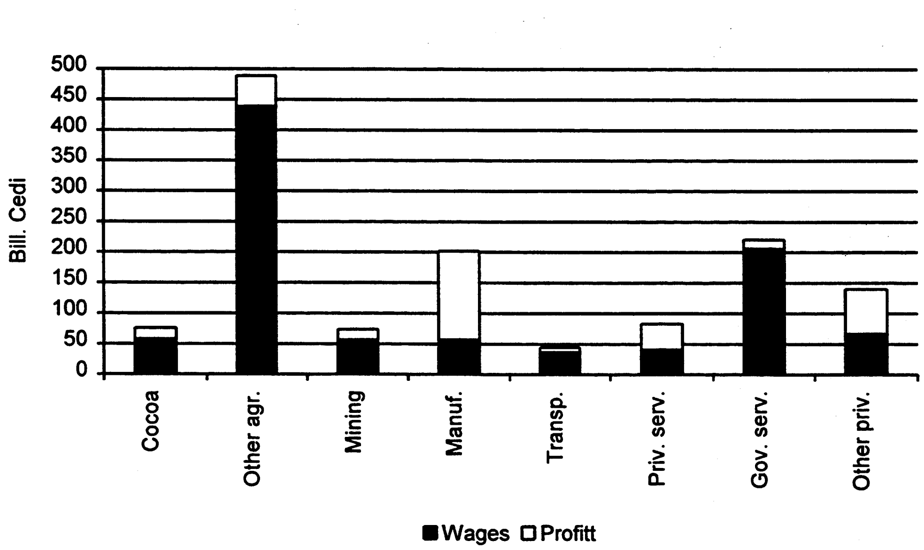


Figure 5 indicates the pattern of profit and wage income across aggregate sectors. However, the division between operating surplus (gross profits including depreciation of real capital) and compensation of employees (total wages) is rather uncertain in some sectors.

Figure 5. Operating surplus and compensation of employees in 1992



Wages amounts to 34 per cent of the payments to the households, while the rest is gross profits. So far we have for simplicity assumed that most of the activity in Private services, manufacturing industries like Food and Wood, and sectors like Fisheries and Other Private industries is carried out by self-employed people or partners in small companies. The cocoa sector is special since it includes the governmental distribution company COCOBOD, expect for transport services carried out by COCOBOD which is located to the transport sector.

5.2 Model simulations

Employing the model described, we have made a number of *illustrative* simulations. The illustrative nature of the simulations is due to the quality of the data, the rudimentary nature of the model, as well as the tentative nature of the policy alternatives.

A main point of the simulations is to outline the macroeconomic effects of degradation of soil productivity or fertility due to soil mining and erosion. The baseline scenario is therefore compared to a scenario where the model is simulated without taking the soil submodel into account. Another point is to illustrate how changes in policy and exogenous assumptions affects economic growth, the use of land and the regional distribution of labour demand.

Agriculture is likely to play an important part in the future development of the Ghanaian economy. The first couple of alternative scenarios therefore explore the consequences of promoting agricultural growth, first in the Western region alone, then on a country wide basis. The policy analyzed is one of increased farm gate prices in the sector Other agricultural products in the Western region and the whole country, respectively.

The loss of soil productivity may be combated to some extent by providing incentives for increased use of fertilizers and pesticides. The next few scenarios therefore illustrate some effects on the macro economy of subsidizing fertilizer use in the agricultural sectors. Input of pesticides in cocoa production is also given a similar subsidy, not because of any beneficial environmental effects, but as a mean to raise the internationally low productivity of this sector. Different methods of financing these subsidies may have different impact on the economy. These effects are illustrated through several runs described in the subsection on Fertilizer subsidy.

The Ghanaian economy receives large transfers from abroad. If these transfers were to be reduced in the future, it might have severe impacts on some of the sectors in the economy, depending on how these reductions would be balanced against other public income or expenditures. A stylized illustration of this subject is given in the subsection on Reduced transfers.

In all the scenarios mentioned so far we have assume that the *nominal* wage rate in Ghana is kept constant over time. Since most of the model simulations shows an increasing domestic price index, real wages are falling in these simulations. This may be unrealistic in the short and medium term when land may be available. An alternative approach is to assume fixed real wage rates. The impacts of these different assumptions on wage formation is illustrated in the subsection on Real wage rates.

Some main results from the various simulations are tabulated in Appendix 1.

5.3 The baseline scenario

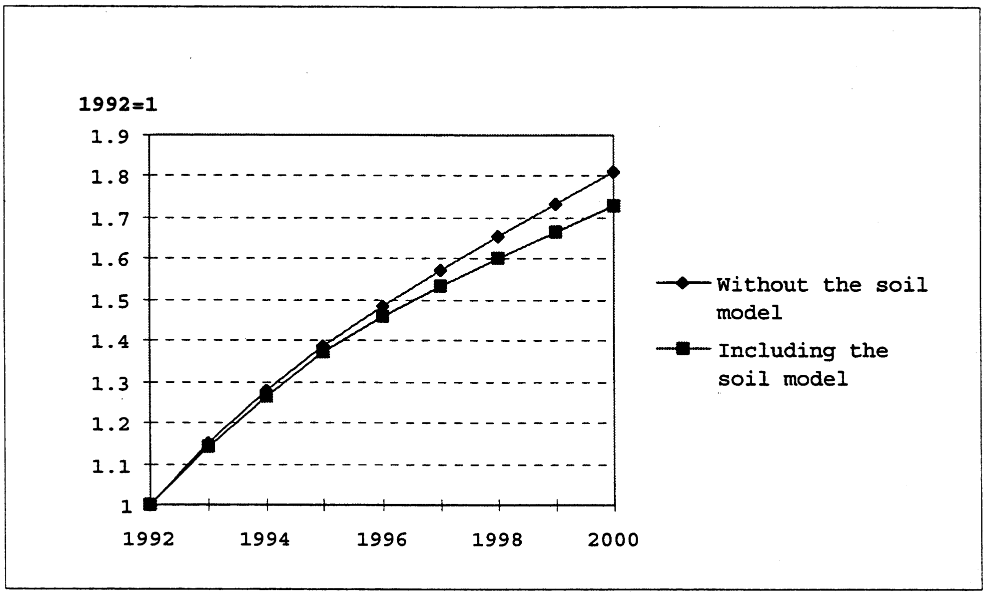
The simulation period is from 1992 to 2000. Including the soil models for production of Cocoa and Other Agriculture products in the core economic model, brings in an additional dynamic element in the model, since nitrogen and phosphorous in the soil depends on harvests and soil coverage in previous years. Thus, the productivity in cocoa production and other agriculture will change in a model simulation even if all other exogenous variables were kept constant.

With base year factor use kept constant, the soil model alone predicts productivity losses of 2.1 per cent per year in Cocoa production, and close to 3 per cent per year in Other agriculture.

Implementing the soil model in the economic core model yields increased factor inputs (labour, fertilizer and land) modifying the loss of soil productivity. Soil fertility in Other agriculture is reduced to an annual rate of 2 per cent averaged over the simulation period, while the productivity loss in Cocoa is only marginally reduced to 2 per cent per year. However, increased factor inputs reduce the profit and production growth rates in these sectors compared to the hypothetical situation where the effects of soil mining and erosion are neglected. Thus, the average annual growth in gross production is reduced by 1.6 percentage points in Other agricultural production and 1.0 percentage points in Production of Cocoa when the soil model is integrated in the core economic model.

The decline in agricultural productivity has several indirect effects on the economy. One effect is through the input-output structure. The agricultural sector's demand for inputs from other sectors in the economy decreases in relative significance, holding back production in these sectors as well. All together, this generates a decrease in income that partially reduces private consumption and investments. This implies relatively less demand for consumer and investments goods. Reduced investments also reduces the Ghanaian economy's production potential. This multiplier effect, however, gradually decreases. In our calculations we find that the sum of the direct productivity loss in the agricultural sector and the indirect input-output, income and investment effects may reduce the annual GDP growth rate by on average 0.6 percentage points over the simulation period, summing up to a total decline in (real) GDP of 4.9 per cent in year 2000. The reason for the relatively small decline in the growth rate, is that the direct reduction in soil productivity is countered by higher use of inputs like labour, fertilizer and land in the agricultural sectors, increasing their annual growth rate by approximately 0.2 percentage points (labour) and 0.8 percentage points (fertilizer and land) relative to the simulation path without the soil model. Growth in real private consumption is reduced from an annual average level of 8.2 per cent to 7.5 per cent due to all the combined effects of the soil model. Figure 6 illustrate the effect on real GDP of including the soil productivity loss.

Figure 6. Real GDP growth without and with the soil model included

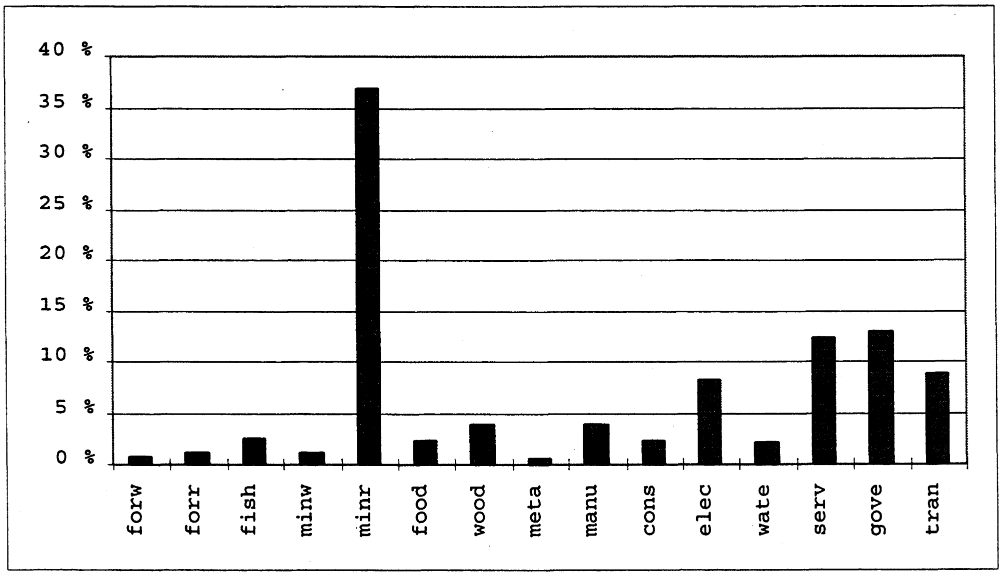


In the base year the total real investments are very high compared to the level of fixed capital assets in Ghana. In our baseline scenario we prolong this high investment rate and leave all other exogenous inputs constant for a period of eight years. Including the negative productivity effects from the soil model, we find that real GDP is growing at an average annual rate of 7.1 per cent, however declining towards an annual growth rate of 4.3 per cent at the end of the period as the full effect of the soil model is taken into account (see figure 6). Private consumption is growing at an annual rate of 7.5 per cent while investment measured in constant prices is growing at around 6 per cent per year on average. The private sector saving rate and real government consumption are assumed to be constant in this scenario. The government sector saving is residually determined and slightly decreasing in the baseline scenario. Total (private plus public) savings measured as a percentage of GDP is, however, almost constant at 12.7 per cent over the time horizon of the simulation.

The domestic price level is increasing at 3.9 per cent measured as an annual rate. (Up from 3.1 per cent in the simulation without the soil model). This implies a reduction in the real wage rate of approximately 35 per cent over the simulated period (remembering that the nominal wage rate is kept constant). This contributes to the significant growth in demand for labour which is calculated to be almost 10 per cent per year. Annual growth in the demand for labour in the Western region is 1.4 per cent higher than in the rest of the country, indicating a migration to the Western region. This follows from an higher initial growth in mining activities and agriculture than in other industries. Growth in gross production in the Western region is 3.5 percentage points above the growth in the rest of the country.

Total gross production is growing faster than GDP with an average annual growth rate of 7.4 per cent. This implies that sectors with a smaller intermediate input rate increase more than sectors with a larger intermediate input rate. Mining, Water, Other agricultural production and Transport are all sectors growing faster than total production. At the low growth end we find Production of Metals, Cocoa, Forestry and Fishing. This is mainly a reflection of the investment/depreciation pattern of the model, which allows for high net investment rates in the mineral and also the water sector, while investment in Forestry, Fishing and Production of Metals are quite low, as in the base year, see figure 7.

Figure 7. Share of total investments in the base year

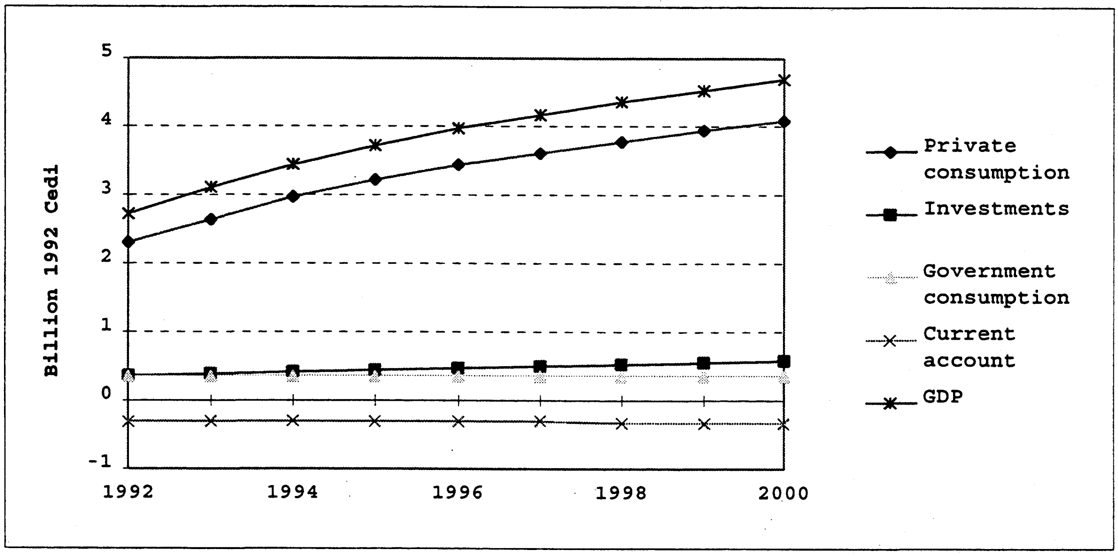


As explained in section 3, there is no real capital in the agricultural sectors in the model, instead they use land. In the baseline scenario, land use increase by almost 11 per cent per year in the agricultural sector and close to 4.5 per cent in Cocoa production. This rapid growth in demand for land must be expected to exert a considerable pressure on for instance forested land.

Similarly, we find an increase in fertilizer/pesticide use, although slightly less than the increase in demand for land. This increase cannot, however, prevent a 2 per cent annual decline in soil productivity in Cocoa and Other agricultural production. The soil model combined with the economic core model indicates that the total effect on land of loss of soil productivity is to increase demand for land by 5.6 per cent in the year 2000.

Figure 8 shows the demand components of real GDP in the baseline scenario.

Figure 8. The baseline scenario



5.4 Alternative agricultural policies

Our first set of simulations focuses on economic incentives directed at the agricultural sectors. The scenarios will illustrate how different ways of encouraging growth will affect the productivity loss of the soil as well as the development potential of the rest of the economy.

5.4.1 Increasing the price of agricultural products from the Western region

Our first alternative scenario investigates the effects of a 10 per cent increase in farm gate prices in the Western region. Such a partial price increase in the Western region might reflect a situation where regional road transport facilities are improved, perhaps in an effort to modernize the mining activities in the region.

We assume that the price increase, either directly or indirectly, is financed by the government, and that only the sector Other agricultural products in the Western region (agrw) benefit from the policy. The drain on public funds implies a decrease in public saving and thereby a decrease in the resources available for investments in the rest of the economy. Thus, the capital stock at the end of the period is

1.3 per cent lower than in the baseline scenario. Total gross production declines by 1 per cent, while GDP is reduced by 0.9 per cent. However, production in the agricultural sector in the Western region is increased by 7.2 per cent relative to the baseline scenario in year 2000. This is achieved by a 25 per cent increase in use of land, obviously putting more pressure on forested areas in the region. The use of fertilizer declines slightly relative to the baseline level. This leads to a loss of soil productivity of almost 3 per cent compared to the baseline scenario in year 2000. Under the assumptions of this scenario, total government revenue is reduced by 5.3 per cent in year 2000 relative to the baseline scenario.

5.4.2 Increasing the price of agricultural products from all regions

If the farm gate prices are increased all over the country at the expence of the public budget, the situation is dramatically worsened. Government net revenue is then cut by 50 per cent compared to the baseline scenario in year 2000, leading to a reduction in real investments of 33 per cent. Total gross production and GDP are both reduced by approximately 11 per cent. Reduced economic activity decreases the demand for agricultural products, so production in year 2000 is 5.6 per cent lower than the baseline level in year 2000 despite the increased farm gate prices.

This and the previous scenario assumes that higher agricultural prices are paid, directly or indirectly, by public funds. A more optimistic view would be that higher farm gate prices would lead to higher efficiency in agricultural production and marketing. In that case, the negative effects obtained in the simulations reported on above, would of course be less serious.

5.4.3 Introducing a 50 per cent subsidy on use of fertilisers and pesticides

The use of fertilizers and pesticides in Ghana is extremely low. According to our data, the cost share of fertilizers is of the order of 0.3 per cent. Increasing the use of fertilizer in agricultural production and the use of pesticides in the cocoa production will most certainly increase the productivity. There may be several reasons why farmers do not use these products more intensively: Prices of fertilizers and pesticides may be to high, there may be hidden costs to their use (e.g. transportation costs) or the farmers may lack the knowledge of the real productive effect of these products. When the income level is low, the calculation rate of "investments" may be high, i.e. the value of today's consumption is extremely high. One way of increasing the use of these products in agricultural production is to introduce a subsidy. The next scenarios illustrates some possible macro economic effects of decreasing the price on fertilizers and pesticides by 50 per cent.

The fertilizer/pesticide subsidy may be paid for in different ways; for instance by reduced investments in the total economy, increased sales tax on consumer goods, increased output tax on forestry, mining or other sectors, increased taxes on fossil fuel uses, etc. We have made several runs on the model to illustrate the differences in macroeconomic effects from the different ways of financing the subsidies.

5.4.4 Subsidies financed by lowering investments

A 50 per cent fertilizer/pesticide subsidy increases the use of these input factors in the production of cocoa and other agricultural products with 75 and 62 per cent, respectively, compared to the baseline scenario in year 2000. The initial use is, however, rather low, so the increased fertilizer use enhances the soil productivity in the agricultural sector by only 1.7 per cent over an eight year period. The first order incremental effect on agricultural production from increased fertilizer use requires increased production of intermediates in other sectors. Altogether this partially implies an upward trend in total income, total consumption and investments. However, several effects counteracts this initial reaction.

Improved agricultural productivity entails a reduced national price level. Since nominal (imported) fuel prices and land prices are fixed, this implies a real price increase and thereby reduced demand for these inputs. This effect is larger than the initial effect such that even agricultural production is reduced.

The fertilizer/pesticide subsidy makes government revenue contract with approximately 40 per cent. Government consumption is assumed kept unchanged in this scenario. Thus, reduced revenue implies reduced government savings. With nearly unchanged private savings and unchanged transfers from abroad, the fertilizer/pesticide subsidy is financed from a decline in investment of almost 40 per cent. The subsidies on pesticides and fertilizer use then is balanced against total investments. This implies a reduction in the total investments growth that in turn implies a counteractive effect on economic growth.

Hence, the total effect in this scenario is a slowdown in economic growth measured by annual growth in real GDP of 2 percentage points. The total real annual investments growth rate is reduced by 4.6 percentage points, while the (real) private consumption growth rate is reduced by 1.8 per cent points. The gross production growth rate is decreased by only 1.7 percentage points due to a smaller decrease in the production growth rate for sectors highly dependent on intermediate deliveries than in other sectors.

Cheaper input factors in agricultural production feeds through the economy to an overall reduction in the annual inflation rate of 0.8 percentage points (3.1 per cent per annum instead of 3.9 per cent). This is equivalent to a devaluation of the Cedi by a similar magnitude, something that initially would help to increase the export. However, the counteractive effects described above more than outweigh this initial terms of trade benefit. Growth in total exports decreases from 12.6 to 10.5 per cent measured as an annual rate. Increased use of fertilizers requires an initial increase in imports. The contraction of the economy and the restriction on the trade balance, however, implies that total import is also reduced.

Annual growth in total demand for labour is reduced by 2.3 percentage points. The labour demand growth rate for the construction sector is almost halved compared to the baseline scenario. Increased productivity in the agriculture sector has as described above a macro economic counteractive effect both on agricultural production and on factor input. The labour demand growth rate in the agricultural sector then declines from a rate of almost 11 per cent in the baseline scenario to a rate of almost 8 per cent in the fertilizer subsidy scenario.

Overall, the simulation clearly bears out the unwise nature of financing productivity increases in the agricultural sectors by reduced investment in other sectors. There are, however, alternatives that shows other and more optimistic economic and environmental results.

5.4.5 Internally financed subsidy

An alternative to financing the fertilizer and pesticides subsidies in the agricultural sector by reducing the investments, is to 'internalize' the financing into the agricultural sectors. In our next scenario we have added a domestic sales tax on domestically produced agricultural products to illustrate some different impacts on the macro economy through the mechanisms in our model. In addition to the effects listed below, this policy might create additional distributional benefits, since all farmers face reduced input prices, but only those with a marketed surplus will have to pay the additional tax.

The dynamics in this scenario are comparable to the dynamics in the above alternative. However, the income distribution effect on private consumption and investments are quite different. In the "internally financed" scenario total income in private sector is decreased and total income in governmental sector increased compared to the "lowering investments" scenario. The counteractive effect on production through lowered investments is then much smaller. In addition the impact on individual sectors is changed. In particular, the negative impact of cuts in investments on the mining sector is eased when the subsidy is financed by taxes. Total production in the Ghanaian model economy is still decreased compared to the baseline scenario (the growth rate is 0.6 percentage points below that of the baseline scenario). The reduction, however, is larger in the intermediate input intensive sectors than in the less intermediate input sectors, hence total GDP in the "internally financed" scenario actually increases and is more than 13 per cent above the baseline level in year 2000. Even private consumption increases in the long run due to a higher level of GDP, and a small decrease in total investments as a share of GDP.

Taxing agricultural products turns out to increase the pressure on land by a very small amount. This is a reflection of the fact that a cut in investments hit the agricultural sectors more than a direct taxation. In this scenario, gross production in the Western region is reduced by 5.6 per cent at the end of the simulation period, compared to a 4.5 per cent reduction in the rest of the country. Still, the Western region fare comparatively better than the rest of the country when the subsidy is financed by a sales tax than when it is financed by cuts in investments.

5.5 Taxing the forestry sector

Historically, the government of Ghana has appropriated less than 5 per cent of the economic rent or stumpage value of timber. The existence of such large surpluses tends to undermine both conservation and economic efficiency in the forestry sector. There are therefore both economic and environmental reasons for increasing the taxation of this sector. We have simulated the effects of a rather modest increase in the sales tax; from 14.6 per cent to 25 per cent. Government revenue rises by close to 1 per cent, allowing an 0.7 per cent increase in total (real) investments. With the fixed sectoral distribution of investments employed in the model, this feeds through to a general increase in economic activity (GDP) of the order of 0.4 per cent in year 2000 when compared to the baseline scenario. The sectoral composition of the growth is not changed much from what we observe in the baseline scenario.

5.6 Reductions in the transfers from abroad

In the next couple of simulations we take a brief look at the effects of reducing transfers from abroad by 50 per cent within the static and the dynamic model framework. These simulations are of interest because, among other things, reduced transfers from abroad may be equivalent to a real depreciation of the exchange rate. In the model this may be followed up by reduced imports or increased exports to keep the trade balance intact, i.e. private sector adjustments. Another alternative may be that the government actively reduces its expenditure in accordance with the reduced foreign transfers.

5.6.1 Reduced transfers - private sector adjustments

In this alternative we keep the governmental expenditures at the baseline scenario level. Reducing the transfers by 50 per cent will then reduce governmental savings and hence total investments. This in turn will result in multiplier effects comparable to the ones described earlier.

Reducing the transfers reduces the total GDP growth rate from 7.1 per cent in the baseline scenario to 5.3 per cent in the "private sector adjustment" scenario. Private consumption is reduced slightly more, i.e. by 2 percentage points, while total investment growth rate is reduced by 3.7 per cent. The current account improves, since it in the model is equal to the transfers from abroad.

Reduced activity in the agricultural sectors reduces demand for land by 16 per cent at the end of the simulation period compared to the land use demand in the baseline scenario.

Gross production in the Western region is reduced by 15.7 per cent, while production in the rest of the country is reduced by 13 per cent in year 2000 relative to the baseline scenario. This regional effect is explained by the importance of the mining sector in the Western region, a sector with a high investment rate. Thus, this sector is hit relatively harder by the investment squeeze than other sectors. Demand for labour is, however, reduced less in the Western region (13.6 per cent) than in the rest of the country (14.8 per cent), indicating a continued migration pressure on the Western region.

5.6.2 Reduced transfers - reduced governmental expenditure

Assuming that the foreign transfers are seen as governmental income, we in the next scenario also reduce governmental expenditures.

Total GDP growth is then reduced by 0.9 percentage points compared to the baseline scenario, i.e. the macroeconomic effect is much smaller than in the scenario where the tightening is by reduced investments alone. When governmental expenditure is reduced this leaves room for a higher investment level, and thereby higher economic growth, than when you reduce private sectors income. The growth rate of private consumption is reduced by half the rate compared to the effect in the "private sector adjustment" scenario. This is mainly due to an investment effect. And again we find that the investment intensive mining sector is faring very much better when investments are not cut.

There are only very small differences between the Western region and the rest of the country with respect to changes in production and labour demand in this scenario.

5.7 Fixed real wage rate

In the baseline scenario the nominal wage rate is fixed at the base year level. The nominal price increase in this scenario reduces the real wage rate to approximately 35 per cent of the wage rate in the base year. This is hardly a realistic path with an economic growth rate of more than 7 per cent per year. In this alternative scenario we therefore fix the real wage rate at the 1992 level throughout the whole simulation period.

Keeping the real wage level constant primarily affects the labour intensive sectors, like agriculture (both Cocoa production and production of other agricultural products) and the government sector. Due to its strong linkage to the agricultural sectors, Food production is also severely hit, compared to the case with a constant nominal wage. All of the mentioned sectors experience reductions in gross production of the order of 10-15 per cent compared to the baseline scenario in year 2000. The fact that agricultural land is still available and a basic right for all members of tribes, supports the assumption of a floor to real wage flexibility downwards.

Compared to the baseline scenario the GDP and private consumption growth rate is reduced by 1.1 percentage points, while the price level is only very slightly increased (by 0.7 per cent at the end of the simulation period compared to the baseline scenario). The labour demand growth rate is reduced by 3.1 percentage points due to substitution between labour and capital as relative wage cost is increasing.

The average annual growth in total export is reduced by 1.2 percentage point compared to the growth in the baseline scenario, while the import growth rate is reduced by 1 percentage point, indicating a deterioration of the competitiveness of the international trade sectors of Ghana when the real wage rate is kept constant.

6. Summary and conclusion

In this report we have presented an illustration of how certain environmental aspects can be taken into account in a Computable General Equilibrium model for Ghana. The integrated economy-land degradation model is a detract from welltrodden paths, and our aim so far has been to establish a model framework and indicate some possibly fruitful tasks to which this tool can be put to good use. Although the stage for strong conclusions is not yet set, we would like to call the attention to a couple of points emerging from this study.

One point is that policy formation clearly affects the degree of agricultural intensification, and consequently the pressure on land and forests. Another point is that there might be policy options of a 'double dividend' type, enhancing economic growth while at the same time not putting too much pressure on soil and forests.

We would like to end this report by pointing out some areas for further work, should one decide to continue to study the environmental impacts of macroeconomic policy and vice versa in Ghana based on a model framework of this kind.

- The data base for the model can of course always be improved, and better data are indeed under way through several ongoing projects. A particular weak point at this stage are the import and export elasticities used in the model. Also the transformation parameters employed in the relations aggregating products from the Western region and the rest of the country are not well founded.
- For improvements in the soil model, one would wish to disaggregate the agricultural sectors further, thus better recognizing the different soil impacts of various crops.
- Also, one should try to improve upon the assumption of undifferentiated wage rates in the various sectors.
- It would be highly interesting to model migration in a more explicit manner. Some modeling of the urban and rural labour markets in the Western regions and in the rest of the country would then be necessary.
- Technical progress in manufacturing industries should be included.
- Finally, we would like to point out that a better grasp on the modeling of investment relations is necessary for an improved economic modeling.

Undoubtedly there are many more points to be covered, but from the point of view of integrated modeling of economy and the environment, we think the above are at least among the more important ones.

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Appendix 1 Tables summarizing some of the main results from the simulations

Table A.1. Real GDP and gross production. Average annual growth rates over the period 1992-2000 and differences from the baseline scenario in year 2000. Per cent

No	Scenario	Real GDP: Average annual growth	Real GDP: Difference from baseline in year 2000	Gross production: Average annual growth	Gross production: Difference from baseline in year 2000
0	Baseline without soil model	7.7	4.8	7.9	4.2
1	Baseline with soil model	7.1	0.0	7.4	0.0
2	Agricultural subsidy to the Western region	7.0	-0.9	7.3	-1.0
3	Agricultural subsidy to all regions	5.6	-10.5	5.8	-11.4
4	Fertiliser/pesticide subsidy	5.0	-14.3	5.7	-11.9
5	As 4 + tax on agricultural products	8.8	13.4	6.8	-4.6
6	Increased tax on forestry	7.1	0.4	7.4	0.4
7	Reduced transfers from abroad	5.3	-12.6	5.5	-13.2
8	As 4+7 combined + cut in government consumption	6.5	-10.6	6.3	-7.6
9	Constant real wage rates	6.2	-6.6	6.5	-6.7

Table A.2. Changes in total input factor use. Per cent deviation from baseline in year 2000

No	Scenario	Labour	Capital	Fertiliser/ pesticide	Land use*
0	Baseline without soil model	-0.7	0.3	-5.3	-5.1
2	Agricultural subsidy to the Western region	-1.2	-1.3	-1.1	1.4
3	Agricultural subsidy to all regions	-13.1	-13.5	-12.2	10.5
4	Fertiliser/pesticide subsidy	-15.6	-12.0	63.1	-18.7
5	As 4 + tax on agricultural products	-9.9	-2.6	64.8	-17.6
6	Increased tax on forestry	0.4	0.3	0.4	0.5
7	Reduced transfers from abroad	-14.6	-11.3	-14.3	-16.2
8	As 4+7 combined + cut in government consumption	-15.2	-6.2	68.8	-15.9
9	Constant real wage rates	-20.4	-1.3	-6.7	-7.4

* Measured as 'homogeneous land', i.e. not taking into account the loss in soil productivity over the simulation period.

Table A.3. Average annual growth rates in gross production in the Western region, rest of the country, and Ghana as a whole.

No	Scenario	Western region	Rest of the country	Total
0	Baseline without soil model	11.0	7.7	9.8
1	Baseline with soil model	10.6	7.1	7.4
2	Agricultural subsidy to the Western region	10.8	6.9	7.3
3	Agricultural subsidy to all regions	8.4	5.5	5.8
4	Fertiliser/pesticide subsidy	8.4	5.5	5.7
5	As 4 + tax on agricultural products	9.8	6.5	6.8
6	Increased tax on forestry	10.6	7.2	7.4
7	Reduced transfers from abroad	8.2	5.3	5.5
8	As 4+7 combined + cut in government consumption	9.4	6.1	6.3
9	Constant real wage rates	9.4	6.2	6.5

Table A.4. Average annual growth rates in labour demand in the Western region, rest of the country, and Ghana as a whole.

No	Scenario	Western region	Rest of the country	Total
0	Baseline without soil model	10.4	9.6	9.6
1	Baseline with soil model	11.1	9.7	9.9
2	Agricultural subsidy to the Western region	10.9	9.6	9.7
3	Agricultural subsidy to all regions	8.9	7.9	8.0
4	Fertiliser/pesticide subsidy	8.7	7.4	7.6
5	As 4 + tax on agricultural products	9.9	8.3	8.5
6	Increased tax on forestry	11.2	9.8	9.9
7	Reduced transfers from abroad	9.1	7.6	7.7
8	As 4+7 combined + cut in government consumption	9.7	7.4	7.6
9	Constant real wage rates	7.8	6.7	6.8

Table 6. Average annual growth of gross production in the baseline scenario over the period 1992-2000 and differences in gross production in year 2000 relative to the baseline scenario.

Sector	Average annual growth 1992-2000 Base-line (1)	Percentage deviation from the baseline scenario in year 2000 for scenario no: 0	2	3	4	5	6	7	8	9
agrw	8.4	13.5	7.2	-5.6	-11.9	-11.8	0.4	-15.9	-8.9	-7.3
agrr	8.2	15.8	-1.2	-5.6	-11.4	-10.4	0.4	-16.0	-8.4	-7.7
agr	8.3	15.6	-0.4	-5.6	-11.5	-10.5	0.4	-16.0	-8.5	-7.6
cocw	0.5	16.7	-1.0	-11.3	-7.3	9.4	0.3	-11.2	-2.3	-15.6
cocr	0.5	16.7	-1.0	-11.4	-7.3	9.4	0.3	-11.2	-2.3	-15.7
coc	0.5	16.7	-1.0	-11.3	-7.3	9.4	0.3	-11.2	-2.3	-15.7
forw	1.9	0.2	-1.0	-11.1	-10.3	-2.4	0.3	-9.8	-5.7	-3.9
forr	1.9	0.2	-1.0	-11.1	-10.3	-2.4	0.3	-9.8	-5.7	-3.9
for	1.9	0.2	-1.0	-11.1	-10.3	-2.4	0.3	-9.8	-5.7	-3.9
fish	1.8	0.3	-0.9	-9.9	-9.3	-2.2	0.3	-8.8	-5.0	-1.9
minw	23.2	-0.5	-2.1	-23.3	-19.8	-3.9	0.5	-17.9	-8.9	-9.7
minr	22.9	-1.6	-1.7	-19.5	-15.7	-2.7	0.4	-13.4	-5.3	-7.7
min	22.9	-1.4	-1.8	-20.4	-16.7	-3.0	0.4	-14.4	-6.1	-8.1
food	5.4	10.2	-1.0	-11.4	-10.0	6.3	0.4	-12.3	-5.2	-12.2
wood	6.3	-0.1	-1.5	-17.4	-13.4	-1.7	0.3	-12.5	-4.9	-6.3
meta	-0.5	0.0	-0.6	-6.5	-3.5	0.5	0.2	-5.1	0.0	-3.1
manu	5.2	0.0	-1.1	-12.8	-5.5	3.2	0.3	-11.5	0.6	-5.4
cons	6.3	0.5	-2.1	-21.7	-19.5	-4.1	0.5	-17.4	-10.7	-6.9
elec	5.1	-0.1	-1.1	-12.4	-10.7	-1.9	0.3	-10.2	-5.5	-4.8
wate	14.5	0.1	-1.3	-15.9	-15.4	-3.8	0.4	-14.1	-9.0	-5.1
serv	3.1	0.2	-0.8	-8.6	-8.0	-1.9	0.2	-7.7	-5.1	-2.2
gove	3.9	0.3	-0.4	-5.2	-7.9	-3.2	0.2	-7.6	-29.4	-11.5
tran	7.4	5.3	-0.9	-11.2	-12.0	-4.6	0.4	-13.3	-7.1	-7.2
Total	7.4	5.5	-1.0	-11.4	-11.9	-4.6	0.4	-13.2	-7.6	-6.7

Appendix 2 Model equations, variables and parameters

Model equations

Regional aggregation:

1	$P_i X_i = P_i^w X_i^w + P_i^r X_i^r$	$i \in SP$	*4*
2	$X_i = ar_i\left[\varepsilon_i X_i^{w-\rho_{ri}} + (1-\varepsilon_i) X_i^{r-\rho_{ri}}\right]^{\frac{-1}{\rho_{ri}}}$	$i \in SP$	*4*
3	$\frac{X_i^w}{X_i^r} = \left[\frac{P_i^r}{P_i^w}\frac{\varepsilon_i}{1-\varepsilon_i}\right]^{\frac{1}{1+\rho_{ri}}}$	$i \in SP$	*4*

Import and export relations:

4	$P_i \cdot X_i = PD_i \cdot XD_i + pe_i \cdot E_i$	$i \in EX$	*12*
5	$P_i \cdot X_i = PD_i \cdot XD_i$	$i \in GD\text{-}EX$	*4*
6	$PC_i \cdot XC_i = PD_i \cdot (1+td_i) \cdot XD_i + pm_i(1+tm_i) \cdot M_i$	$i \in IM$	*11*
7	$PC_i \cdot XC_i = PD_i(1+td_i) \cdot XD_i$	$i \in GD\text{-}IM$	*5*
8	$X_i = at_i \cdot \left[\gamma_i \cdot E_i^{\rho_{ei}} + (1-\gamma_i) \cdot XD_i^{\rho_{ei}}\right]^{\frac{1}{\rho_{ei}}}$	$i \in EX$	*12*
9	$X_i = XD_i$	$i \in GD\text{-}EX$	*4*
10	$\frac{E_i}{XD_i} = \left\langle \frac{pe_i}{PD_i} \cdot \frac{1-\gamma_i}{\gamma_i} \right\rangle^{\frac{1}{\rho_{ei}-1}}$	$i \in EX$	*12*
11	$XC_i = ac_i \cdot \left[\delta_i \cdot M_i^{-\rho_{mi}} + (1-\delta_i) \cdot XD_i^{-\rho_{mi}}\right]^{\frac{-1}{\rho_{mi}}}$	$i \in IM1$	*10*
12	$XC_{fuel} = M_{fuel} \cdot (1+tm_{fuel})$		1
13	$XC_i = XD_i \cdot (1+td_i)$	$i \in GD\text{-}IM$	*5*
14	$\frac{M_i}{XD_i} = \left\langle \frac{PD_i(1+td_i)}{pm_i(1+tm_i)} \cdot \frac{\delta_i}{1-\delta_i} \right\rangle^{\frac{1}{1+\rho_{mi}}}$	$i \in IM1$	*10*
15	$XD_{fuel} = 0$		*1*

Production functions

16 $X_i^{1-\alpha_i} = ad_i \cdot LC_i^{\alpha_i} \cdot kf_i^{1-\alpha_i}$ $\quad i \in NAGR \quad$ *15*

17 $X_i = AD'_i \cdot \left[LC_i \cdot X_i\right]^{\alpha_i} \cdot \left(\frac{F_i}{KL_i}\right)^{\beta_i} \cdot KL_i^{1-\alpha_i}$ $\quad i \in AGR \quad$ *4*

Profit:

18 $PRFT_i = \left[P_i - \sum_j PC_j \cdot a_{ji} - w_i \cdot LC_i\right] \cdot X_i$ $\quad i \in NAGR, j \in GD \quad$ *15*

19 $PRFT_i = \left[P_i \cdot (1 + tsub_i) - \sum_j PC_j \cdot a_{ji} - w_i \cdot LC_i\right] \cdot X_i - PC_{manu} \cdot (1 + tf_i) \cdot F_i$

$i \in AGR, j \in GD \quad$ *4*

Factor demand:

20 $pkl0_i \cdot KL_i = \eta \cdot PRFT_i$ $\quad i \in AGR \quad$ *4*

21 $PC_{manu} \cdot (1 + tf_i) \cdot F_i = \beta_i \cdot \left[P_i - \sum_j PC_j a_{ji}\right] X_i$ $\quad i \in AGR, j \in GD \quad$ *4*

22 $w_i \cdot LC_i = \alpha_i \cdot \left[P_i - \sum_j PC_j a_{ji}\right]$ $\quad i \in I1, j \in GD \quad$ *19*

Private income and consumption:

23 $= \sum_i w_i \cdot LC_i \cdot X_i + er \cdot trxk + \sum_i PRFT_i - PRFT_{gove} + yx$

$i \in I1 \quad$ *1*

24 $EXPEND = (1 - s) \cdot (1 - ty) \cdot Y$ $\quad$ *1*

25 $PC_i \cdot CD_i = PC_i \cdot csub_i + q_i \cdot (EXPEND - \sum_j csub_j PC_j)$ $\quad i,j \in GD \quad$ *16*

Public income, saving and investments:

26

$$GR = \sum_i \left[td_i \cdot PD_i \cdot XD_i + tm_i \cdot pm_i \cdot M_i + te_i \cdot pe_i \cdot E_i + tf_i \cdot PC_{manu} \cdot F_i\right] + ty \cdot Y + PRFT_{gove}$$

$i \in I1$ 1

27 $GR = \sum_i PC_i \cdot gshare_i \cdot gdtot + SGOB$ $i \in GD$ 1

28 $INV = s \cdot (1 - ty) \cdot Y + SGOB + er \cdot sfor$ 1

29 $INV = \sum_{i,j} PC_j \cdot imat_{ji} \cdot kshare_i \cdot DKTOT$ $i \in I1,\ i \in GD$ 1

Material balance:

30 $XC_i = \sum_j a_{ij} \cdot X_j + CD_i + gshare_i \cdot gdtot + \sum_l imat_{il} \cdot kshare_l \cdot DKTOT$

$i,l \in GDM,\ j \in I1$ 15

31

$XC_{manu} = \sum_j a_{manu,j} \cdot X_j + CD_{manu} + gshare_{manu} \cdot gdtot + \sum_l imat_{manul} \cdot kshare_l \cdot DKTOT + \sum_i F_i$

$i \in AGR, l \in GD,\ j \in I1$ 1

Exogenous fuel price:

32 $P_{fuel} = 1$ 1

Soil model:

33 $NRR_i = \xi_i \cdot \frac{X_i}{KL_i} \cdot \left(ncs_i \frac{1 - h_i}{h_i} + ncr_i \frac{1}{h_i sr_i} \right)$ $i \in AGR2$ 2

34 $NE_i = 1000 \cdot rkswm \cdot ncc \left(1 - cpar_i \cdot \xi_i \frac{X_i}{KL_i} \right)$ $i \in AGR2$ 2

35 $NS_i = (1 - rn) \cdot NS_{t-1,i} + (1 - \Gamma) \cdot NRR_{t-1,i} - NE_{t-1,i}$ $i \in AGR2$ 2

36 $NR_i = \frac{1}{2} \left[rn \cdot NS_i + \frac{1}{3} \Gamma \sum_{s=t-4}^{t-2} NRR_{s,i} + nat \right]$ $i \in AGR2$ 2

37 $AD'_i = ad_i \frac{\left(a_i^0 + a_i^1 \cdot NR_i\right)\left(\varphi_i \kappa_i\right)^{b_i^0 + b_i^1 \cdot NR_i}}{\left(a_i^0 + a_i^1 \cdot NR_{0,i}\right)\left(\varphi_i \kappa_i\right)^{b_i^0 + b_i^1 \cdot NR_{0,i}}}$ $i \in AGR2$ 2

38 $AD'_i = ad_i \cdot (1 - \zeta)^t \cdot (1 - \chi \cdot es_i$ $i \in AGR1$ 2

39 $es_{t,i} = es_{t-1,i} + 1000 \cdot rksw \cdot \left(\varepsilon_0 - \varepsilon_1 \cdot \psi_i \frac{X_i}{KL_i} \right)$ $i \in AGR1$

List of variables

Endogenous variables:

Variable name		Comment	No. of variables	List
AD'_i	=	Adjusted productivity variable	4	AGR
CD_{ik}	=	Demand for commodity *i* by class *k*	16	GD
DKTOT	=	Total real investments	1	
E_i	=	Exports of commodity *i* in local currency	12	EX
$EXPEND_k$	=	Expenditure on consumption by class *k*	1	
F_i	=	Fertilizer	4	AGR
GR	=	Total income to the government	1	
INV	=	Total nominal investment	1	
KL_i	=	Land capital	4	AGR
LC_i	=	Labour per activity unit in sector *i*	19	I1
M_i	=	Imports of commodity *i* in local currency	11	IM
NE_i	=	Nitrogen loss due to erosion	2	AG2
NR_i	=	Natural mineralized nitrogen	2	AG2
NRR_i	=	Nitrogen in plant residual	2	AG2
NS_i	=	Stock of soil organic nitrogen	2	AG2
P_i	=	Output price	24	I
PC_i	=	Composite price of domestic and imported commodities	16	GD
PD_i	=	Price of domestic commodity *i*	16	GD
$PRFT_i$	=	Total profit in sector *i*	19	I1
SGOB	=	Government saving	1	
X_i	=	Activity in sector *i*	24	I
XC_i	=	Composite commodity of domestic and imported products	16	GD
XD_i	=	National production for the domestic market	16	GD
Y_k	=	Nominal income by class *k*	1	

Exogenous variables and parameters

α_i	=	Cost share of labour
β_i	=	Cost share of real capita/fertilizers
γ_i	=	Share parameter in export equation
Γ	=	Share of N in plant residues directly mineralized
δ_i	=	Share parameter in creation of composite commodity
ε_i	=	Share parameter in regional aggregation
ε_0	=	Erosion parameter
ε_1	=	Erosion parameter
κ_i	=	Conversion to physical fertilizer intensities
ξ_i	=	Conversion to physical food production intensities
ρ_{ei}	=	Transformation parameter in export equation
ρ_{mi}	=	Transformation parameter in import equation
ρ_{ri}	=	Transformation parameter in regional aggregation
χ	=	Conversion of soil loss to prod. loss
ζ	=	Depletion of natural P
φ_i	=	N content of fertilizer
ψ_i	=	Convertion to physical values for cocoa
a_0	=	Parameter in productivity index
a_1	=	Parameter in productivity index
a_{ij}	=	Input-Output coefficient
ac_i	=	Shift parameter in creation of composite commodity
ad_i	=	Shift parameter in Cobb-Douglas production function
ar_i	=	Shift parameter in regional aggregation
at_i	=	Shift parameter in activity equation
b_0	=	Parameter in productivity index
b_1	=	Parameter in productivity index
$cpar_i$	=	Parameter for vegetation coverage
$csub_{ik}$	=	Basic consumption
depre	=	Depreciation rate of capital
er	=	Exchange rate
es	=	Soil loss due to erosion
g	=	Growth rate of population
gdtot	=	Total real government consumption in base year
h_i	=	Food share
ipc_k	=	Consumer price index for class *k*
$gshare_i$	=	Government expenditure coefficient
$imat_{ij}$	=	Conversion matrix from destination to origin in investment
kf_i	=	Capital by sector
$kshare_i$	=	Share coefficient on total investment
nat	=	Atmosheric nitrogen
ncc	=	Index for concentration of N in soil
ncr_i	=	Index for concentration of N in roots
ncs_i	=	Index for concentration of N in stover
pe_i	=	Price of exports in local currency
pkl_i	=	Price on land
pm_i	=	Price of competitive imports in local currency

q_{ik}	=	Budget share of consumption by class
rkswm	=	Combined erosion parameter from USLE
rksw	=	Combined erosion parameter from USLE
rn	=	Parameter for N mineralization
s_k	=	Marginal propensity to consume by class
sfor	=	Foreign savings
sr_i	=	Weight between surface N and root N
td_i	=	Tax on domestic sale
te_i	=	Tariff rate on exports
tf_i	=	Tax on fertilizers
$tsub_i$	=	Agricultural subsidies to producers
tm_i	=	Tax on competitive goods imports
$trxk_k$	=	Transfers from abroad to class k in $
ty_k	=	Direct taxes on income
w_i	=	Wage rate

Sectors

I	I1 (I)	NAGR (I1)	AGR (I1)	AG1 (AGR)	AG2 (AGR)	GD (I)	GDM (GD)	SP (GD)	IM (GD)	IM1 (IM)	EX (GD)
	Sector	Non-agri-culture sectors	Agri-culture sectors	Cocoa	Other agri-culture	Goods	Goods less manu-facture	Agg-rega-ted	Import	Import less fuel	Export
agrw	x		x		x						
agrr	x		x		x						
agr						x	x	x	x	x	x
cocw	x		x	x							
cocr	x		x	x							
coc						x	x	x			x
forw	x	x									
forr	x	x									
for						x	x	x	x	x	x
fish	x	x				x	x		x	x	x
minw	x	x									
minr	x	x									
min						x	x	x	x	x	x
food	x	x				x	x		x	x	x
wood	x	x				x	x		x	x	x
meta	x	x				x	x		x	x	x
manu	x	x				x			x	x	x
cons	x	x				x	x				
elec	x	x				x	x				x
wate	x	x				x	x				
serv	x	x				x	x		x	x	x
gove	x	x				x	x		x	x	x
tran	x	x				x	x				
fuel						x	x		x		
24	19	15	4			16	15	4	11	10	12

Appendix 3 The Social Accounting Matrix (SAM) for Ghana

industries		Cocoa	Cocoa	Other Agr	Other Agr	Forestry	Forestry		Mining	Mining				Other				Private	Gov.	Trans./	Gross
goods	Import	west	rest	west	rest	west	rest	Fisheries	west	rest	Food	Wood	Metals	manuf.	Elect.	Water	Constr.	serv.	serv.	comm.	Invest.
Cocoa											3594										
Other agriculture	70540			3920	68605						20602							9902			
Forestry	279										56	14916		11			30000				
Fisheries	13640										7492										
Mining	3906								1085	7730			21414								
Manufactured food	33556																	7972			
Manufactured wood	15205								1085	3865	1873	2486		9026			30515				
Manufactured metals	38471								542	3865				66102			41801				
Other manuf. goods	385726	8383	9880	10387	39228	4064	2943	54939	1189	16276	1498	4972		33179		617	10000	41849	14861	8042	185469
Electricity									539	4838	1036	741	17410	2686	5680	1087	7955	1716	2358		
Water				6	69				542	3865	1873						956	1103	1358		
Construction		1857	2188						1085	11595	375	1243	16061	36102		1233	60000	40000	3715		200274
Total private services	132682					5295	3834	78028	2169	10751			5354	18051		206	1340	19181	11146	26555	
Government services	97146								543	843											
Transport/comm.		7542	8889	8126	73997	2900	2100	4493	2169	15460	3746	1243	10707	18060	5000	1594	2031	27149	3755	200	
Fuels	206465	257	303	270	5129	4938	3576	12253	360	3067	1480	3588	53	18850	1236	197	30000	3640		83447	
Sum (intermediates)	997617	18039	21261	22710	187029	17197	12453	149712	11309	82154	43625	29189	70999	202066	11916	4933	214597	152512	37192	118243	385742
Operating surplus		4537	5347	57234	514554	52903	38309	37513	30437	69012	23936	18695	32693	69631	45146	11348	162589	615090	19725	91914	
Comp. of employees		26510	31246	40698	398422	7173	5194	1435	15872	41477	7888	9694	13524	25633	4395	2242	46999	41010	205739	36675	
Indirect taxes prod.		10367	12219	178	210	9668	7001	132	1845	6168	33450	2070	1471	22851			1242	20788		3683	
export tax		10367	12219	178	210	4323	3131	132	1845	6168	442	780	1345	14828				3268			
sales tax						5345	3870				33009	1290	126	8023			1242	17520		3683	
Sum (GP)		59452	70073	120820	1100215	86940	62957	188792	59462	198811	108900	59649	118687	320181	61456	18523	425426	829401	262656	250515	
Capital consumption						3154	4356	9458	800	18171	3072	7385	6059	6940	15956	1882	6384	26048	17120	29560	
Gross investments						3154	4356	9458	4707	141914	8957	15022	1989	15167	31912	7961	9267	47707	50199	33972	
construction						631	871	1892	1280	69878	3591	1752	18	3639	6805	5131	2317	45321	43560	13589	
other manufacture						2523	3485	7567	3427	72035	5366	13270	1972	11527	25107	2830	6950	2385	6640	20383	
Real capital						63082	87114	189170	4980	113165	43820	54006	150048	72363	638239	14881	95290	1041903	684819	441195	
depretiation rate						0.050	0.050	0.050	0.161	0.161	0.070	0.137	0.040	0.096	0.025	0.126	0.067	0.025	0.025	0.067	
net capital growth						0.000	0.000	0.000	1.080	1.080	0.134	0.141	-0.027	0.114	0.025	0.408	0.030	0.021	0.048	0.010	
Gross capital growth						0.050	0.050	0.050	1.241	1.241	0.204	0.278	0.013	0.210	0.050	0.535	0.097	0.046	0.050	0.077	

Appendix 4 Documentation of the Social Accounting Matrix (SAM) for Ghana

Our Social Accounting Matrix (SAM) for Ghana consists of 19 producing industries and 16 commodities. Cocoa production, Other Agricultural production, Forestry and Mining production are distributed among two regions, the Western region and Rest of Ghana. Both regions produces a homogenous product. One commodity, Fuels, is just imported.

All figures for the sale of goods are made in purchasers prices. Supply equals demand for each commodity by definition in the lines, while the distribution of the GP value for each industry is done in the columns.

The National Account (NA) for 1992 in Ghana Statistical Service (1993) is our main source to make the SAM. We have just chosen to use other figures when there is a huge discrepancy between NA and other credible sources. A complete set of intermediates and the distribution of the value added are available in the printed NA. Out of this and small pieces of information form other sources, have we been able to mantle the SAM.

The source for estimating the size of the "Cocoa" industry, has been the export figures from Trade Statistics. We assume that GP just consists of the exports of raw and roasted beans and deliveries to "Manufacture of Food" industry that amount to 30 per cent of the export value of processed cocoa goods. This figure is consistent with information from the Ghana Cocoa Board (COCOBOD), but much smaller that the figure in the NA. Informal trade is excluded this way, but smuggling is less of a problem today as the produces prices is nearly 50 per cent of the world marked price. Information of cultivating technology is given by COCOBOD. We use this to calculate the expenses on intermediates and labour cost. The residual of the given farmgate price, is assumed to be gross profits (operating surplus). "Cocoa" in the SAM includes Cocobods services. The difference between export price (FOB-price) and farmgate price is split in two; one part as use of the intermediates "Transport/communication" and the rest as salaries to the employees of Cocobod.

We have split all parts of the Cocoa industry into "Cocoa-west" and "Cocoa-rest" according to the share of the production-volume in the country (COCOBOD, 1993). This way we assume the same cultivating technology all over the country, even though the climate and earth-quality is quite different between the regions.

We assume that "Cocoa" doesn't use any fixed capital assets, i.e. all machinery is included as use of intermediates from "Other manufactured Goods". Buildings as drying platforms, is classified as use of intermediates delivered from "Construction". This same definition also yields for "other Agriculture"

We have calculated GP in "Other Agriculture" from volume and price figures for each crop. Most of this information comes from the Ministry of Agriculture (MAG). Cultivating technology for some of the most important crops are given by MAG. Assuming that other crops uses an average production technology, we are able to calculate the use of intermediates and labour for the whole industry. The discrepancy between our calculated GDP and the GDP from NA, is just 0,4 per cent. Concerning intermediates, internal deliveries of seeds is the most important. The use of "Transport/communication" is assumed to be the difference between wholesale and farmgate prices as given by MAG.

The split between "Other Agriculture-west" and "Other Agriculture-rest" is done for each crop according to the regional distribution of production volume. Although the two regions uses the same cultivating technology on crop-level, the composition of crops gives rise to different production technology on an aggregated level.

The GDP in the industries "Forestry", "Fisheries", "Transport/Communication" and "Government Services" are NA figures. Further calculation of GP and use of intermediates in "Forestry" is taken from a forestry report (IIED(1993)). They assess the use of intermediates to be quite small (20 per cent of GP) and Operating Surplus as quite big (60 per cent) after all taxes being paid. We assume the same production technology in "Forestry-west" as in "Forestry-rest", and just distribute 58 per cent of all figures to the former and 42 per cent to the latter (IIED(1993)). This distribution reflects the fact that there is now just major virgin forests left in the Western region for further exploitation.

The use of intermediates in "Fisheries" are much bigger, with "Other Manufactured Goods" reflecting fishing equipment of different types, "Fuels" for the vessel-engines and "Private Services" contains much of the distribution and resale of the catch. We have made operating surplus 26 times as big as compensation on employees, because most of the fishermen are self-employed or partners on the vessel.

"Transport/Communication" is a huge intermediates consumer of "Fuels" and "Other Manufactured Goods", even though the main production capital like buses are assumed to be investments. "Private services" delivers repairs and maintenance. The huge amount of operating surplus reflects a huge degree of self-employment (f.ex. taxi-drivers). "Government Services" is treated as a producing industry, but owned by the state. By nature it is not maximising profits, but we still calculate Operating Surplus equal to depreciation of fixed assets.

We have four manufacturing industries in our SAM. The GDP of the aggregate Manufacture in NA is split into four according to the distribution of GDP in the Ghana Industrial Census 1987 (GIC-87) in GSS(1991). To calculate the use of intermediates and GP in each sector, we have used the GP/GDP-ratio from GIC-87, which also gives the ratios for wages, operating surplus and taxation. Unfortunately the report on GIC-87 doesn't make the split between intermediates (except "Electricity" and "Fuels") so they are mainly just guesstimates. "Manufacture of Food" uses a lot of "Other Agriculture" and "Fisheries" as input, and Operating Surplus is quite big due to self-employment in the industry. The main supplier to "Manufacture of Wood" is "Forestry", while "Manufacture of Metals" uses a lot of "Mining" and "Electricity". This industry consists of huge aluminium melting factories and the mere fact that the supply of "Electricity" is in short compared to 1987, could make this figures out of date today. In "Manufacture of Other Goods" we assume that the industry uses much internal deliveries (on company level is much of it imported goods).

We have split the NA figure Electricity&Water into "Electricity" and "Water" according to the GIC-87 ratio. The main use of intermediates comes from "Other Manufactured Goods", "Transport/communication" and "Fuels".

GIC-87 is also our main source for calculating the figures in "Mining", but our starting point is the GP which is calculated on the basis of the export figures. This industry has developed rapidly since the depressing situation in 1983. The export figures gives a better description of the industry today that the GDP figures in the NA. So GP is calculated as a residual, making supply equal total demand of the good. This GP figure is split into GP in "Mining-west" and "Mining-rest" according to the distribution in the GIC-87. Each regional sector is then calculated from the GIC-87. The use of intermediates is supposed to be bigger in "Mining-rest", reflecting that the mines in the rest of the country are using more capital intensive production technologies. This technology-gap may even be wider because of the legalisation of small scale mining and the shift in technology in the huge mines.

We assume that NA has not caught up evolution in the industry "Construction". To match NA's own assessments of deliveries from the sector to investments and other consumption of "Construction", this implies that we have to double the GDP figure of NA in the SAM.

While computing "Private Services", we starts out with three industries; Wholesale&Retail, Hotel&Restaurants and Other Private Services and then aggregating them. Our starting point is the GDP figure in NA. The use of intermediates is our own estimation based on the accounting framework.

Investment figures are taken from NA. Deliveries from "Construction" is the summation of Buildings and Other Construction Work (tab.97), while investments delivered by "Other Manufactured Goods" are Machinery&Equipment and Transport Equipment. The distribution of the gross investment goods on industries (all expenditure by the household is assumed to be consumption) are based partly on information from GIC-87 and partly on guesstimates of depreciation rates and net investment rates. Again a accounting restriction is followed.

Government Consumption is separated from the production sector "Government Services", but is of course the main consumer of this service. According to the World Bank they use 63 per cent of their total consumption expenditure on their own service and we assume that the rest is spent on "Private Services".

The NA is our main source for total Private Consumption. The distribution on commodities is mainly calculated from the Ghana Living Standard Survey 1988 (Boateng, Oti E. et al (1990)). Since the GLSS operates in retail prices, we have transferred some of the value of the goods to "Private Services" that contains Wholesale&Retail. We have also made some other minor changes to make demand match supply for each good. The total amount of Private Consumption in the SAM is 1.2 per cent higher than the NA figure.

The Import/Export figures are calculated from different sources of information, mainly the Balance of Payments, (Bank of Ghana). The major adjustment that is made is a radical turndown in the reported export of Electricity.

We operate with three categories of Taxes in the SAM; Import-tax is added to the CIF-value on imports and paid by the purchaser of the good, Export tax/Sales tax is paid by the producing industry. It is important to notice that one unit of good can not be taxed in more than one way. The tax-rate on imports are assessed to be a flat 4 per cent on all goods, except petroleum taxes that is quite high. WB (1994) assesses it to be 42 per cent. Some of the petroleum products are imported as "Other Manufactured Goods" but has kept the high taxation rate, this implicitly pulls the overall taxation rate of this good up to 6 per cent. The overall taxation rate of exports are assessed to be 3 per cent. The major exceptions are "Cocoa" with a taxation rate of 22 per cent (WB(1994)). "Forestry" is another sector that is treated especially. The major taxation in this industry is through a royalties-taxation paid for logging. The royalties are split into an export tax and a sales tax according to the distribution of gross value of goods delivered to the domestic marked and to the export-marked. The export taxation on "Other Manufactured Goods" are calculated residually to assertion total export taxation add up to the WB(1994) estimation for the whole country. This implies a export tax rate of 24 per cent for this industry. Quite high, but according to CEPS (Customs and Excise Preventive Service) most of the export taxes are collected from this industry (aside from cocoa-taxation) fx. through taxation on refinery products.

Looking at the aggregates of the whole economy, our figures reflects more or less the same numbers as in NA. However our SAM reflects a more open economy than the NA, since exports are 36 per cent and imports are 11 per cent higher. GDP, Private Consumption, Government Consumption and both Government and Private investments are almost equal in our SAM and in NA. Domestic savings

(GDP-Private Consumption - Government Consumption.) is just 1.6 per cent, but still positive. Total savings (including foreign savings in Ghana) is equal to Gross Investment, and gives rise to a gross investmentrate of 12,9 per cent and net investmentrate of 7,7 per cent.

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Appendix 5 The soil productivity model

In the following, we list the set of equations included in the soil productivity moduls for nitrogen and phosforus constrained crops.

Nitrogen-constrained

We start with the output of a single crop, determined in an economic model framework, and determine the yield Y^G of (for instance) grain, which is total output per ha cultivated land. The plants which are grown contain 3 parts which must be treated differently in the nutrients cycle: grain, stover and roots. Grain is by intention removed from the soil, stover might be removed or recycled, while roots are recycled. The model specify their contributions to nitrogen stock.

The biomass in roots is roughly 30 percent of total biomass (for annual crops). Hence, total biomass produced (B_t) is:

$$B_t = (Y_t^G + Y_t^s)\frac{1}{0,7} \tag{1}$$

where Y_t^G = grain yield at time t in tonnes (biomass) and Y_t^S = stover yield in tonnes biomass. The grain/stover relation is called SG and the amount of stover is calculated as

$$_t^s = \frac{1}{SG}Y_t^G \tag{2}$$

The nitrogen content in roots N_t^{RO} and stover N_t^{ST} is recycled to the soil. The amount of nitrogen in the process is determined by the nitrogen consentrations in roots (N^{CR}) and stover (N^{CS}).

$$N_t^{RO} = N^{CR} \cdot 0.3\,B_t = N^{CR}(Y_t^G + Y_t^s)\frac{0.3}{0.7} = N^{CR}Y^G(1+\frac{1}{SG})\frac{0.3}{0.7}$$

$$N_t^{ST} = N^{CS}\ Y_t^S = N^{CS}[0.7\,B_t - Y_t^G] \qquad = N^{CS}[\frac{1}{SG}Y^G]$$

Here the nitrogen content is expressed in terms of grain output which is the relevant input from the economic model.

Nitrogen content of roots and stover is transformed according to the following processes:

$$N_t^R = N_t^{ST} + N_t^{RO} \tag{3}$$

N_t^R is total nitrogen content of plant residues. These residues are decomposed, partly directly into soil organic nitrogen (SON), and partly mineralized in a time consuming process (4 years to complete).

The important aspect for soil productivity is the amount of nitrogen which is mineralized, because this is the form of nitrogen which is available for plant uptake.

At time t, the amount of nitrogen which is mineralized from residues N_t^{RM} is determined by the supply of plant residues 2-4 years earlier:

$$N_t^{RM} = \frac{1}{3}\Sigma_{k=2}^{4}\,\beta \cdot N_{t-k}^R \tag{4}$$

where β is the share of nitrogen in plant residues which is available for mineralisation (the rest has been transformed directly into SON).

Then we will focus on the nitrogen stored in organic matter. N_t^S is soil organic nitrogen in upper 20 cm of the soil. Decay of soil organic matter occurs at a constant rate (r), and so with the soil organic nitrogen:

$$N_t^s = N_{t-1}^s(1-r) \tag{5}$$

The rate r is set to 0.04. However, to properly describe the change in stock of soil organic nitrogen, eq. (5) must be modified because soil erosion and addition of residues will affect the size of the SON pool to mineralize from:

$$N_t^S = [N_{t-1}^S + (1-\beta)N_{t-1}^R - N_{t-1}^E](1-r) \tag{6}$$

where N_t^E is loss of soil organic nitrogen through soil erosion in the previou year. The decay in organic matter is providing mineralized nitrogen (N^{SM}) from SON::

$$N_t^{SM} = r(N_{t-1}^S - (1-\beta)N_{t-1}^R - N_{t-1}^E) \tag{7}$$

The soil erosion is calculated by means of the Universal Soil Loss Equation (USLE) (FAO,1979: A provisional methodology for soil degradation assessment. Rome). It is time dependent because vegetation cover and nitrogen consentration will change over time as a function of the yeild obtained.

The total supply of mineralized nitrogen is determined by

$$N_t^{MIN} = N_t^F + \frac{N_t^{SM} + N_t^{RM} + N_t^A}{2} \tag{8}$$

The nitrogen limit affects the crop:

$$I_t^N = 1 - 1.067\ e^{(-0.0095 N_t^{MIN})} \tag{9}$$

I_t^N denotes the level of yield relative to the potential yield for the specific crop and covers the effect of nitrogen both from commercial fertilizer and supplies from the soil.

Phosfor-constrained

For cocoa, it is phosfor supply which determines the relation between actual and potential yield.

The phosfor model is a simplified version containing the following equations:

$$_t = S \cdot P_t^S \cdot E_t \cdot Y^P \tag{10}$$

Actual yield Y_t in proportion to potential yield Y^P is a product of the shadow index (S), the soil phosfor status (P_t) and soil erosion (E_t). We assume that all cocoa is cultivated with shade. If there is no shade, the shade indicator would be 1 as a maximium, but the production system would experience higher soil erosion in turn reducing the productivity.

The soil status is improved by fertilizer use, P_t being the amount of phosforous which is used per ha:

$$P_t^S = (1-\zeta)^t\ P_0^S + 0.01(P_t + \frac{2}{3}P_{t-1} + \frac{1}{3}P_{t-2}) \tag{11}$$

There is a lag in the contribution of fertilizer to the soil P status. After the third year, there is no effect.

The soil loss due to erosion (C_t) is modified by the effect that high yields (Y_t) provide a better vegetative cover than low yields:

$$C_t = \varepsilon_0 - \varepsilon_1 \cdot Y_{t-1} \tag{12}$$

Hence, the erosion productivity loss index (E_t) is:

$$E_t \ = \ 1 - 7{,}7 \cdot 10^{-7} \cdot ES_t \tag{13}$$

$$ES_t = ES_{t-1} + 1000 \cdot rksw \cdot C_{t-1} \tag{14}$$

When linking the soil moduls to the production functions for agricultural sectors we want to deal with the yield impact of commercial fertilizer and nitrogen in recycled residues as separat indicators. The implementation of these soil models in the CGE framework is described in appendix 6.

Appendix 6 Integrating the soil model in the CGE model

The point of departure is a Cobb-Douglas production function of the following form:

$$\frac{X}{KL} = ad \cdot I_N \cdot \left(\frac{L}{KL}\right)^{\alpha}$$

where X is crop output, and L and KL is input of labour and land, respectively. I_N is a soil productivity index which is reflecting the nitrogen supply to plants.

As described in appendix 5, the soil productivity indicator is given by

$$I_N = 1 - \gamma e^{-\tau(N_R + N_F)}$$

where N_R is the stock of minreralized soil nitrogen and N_F is nitrogen supplied as chemical fertilizer.

Before substituting this in the production function we separate the effects coming via the stock of mineralized soil nitrogen and chemical fertilizer by approximating the soil productivity indicator in the following manner:

$$I_N \approx A(N_R) \cdot N_F^{\beta_F} \approx (a_0 + a_1 N_R)\left(N_F^{b_0 + b_1 N_R}\right)$$

The first paranthesis on the right hand side represents the effect of the soil stock of nitrogen, while the second paranthesis takes care of the chemical fertilizer impact.

The soil productivity indicator implemented in the production function is then

$$\frac{X}{KL} = ad \cdot \left(a_0 + a_1 N_R\right) \cdot \left(N_F^{b_0 + b_1 N_R}\right) \cdot \left(\frac{L}{KL}\right)^{\alpha}$$

The soil productivity indicator is based on amounts of nitrogen (N_F) added per ha of land. To convert this to a form suitable to our model framework, we substitute

$$\xi \cdot \varphi \cdot \frac{F}{KL} = N_F$$

where φ is the nitrogen content of fertilizer (F), and ξ is a calibration parameter converting physical units into monetary units. This gives

$$\frac{X}{KL} = ad\left(a_0 + a_1 N_R\right) \cdot \left[\xi \cdot \varphi \cdot \frac{F}{KL}\right]^{b_0 + b_1 N_R} \cdot \left[\frac{L}{KL}\right]^{\alpha}.$$

We simplify further by assuming that the fertilizer dependent exponent is fairly stable over a relevant range of levels for our analysis:

$$b_0 + b_1 N_R = \bar{b}.$$

Hence,

$$\frac{X}{KL} = ad\left(a_0 + a_1 N_R\right)\left(\xi \cdot \varphi\right)^{\bar{b}}\left[\frac{F}{KL}\right]^{\bar{b}} \cdot \left[\frac{L}{KL}\right]^{\alpha}$$

For the sector activity level we then have:

$$X = a\hat{d} \cdot L^{\alpha} \cdot F^{\bar{b}} KL^{1-\alpha-\bar{b}}$$

with

$$\hat{a}d = ad(a_0 + a_1 N_R) \cdot (\xi \cdot \varphi)^{\bar{b}}.$$

We want to replace the more technical (experimental) fertilizer impact embedded in the soil model $(F^{\bar{b}}$ with the impact consistent with our economic model (F^{β})i.e. β equals the cost share of fertilizer or observed price elasticity.

Best fit in the above approximation is obtained, within relevant ranges for N_R and N_F, with the following parameter values:

a_0:	-0.1721	b_0:	0.11358
a_1:	0.01199	b_1:	-0.0018

Other parameters employed in the model are:

	agrw	*agrr*
φ	0.25	0.25
κ	160.542	158.120
β	0.1	0.1
ad	2.899	2.721

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