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May 2007

Cost Implications of Agricultural Land Degradation in Ghana

An Economywide, Multimarket Model Assessment

Xinshen Diao, International Food Policy Research Institute
Daniel B. Sarpong, University of Ghana, Legon-Accra

Development Strategy and Governance Division

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ABSTRACT

An economywide, multimarket model is constructed for Ghana and the effects of agricultural soil erosion on crop yields are explicitly modeled at the subnational regional level for eight main staple crops. The model is used to evaluate the aggregate economic costs of soil erosion by taking into account economywide linkages between production and consumption, across sectors and agricultural subsectors. To fill a gap in the literature regarding economic cost analysis of soil erosion, this paper also analyzes the poverty implications of land degradation. The model predicts that land degradation reduces agricultural income in Ghana by a total of US$4.2 billion over the period 2006–2015, which is approximately five percent of total agricultural GDP in these ten years. The effect of soil loss on poverty is also significant at the national level, equivalent to a 5.4 percentage point increase in the poverty rate in 2015 compared to the case of no soil loss. Moreover, soil loss causes a slowing of poverty reduction over time in the three northern regions, which currently have the highest poverty rates in the country.

Sustainable land management (SLM) is the key to reducing agricultural soil loss. The present findings indicate that through the adoption of conventional SLM practices, the declining trend in land productivity can be reversed, and that use of a combination of conventional and modern SLM practices would generate an aggregate economic benefit of US$6.4 billion over the period 2006–2015. SLM practices would therefore significantly reduce poverty in Ghana, particularly in the three northern regions.

Key Words: Ghana, Agricultural Soil Loss, Economywide modeling

1. INTRODUCTION

Soil erosion, the most visible and most widespread form of soil degradation, could have a serious negative effect on economic development in Ghana as the economy of this country depends heavily on land, forests, and water bodies for its agricultural growth and rural development. Unless emphasis is placed on technological improvement and sustainability measures, the accelerated growth goal set by the Ghanaian government will be difficult to realize, as the impact of soil degradation and the associated effects on water, vegetation and nutrients on agricultural productivity will have negative repercussions on the rest of the economy.

Ghana has a relatively large amount of cultivated land per capita; however, most lands are characterized by poor fertility and are subject to degradation. To sustain crop production increases and ensure food security, soil, nutrient and water resources need to be properly managed and conserved (Quansah, 1996). Hence, soil management is crucial to Ghana's economic development in several respects.

In this paper, an economywide, multimarket (EMM) model is constructed for Ghana and the effects of agricultural soil erosion on crop yields are explicitly modeled at the subnational regional level for eight main staple crops. The model is used to evaluate the aggregate economic costs of agricultural soil erosion, taking into account economywide linkages between production and consumption, between agricultural and nonagricultural sectors, and across agricultural subsectors. We also use the model to analyze the effects of soil erosion on poverty at both the national and subnational levels, a topic that has received little attention in previous studies.

We find that the economic cost of agricultural soil erosion determined using the EMM model is comparable with the values in the literature about Ghana. In our model, agricultural soil loss reduces the total cumulative agricultural income by approximately five percent for the period 2006–2015, which is equivalent to a loss of US$4.2 billion over 10 years. The effect of soil loss on poverty is found to be significant at the national level in the simulation, equivalent to five percentage points higher poverty rate in 2015 than would be the case in the absence of soil loss effects. Moreover, at the subnational level, the reduction of poverty through economic growth is further degraded in the three northern regions, which currently have the highest poverty rates in the country.

This paper emphasizes sustainable land management (SLM) as the key to reducing agricultural soil loss and overcoming the negative effects of land degradation on agricultural production, income growth, and poverty reduction. The results indicate that if most smallholder farmers adopt conventional SLM practices, the declining trend in land productivity (crop yield) would be reversed, but without any additional, significant gain in terms of aggregated agricultural income. If, on the other hand, conventional SLM practices are implemented in conjunction with the use of organic and inorganic fertilizers, the aggregate economic benefit would be US$6.4 billion over the period 2006–2015. That is, mitigating the effects of soil loss would lead to a US$1.4 billion increase in real agricultural GDP in 2015. Moreover, mitigating soil loss effects would significantly reduce poverty, particularly in the three poor northern regions.

The remainder of this paper is organized as follows: Section 2 highlights the land degradation process in Ghana, with a focus on the effect of agricultural practices on soil loss. Section 3 introduces the EMM model developed in this study, and the relationship between agricultural soil loss and crop yields is explicitly captured in a soil loss module included in the model. Utilizing the model, Section 4 discusses the economywide cost of agricultural soil degradation in Ghana, with particular attention devoted to the aggregate effect on agricultural GDP (AgGDP) and poverty. Section 5 outlines sustainable land management practices suitable for Ghana and evaluates both conventional and modern measures and their effects on economic growth and poverty reduction. Caveats and policy implications of SLM practices are presented in Section 6, which concludes the paper.

2. LAND DEGRADATION IN GHANA: AGRICULTURAL SOIL EROSION

Many factors are driving long-term soil and vegetation degradation in Ghana, including population pressure, increased urbanization, and climatic changes. These long term driving factors are reflected in agricultural, mining and other production practices that have led to soil erosion, soil nutrient depletion, overgrazing, pollution, river and groundwater depletion, and desertification arising from deforestation.

The short-term causes of land degradation are mainly natural factors and human activities. Natural factors include the physical and other characteristics of the soil, which affect the erodibility of the soil and its capacity to retain and drain water and to hold nutrients; topography; and climatic conditions. Climatic conditions are important for soil erosion as prolonged periods of heavy rain separated by prolonged dry periods contribute to the reduction of vegetative cover, thereby increasing the risk of soil erosion. Such climate patterns are more prevalent in the Guinea and Sudan Savannah zones, as these areas have soil/vegetation types that are particularly susceptible to such type of climate pattern. In addition to the seasonal variability in rainfall, wide fluctuations in spatial distribution and amount of rainfall, as well as number of rainy days that occur over years and decades, lead to frequent droughts. The major droughts of 1968–73, 1982–85, and 1990–92 in Ghana caused serious hydrological imbalances that negatively affected land resources, particularly soil quality and fresh water supplies (EPA, 2002). Climate change may also contribute to accelerated coastal erosion, to which Ghana is particularly vulnerable (ISSER/DFID/WB, 2005).

The human-associated factors driving long-term soil and vegetation degradation in Ghana are reflected in unsustainable farming practices, removal of vegetation cover (including deforestation and overgrazing), mining activities, and urbanization and industrial activities caused by increased population growth pressures. Various agricultural farming systems in Ghana and their effects on agricultural soil are summarized in Table 1. The agricultural farming systems used in Ghana can be categorized as rotational bush fallow, permanent tree crop, compound farming, mixed farming, and special horticultural farming systems. These farming systems have peculiar characteristics that have different effects on the soil. The rotational bush fallow system, which is characterized by clearing and burning of the vegetative cover, is the dominant farming system throughout Ghana. The clearing and burning normally destroys the vegetative cover and makes the soil susceptible to erosion and leaching to soil infertility.

Table 1: On-site effects of agricultural practices on agricultural soil in Ghana

Type of farming system in Ghana	Farming practice	Effects on soil
Rotational bush fallow system	Slash and burn. Fallow periods. With or without fertilizer	Destroy vegetative cover. Expose the soil to erosion. Leaching of soil nutrients
Permanent tree crop system	Slash and burn but provide tree cover	No serious soil loss consequence identified in this system. Good forest cover
Compound farming system	Slash and burn with or without fertilizer/manure. Grazing livestock	Soil loss as a result of erosion, leaching of soil nutrients, compaction from livestock
Mixed farming system	Slash and burn with or without fertilizer/manure	Soil erosion and nutrient depletion
Special horticultural farming system	Slash and burn with fertilizer/manure And chemical application	Soil erosion, eutrophication and acidification of the soil as a result of fertilizer and chemical application

Source: Asuming-Brempong, Seini and Botchie (2003)

Soil fertility can be restored through long fallow periods; however, fallow periods have drastically decreased in Ghana in recent years owing to population pressures and increases in the cost of land clearing, among other factors. The long fallow periods of 5 to 15 years or more associated with traditional shifting cultivation have now been reduced to 1 to 3 years (Acquaye, 1990; Ahenkora and Appiah 1996). On the other hand, the permanent tree crop farming system is typically characterized by the cultivation of a mono-crop such as cocoa, citrus, oil palm, avocado, rubber, coffee or mango. Cocoa is the most extensively cultivated of these tree crops. The permanent tree crop farming system predisposes the soil to some form of degradation during the early years of the tree crop’s life-cycle but is not associated with serious soil loss problems after the tree crop canopy closes. The major impacts on agriculture of these farming systems stem from soil erosion, serious deforestation, and rural landscape degradation.

The major processes of land degradation in Ghana are physical (in the form of soil erosion, compaction, crusting, and iron-pan formation), chemical (depletion of nutrients, salinity, and acidification), and biological (loss of organic matter). Water erosion has destroyed tracts of land throughout Ghana, as evidenced by the Erosion Hazard Map of Ghana (Obeng, 1971). This map shows that many regions of Ghana contain land affected by severe sheet and gully erosion, with very severe erosion being particularly prevalent in the Upper West Region, Northern Region and Ashanti Region.

3. AN EMM MODEL WITH AGRICULTURAL SOIL LOSS–CROP YIELD RELATIONSHIP

3.1 The model

Soil loss has a direct negative effect on land productivity in crop production, which has repercussions for the rest of the economy. In order to fully capture the potential economic cost of agricultural soil loss, it is necessary to integrate the effects of soil loss into an economic model. For this purpose, and in order to capture the linkages among agricultural soil loss, crop productivity, farm income and poverty in a macro–micro integrated framework, we develop an EMM model for Ghana. While the model has an agricultural focus and includes 33 primary agricultural commodities or commodity groups, it also includes 3 processed agricultural sectors and 10 nonagricultural sectors, such that it covers almost all production activities in the country. The 33 agricultural commodities are from six broad agricultural subsectors: (1) cereals, (2) roots and tubers, (3) pulses and oilseeds, (4) traditional and non-traditional export crops, (5) other cash crops, and (6) livestock products. A detailed description of these 33 agricultural commodities and 10 nonagricultural subsectors is given in the Appendix. Although many activities performed in agricultural production can cause land degradation, we focus on eight major crops: maize, sorghum, millet, cassava, yam, cocoyam, pulses, and groundnuts.[1] Agricultural farming activities associated with these crops are major contributors to soil loss in Ghana, and these crops play important roles in food consumption and farm income and hence poverty reduction. To take into account regional heterogeneities in economic activities and soil loss, the EMM model further disaggregates the national level production and consumption of each agricultural or nonagricultural sector into 10 regions.[2] Hence, the relationship between soil loss and crop yields is described at the regional level.

The EMM model is based on neoclassical microeconomic theory. In the model, an aggregate producer represents a subnational region in the production of a specific commodity. Consistent with other multimarket models, the supply function, instead of the production function, is used to capture each representative producer's response to the market. Specifically, the supply functions are derived under producer profit-maximization and based on the producer prices of all commodities (including both agricultural and nonagricultural commodities). In the

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[1] Information about the relationship between soil loss and yield loss is available only for these eight crops.

[2] Land structure is quite different even within each region in Ghana. Ideally the model should be disaggregated according to types of land rather than administrative regions. However, such disaggregation is impossible because all other data (especially economic and household data) can only be disaggregated into the 10 subnational regions.

crop subsectors, the supply functions have two components: (1) yield functions, which are used to capture supply response to the own prices given the farm area allocated to a crop; and (2) land allocation functions, which are functions of all prices and hence are responsive to changing profitability across different crops given the total available land. The yield function is also linked to soil loss, as discussed below in Section 3.3. The own-price elasticities employed in the yield functions are drawn from other studies on Ghana and elsewhere with adjustments, while the cross-price elasticities in the area functions are calibrated according to the value share of each commodity within a region's total agricultural production. By taking into account land constraints on crop production, the price elasticities in the area functions are further constrained by a homogeneousness condition, which requires that the total cultivated land area be fixed in a given year. Thus, increasing the area of one crop as a supply response to an increase in the price for that crop must be accompanied by decreases in the production areas of other crops.

The demand function in the EMM model is also disaggregated to 10 regions by two household groups: rural and urban. In contrast to the production side, in which the supply function (or area function) is defined at the aggregated production level by region, the demand function is defined at the per capita level. A representative consumer of either rural or urban household groups of a region consumes all kinds of goods, and his/her demand for each of these goods is derived by maximizing the Stone-Geary utility function, and the subsistence level of consumption is calibrated to the households' home consumption (by rural and urban household groups for each region). Data used to calibrate the demand function are from the fourth Ghana Living Standards Surveys (GLSS4), 1998/99. Both income and price elasticities for any specific commodity vary between the rural and urban households and across regions due to different consumption patterns at different income levels or locations. Such differences not only imply that the aggregate effect of consumers' market responses is often non-linear and much more complicated than that in the case where demand is defined at the national level, but also indicate similar income increases in the country can have differential effects at household level and hence differential effects on poverty reduction. These are a focus of the model simulations discussed later in this paper.

In contrast to most multi-market models, which are usually partial equilibrium models, the per capita income for a household group is an endogenous variable in the EMM model and is determined by the group's production (of agricultural and nonagricultural) revenue divided by the population, which grows exogenously over time. Because of this setup, the model has a general equilibrium nature, which allows production and consumption decisions to be linked. Since intermediate inputs are not explicitly modeled, producer prices are adjusted to represent the value added. Thus, the aggregated agricultural production at the value added prices is the AgGDP. For the ten nonagricultural sectors, the sector level value-added is used to represent production output with unit price. Thus, national GDP (as well as regional level GDP) comprises AgGDP and nonagricultural GDP, which are both endogenous in the model.

As the name of the model suggests, a multiple market structure is specified. There is perfect substitution between domestically and internationally produced commodities. However, transportation and other market costs distinguish trade in the domestic market from imports and exports. For example, while imported maize is assumed to be perfectly substitutable with domestically produced maize in consumers' demand functions, importing maize will not be profitable if the domestic price is lower than the import parity price plus transactions costs. Maize imports can only occur when domestic demand for maize grows faster than domestic supply, causing the local market price to rise significantly. A similar situation applies to exported commodities. Even though certain horticultural products are exportable, if domestic production is not competitive in international markets, either due to low productivity or high transactions costs, then exports of such commodities will not be profitable. Only when domestic producer prices plus market costs are lower than the export parity price for the same product does it become profitable to export that product. Except for export commodities such as cocoa or import ones such as rice and dairy products, many food crop and livestock products are assumed to have balanced supply and demand in the national market in the base year (2003). When the supply and demand for a specific commodity are balanced without external trade, the price of the commodity is endogenously determined by domestic supply and demand. When either imports or exports occur for a specific commodity, the price of the commodity is exogenously linked with an international price (such as cocoa in the case of exports and rice and milk products in the case of imports).

For commodities that are assumed to have balanced domestic demand and supply in the base year, however, imports or exports of these commodities may still occur in the following years. Similarly, the international trade of a commodity imported or exported in the base year may be stopped in the following years if the domestic price varies such that the trade is no longer profitable. We will discuss these possibilities below in the context of model simulations of the effects of soil loss on agricultural growth in a series of scenarios.

To analyze the effect of agricultural soil loss on poverty through its effect on agricultural production, a nationally defined poverty line is adopted in the model. This line is measured by household total expenditure using the date from the 1998/99 GLSS4 (GSS, 2004). The detail household data from 1989/99 GLSS4 is also used to develop a micro-simulation model to capture household consumption patterns. Households in the micro-simulation model are linked to their corresponding representative rural or urban households in a region in the EMM model. Due to a lack of more detailed information, population growth rate is assumed to be the same in all 10 regions, and hence, the sample weight employed in the GLSS4 on each individual sample household augments proportionally with population growth. This assumption implies that the population grows at the same rate within each household group.

A top-down linkage from the EMM model to the micro-simulation model is through income and expenditure by commodities. As production patterns and land allocations vary across sample households as well as regions, the absolute levels of income generated from different agricultural and nonagricultural activities, and hence the total income, differ across the sample households. As a result, if maize or cassava production is negatively affected by soil loss, income of households in regions where maize and cassava are important income sources would fall to a greater degree than the income of households in regions with more diversified income sources. Such differential effects allow the EMM-micro-simulation model to estimate national or regional income distribution changes and poverty reduction effect of soil loss.

3.2 The economic data

The economic and population data used to calibrate the base year of the model are drawn from various sources. Specifically, data for the regional level agricultural production by crop (including crop output and areas) are mostly sourced from the Ministry of Food and Agriculture (MoFA). Data from Food and Agriculture Organization (FAO) are used for the few crops whose production and area data are not available in the MoFA data set. Livestock production data, as well as import and export data, are from the FAO. The 2000–04 average level of production and 2000–03 average level of trade data are used for the base year (2003). The non-agricultural sector data are from International Monetary Fund (IMF) (2000–04). Price data are from the MoFA and GLSS4.

3.3 The agricultural soil loss module and soil loss data

Most researchers agree that soil erosion has a serious impact on agricultural production. However, it is difficult to quantify the effect of the loss of a unit of soil on crop yield (Lal, 1987) because of lack of direct, clear-cut relationship between erosion and productivity. Moreover, soil is only one of the factors affecting productivity, as crop yield is a function of many variables (Perrens and Trustum, 1984).

Several researchers have systematically analyzed data from field experiments relating erosion and productivity. Such studies consider the relations between soil erosion and crop yields on different types of soils along different slopes and under different tilling and fertilization conditions (see, for example, Lal, 1988, 1994; Stocking and Peake, 1986). Alfsen et al. (1997) used a computable general equilibrium (CGE) model to explore the relationship between soil erosion and crop productivity in Ghana. According to Stocking and Peake (1986), an exponential relation best describes the fall in yield in most cases with cumulative erosion, with the coefficient in the exponential equation ranging from –0.002 to –0.036 depending on the crop type. The relations between erosion and the yield of maize and cowpeas grown on one soil type (Alfisols) in Southeast Nigeria have been documented by Lal (1983). In Ghana, Adama (2003) studied the relation between soil erosion and maize crop yield on another soil type (Acrisols). In other work in this area, Thao (2001) studied the effect of erosion on root crops, in particular cassava, in Vietnam.

According to Adama (2003), the marginal effect of soil loss on yield loss (MYL) is equivalent to 14 kg/ha for maize in Ghana, while adopting Stocking and Peake's coefficient for cowpeas in the exponential equation, the MYL is 3.86 kg/ha for cowpeas. Based on the results of Thao (2001), the MYL is 39.8 kg/ha in the case of cassava. However, according to Biggelaar et al. (2004), the impact of past erosion on crop yields is much smaller than the above estimations, whereas the impacts of present erosion on crop yields are higher than the estimations (Table 2). To be consistent with the country's historical trends of actual crop yields, the values of the MYL coefficients used in the model are chosen to be the same as the past impacts in Biggelaar et al. for Africa as a whole (Table 3).

Table 2: Impacts of past and present erosion-induced yield loss for Africa

Crops	Kilogram loss in yield due to 1 ton of soil erosion per hectare		Percent relative yield decline due to 1 ton of soil erosion	
	Past	Present	Past	Present
Maize	0.86	72.0[1]	0.03	2.45
Millet	1.25	54.0	0.29	11.13
Beans	0.06		0.02	
Cowpeas	0.29		0.03	
Peanuts		47.0		7.11
Cassava	3.96		0.03	

[1] Includes Ghanaian studies of Bonsu and Obeng (1979)

Sources: summary from Tables III (p.15), IV (p.22), V (p.25), VI (p.27), and VII (p.30) in Biggelaar et al. (2004).

Table 3: Value of MYL coefficient and C-factors used in the model

Crops included in the model	MYL (kilogram loss in yield due to 1 ton of soil loss per hectare)	C-factor (CFC)
		Intercrop Cassava-Maize
Maize	0.86	0.073
Sorghum and millet	1.25	0.073
Cassava	3.96	0.073
Yam	3.96	0.073
Cocoyam	3.96	0.073
		Legumes
Pulses	0.06	0.31
Groundnut	0.06	0.31

Source: Authors' compilation

Table 3 also includes the values of the Crop Management Factor (C-factor[3]), a technical variable that describes the relationship between soil loss from an area of land covered by a given crop and soil loss from the same area of land without vegetation. Vegetation covering can significantly reduce soil loss, which explains why the C-factor is much smaller than one.

The two sets of coefficients reported in Table 3 are used in the model to convert the potential soil loss (PSL) into the actual soil loss (ASL) in order to calculate the yield loss for a specific crop. The PSLs are estimated based on the Universal Soil Loss Equation on bare uncultivated soils, and in many cases are derived from GIS imagery with additional field observations. Different soil conditions and patterns of crops grown are taken into account in this estimation. PSL represents a long-term average annual soil loss expressed in ton/ha/year, and is determined with accounting for rainfall erosivity, soil erodibility, and topographic factors such as slope length and gradient factors. Because many factors affect PSL, the value of PSL often varies with geographic location. The PSL data for the 10 regions of Ghana was sourced from Council for Science and Industrial Research (CSIR) unit of the Crop Research Institute.[4] The PSL values

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[3] We are grateful to Professor Charles Quansah of the Kwame Nkrumah University of Science and Technology, Kumasi-Ghana, for these insights.

[4] We thank Mr. Samuel Osei-Yeboah for helping in getting this data set.

range from less than 200 ton/ha/year in Accra, Upper West Region and Upper East Region, to close to 700 ton/ha/year in Ashanti, Northern Region, and Western Region.

The ASL varies not only by region but also by crop due to the different C-factor coefficients (CFC) of maize-cassava intercropping and legume crops. The following equation for ASL is used:

$$(1) \qquad ASL_{i,R} = PSL_R \times CFC_i,$$

where *i* is the crop type (maize, sorghum and millet, cassava, yam, cocoyam, pulses, or groundnut), and *R* represents the region among the 10 regions of Ghana. The equation for the crop yield loss due to soil loss is as follows:

$$(2) \qquad \Delta Y_{i,R} = MYL_i \times ASL_{i,R},$$

where $\Delta Y_{i,R}$ is the lost yield of a crop in ton per hectare. For example, PSL is 630 ton/ha/year in Northern Region, and the ASL in this region for maize is 630 (PSL) x 0.073 (CFC) = 46 ton/ha/year. The maize yield loss, $\Delta Y_{i,R}$, is thus 46 (ASL) x 0.86 (MYL) = 0.03956 ton/ha in this region. Detailed calculations of yield loss in 2004 can be found in ISSER/DFID/WB (2005).

ASLs have increased in Ghana in the last two decades due to both natural factors and human activities. The soil loss growth rate based on the ASL data for 1979 (Bonsu 1979) and 2004 is very high, 6–10 percent annually. Considering that Young (1999) predicted a much lower soil loss growth rate for developing countries in general, and the lack of other information about actual and potential annual soil losses, we chose soil loss annual growth rates of 3–5 percent depending on the region. As the model simulates the mid-term effect of soil loss until 2015, the following equation for ASLs is employed in the model:

$$(3) \qquad ASL_{i,R} = (1 + x_{i,R}) \times ASL_{i,R},$$

where $x_{i,R}$ is the annual growth rate of soil loss for crop *i* and region *R*.

To incorporate the agricultural soil loss module into the EMM model, the yield function for the crops is modified as follows:

$$(4) \qquad Y_{i,R,t} = (1 + gy_{i,R})^{t} \times AY_{i,R} \times P_{i,t}^{\varepsilon_{i,R}} ; i \notin \text{ 8 crops; and}$$

$$(4') \qquad Y_{i,R,t} = (1 + gy_{i,R})^{t} \times AY_{i,R} \times P_{i,t}^{\varepsilon_{i,R}} - MYL_{i} \times ASL_{i,R} ; i \in \text{ 8 crops,}$$

where *gy* is the exogenous annual growth rate based on the historical trends of 1998–2004 and varies across crops and regions, AY is the productivity coefficient, P is the output price for crop i, and ε is the elasticity.

4. ASSESSING THE ECONOMYWIDE COSTS OF AGRICULTURAL SOIL DEGRADATION IN GHANA

The EMM model developed in this study is first used to simulate a ‘business-as-usual’ growth path in which the effects of soil loss are ignored (Scenario 1). In this simulation we assume that the economy will continue to grow along its historical trend until 2015. The average annual growth rate of area under cultivation, which is a main source of growth in crop production in Ghana (but also a contributor to soil erosion), and the growth rates of crop yields are calculated based on the data of 1998 to 2004. The annual growth rate of non-crop agricultural and non-agricultural production is also calculated using data from the same period.

We then simulate another growth path in which agricultural soil loss is taken into account (Scenario 2), with other assumptions remaining the same as in Scenario 1; that is, the annual growth rates in crop area and crop yields employed in Scenario 1 are also used in Scenario 2. The calculated yield loss is quite high if we consider only the effect of soil loss without taking into account other factors that may reduce yield loss. For example, soil loss can cause yield losses as high as 39.56 kg/ha per year in maize crops in Northern Region (ISSER/DFID/WB, 2005), which is equivalent to 2.6 percent of the current yield level. This yield loss is close to that estimated by Young (1999) for developing countries as a whole.

In Ghana, there has been no significant growth in the yields of most crops in last 10 years, and the yields of certain crops (e.g., sorghum, millet, cassava, yam, cocoyam, and beans) have shown modest declines, in the range of 1–2 percent between 1995 and 2004. In fact, the declines observed for some crops may be related to expansion into less fertile land. For this reason, in the model we focus on the increased agricultural soil loss and its effect on future yields, assuming that the stagnant growth or slight declines in crop yields observed over the period 1995–2004 are the result of the effects of both soil loss (negative) and land management improvement (positive). However, with continuous increases in soil loss and without further improving land management, it is reasonable to expect that the negative effect of soil loss on the yield will become stronger in the future. After applying an annual increase in soil loss of 3 to 5 percent in Equation (3), Equation (2) is then used to describe the marginal effect of additional soil loss on the yield after 2005. This assumption is supported by the prediction of Young (1999) that the loss of agricultural production will continuously rise at a rate of one percent every 5–10 years.

4.1 Crop level effect of agricultural soil loss

We first look at the crops that are directly affected by agricultural soil loss in the model. The marginal effect of increased soil loss on crop yield varies across crops and regions (we report only the average effect at the national level for seven selected crops in Table 4).

Table 4: Soil loss effect on the yields of selected crops

	Base year	Model projection in 2015			
		Base-run			
	(1999-03 average) (ton/ha)	Without soil loss (ton/ha) Scenario 1	With soil loss (ton/ha) Scenario 2	With soil loss and conventional SLM (ton/ha) Scenario 3	With soil loss and modern SLM (ton/ha) Scenario 4
Maize	1.50	1.72	1.08	1.60	2.26
Sorghum	0.93	1.19	0.69	1.12	1.28
Cassava	12.40	14.39	10.94	13.92	16.05
Yam	12.50	12.87	10.10	12.49	15.07
Cocoyam	6.56	6.95	3.60	6.38	7.44
Groundnuts	1.04	1.25	0.82	1.19	1.64
Pulses	0.95	1.01	0.61	0.95	1.29

Source: Authors' model simulations

In the simulations that did not include soil loss, the yields of most crops are higher in 2015 than at present (Scenario 1, Table 4); for example, the national average maize yield is projected to be around 1.72 ton/ha in 2015, compared to 1.50 ton/ha in 1999–2003. However, once the negative effect of soil loss on marginal production of land is taken into account, the maize yield in 2015 is reduced to 1.08 ton/ha, which is lower than the current level (Scenario 2, Table 4).

Table 5: Soil loss effect on the production of selected crops

	Base year (2003)	Model projection in 2015			
		Base-run		With soil loss and convention SLM	With soil loss and modern SLM
	(1000 ton)	Without soil loss (1000 ton)	With soil loss (1000 ton)	(1000 ton)	(1000 ton)
		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Maize	1,305	1,736	1,053	1,591	2,326
Sorghum	546	827	471	776	885
Cassava	11,135	19,653	14,808	19,066	21,069
Yam	4,384	7,572	6,288	7,414	9,354
Cocoyam	2,048	3,412	1,753	3,136	3,617
Groundnuts	445	824	541	775	1,080
Pulses	170	249	146	231	320

Source: Authors' model simulations

Because of yield declines, production of the seven crops in Table 4 is expected to either grow very slowly or decline between now and 2015, even assuming that the expansion of agricultural area continues at the current rate (Scenario 2 of Table 5). For example, maize production is projected to be 19 percent lower in 2015 than currently when the soil loss effect is taken into account, compared to the prediction of a 33 percent increase in maize production over the same period if soil loss is not accounted for (almost 2.9 percent of annual growth). The projected slow-down in production growth of these staple food crops would cause food security problems, given that the population of Ghana is expected to grow at 2 percent per annum. Indeed, the model predicts an increasing gap between supply and demand for maize and cassava products. For example, the un-met demand for maize (including both food and feed demand) will be half of the total demand by 2015, leading to a high consumer price for maize and increased maize imports to address maize shortages.

4.2 The aggregate effect of agricultural soil loss on agricultural GDP

We next examine the economywide cost of agricultural soil loss. Biggelaar et al. (2004) calculated the total loss in the value of agricultural production due to soil erosion by multiplying production lost by price for each crop. In our model, a series of indirect effects are also taken into account. For example, a decline in the production of a crop has a direct negative effect on the income of farmers who grow that crop, which reduces their demand for all agricultural and nonagricultural commodities differently (as income elasticities vary across commodities). When prices for some commodities are endogenous, they will change with changes in the balance between supply and demand in the domestic market. Such endogenized price changes further complicate the picture, as land allocation across crops can be affected by the supply price elasticities of different crops. Thus, the economywide effect of soil erosion will not be simply equal to the direct effect on crop production multiplied by a given price. Through the linkages across sectors and between supply and demand, production, demand, prices and trade of all agricultural commodities, beyond the crops directly affected by soil loss, will also be affected. In our discussion below, we focus on agricultural GDP and poverty for the aggregate effect.

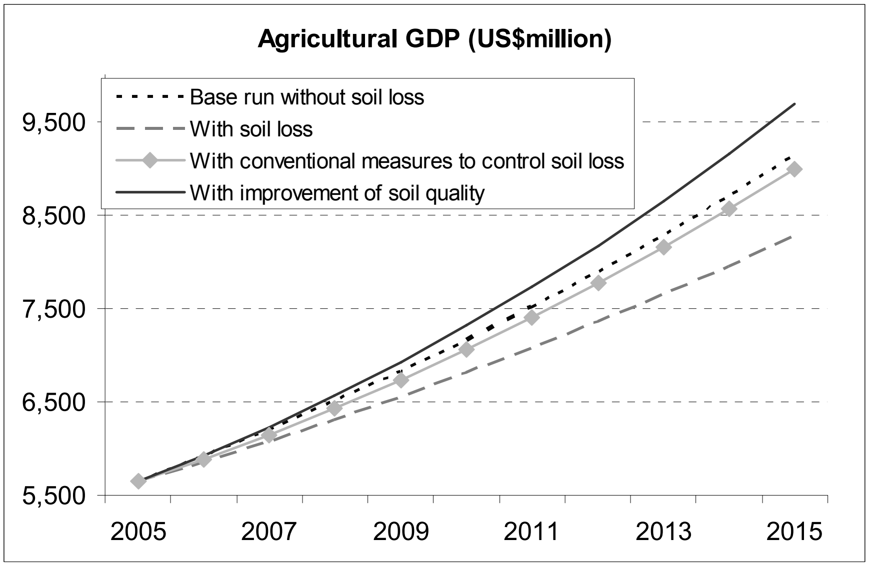
Figure 1 depicts the growth trends of real AgGDP under different scenarios. The gap between the AgGDP levels of the two scenarios, base-run without and with considering soil loss, indicates the potential loss to total agricultural income caused by the effect of agricultural soil loss on the yields of the eight crops. This gap gradually increases with time as agricultural soil losses increase over time. In the first three years, the difference in AgGDP between the two scenarios corresponds to 1–3 percent of the AgGDP of the case without soil loss (Scenario 1), and the gap increases to 4–6.7 percent in 2009–2012, before eventually reaching 9.4 percent in 2015. The model predicts that soil loss effects cause the 2015 AgGDP to be $US860 million lower than it would be in the absence of such effects. The cumulative effect over the 10 years (2006–2015) reaches $US4.2 billion, approximately 5 percent of the total AgGDP in these 10 years.

The estimated effect of soil loss on the aggregate agricultural income in our model is comparable with those in the literature. For example, Young (1999) concluded that it may not be unreasonable to say that land degradation is costing developing countries between 5 and 10 percent of their total agricultural sector production. Bojö (1996) estimated that the annual economic loss due to erosion in sub-Saharan Africa is 2–5 percent of AgGDP. In the case of Ghana, Convey and Tutu (1992) estimated that erosion and nutrient depletion cause annual production losses of about 5 percent of AgGDP, and Drechsel and Gyiele (1999) provided a similar assessment. Recently, an ISSER/DFID/World Bank (2005) study indicated that a conservative estimate of the loss in annual GDP growth in Ghana due to agricultural soil erosion and poor land management in crop production would be 1.1–2.4 percent.

The results of our EMM model are comparable with those drawn from other economywide models. For example, using a CGE model and data for 1992, Alfsen et al. (1997) found that soil degradation in Ghana accounts for an approximately one percent reduction in real

GDP growth per year. In general, the economywide assessment of soil loss effects is relatively modest because within the model, declines in the production of a crop can cause the price of that crop to rise if domestic demand for the crop does not fall as fast as the production decline. For example, sorghum and millet are two crops for which domestic demand and supply are relatively balanced in the base year in our model. When the production levels of these crops fall due to negative soil erosion effects, demand for them does not fall much without change in prices. This causes prices for sorghum to rise by 50 percent to force domestic demand to fall. Increased prices for these crops in turn cause supply of sorghum and millet to increase through the supply response to price changes, such that the total declines in the production of these crops, as well as the income farmers receive from growing these crops, become modest.

Figure 1: Level of agricultural GDP under different scenarios



Source: Authors' model simulations

4.3 The poverty effect of agricultural soil loss – national and regional level assessment

The literature assessing the economic cost of soil loss pays little attention to the potential effect of soil loss on poverty. Given that our economywide model is linked to a micro-simulation model in which all sample households of GLSS4 are included, it is possible for us to evaluate the poverty effect of agricultural soil loss at both the national and subnational levels.

While Ghana's economy has grown steadily over the last two decades, agriculture is still a major income source for the rural population, which accounts for more than 50 percent of the total population. The agricultural sector, especially staple crops, is especially important for the rural poor as their income mainly derives from staple crops and such crops still constitute the dominant calorie and nutrition sources for poor individuals. For this reason, special attention should be devoted to the possible effects of agricultural soil loss on rural poor households. We first evaluate such effects at the national level.

Ghana's rural poverty rate (head count) was about 50 percent in 1999 according to 1998/99 GLSS4, whereas the poverty rate in urban areas was much lower (19.4 percent). The national poverty rate was 39.5 percent in the same survey. Without taking into account the negative effect of agricultural soil loss on crop production and agricultural growth, our simulation shows that Ghana meets her Millennium Development Goal (MDG) One of halving the 1990 poverty rate by 2015 along the 'business as usual' growth path. In the base-run simulation without considering soil loss (Scenario 1), the national poverty rate falls to 23 percent (Table 5) and the rural poverty rate falls to 30 percent by 2015 (Figure 2), both of which are less than half of their 1990 levels.[5]

At the national level, the negative effect of agricultural soil loss on the rate of poverty decline is significant; specifically, the declines in the national and rural poverty rates between 2006 and 2015 are 5.4 and 7.1 percentage points less when soil loss is taken into account (see Figure 2 for the rural poverty rate). Moreover, assessing poverty at the national level may underestimate the severity of the impact of soil degradation on the country's poor, as many poor rural households live in the areas with higher levels of land degradation and food insecurity compared to the national average (Aryeetey and McKay, 2004). For this reason, we further evaluate the poverty effect at the subnational level.

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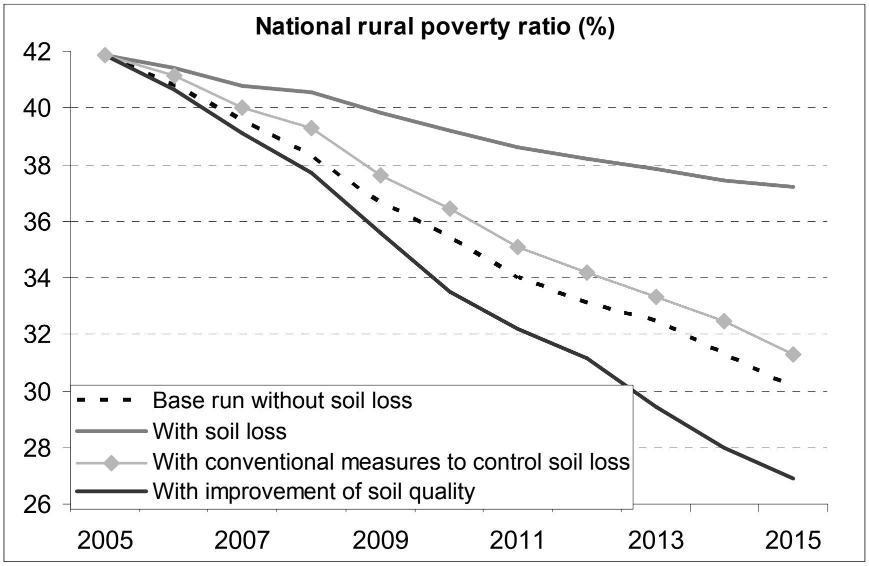
[5] According to GLSS3, the national poverty rate in rural areas was 52 percent and 64 percent in 1991/ 92 respectively. The MDG One is therefore based on these poverty rates.

Figure 2: Rural poverty rates in different simulations



Source: Authors' model simulations

Various analyses have shown that poverty is endemic in northern Ghana, which continues to lag behind the rest of the country in most development indicators. Unfavorable climate and agricultural production conditions, among many other factors, are often quoted as major sources of poverty and underdevelopment in northern Ghana. Although agriculture is the main component of rural households' livelihood strategies, the conditions for agricultural production in many parts of northern Ghana are inadequate, particularly when compared to those in the south. Rainfall levels are low and distributed with one peak, soils are poor in organic matter, and runoff is high because of the concentration of rains in short periods (torrential rains). Because of these characteristics, it is important to analyze the potential impact of agricultural soil degradation not only at the national level, but also at the regional level, paying special attention to northern Ghana.

As described earlier, the EMM model disaggregates Ghana's economy into 10 regions and the PSL and ASL data are collected at the regional level. This approach allows us to analyze the linkages between agricultural soil degradation, agricultural production, farm income, and hence poverty changes, across the 10 regions included in the model. As discussed above, in the base-run without taking into account soil loss effects, the national rural poverty rate falls significantly in 2006–2015. However, the regional level assessment of growth and poverty reduction linkages predicts that the reduction in poverty will be much less in the poor regions (mainly in the north) where the current poverty rate is much higher than the national average. For example, the 1998/99 poverty rate was 69.2–88.2 percent in the three northern regions, Northern

Region, Upper West Region and Upper East Region. Along the ‘business as usual’ growth path without taking into account soil loss effects, the poverty rate will be as high as 56.5–69.9 percent by 2015 in these three regions, which is higher than the national poverty rate in 1999 (Table 6).

Table 6: Poverty rate at the regional level in different simulations

		Model projection in 2015			
		Base-run			
	1999 (%)	Without soil loss (%) Scenario 1	With soil loss (%) Scenario 2	With soil loss and conventional SLM (%) Scenario 3	With soil loss and modern SLM (%) Scenario 4
Greater Accra	5.2	2.1	2.1	2.1	1.9
Ashanti	27.7	13.4	19.1	14.1	12.6
Brong Ahafo	35.8	12.9	20.2	13.3	8.4
Central	48.4	20.4	24.0	20.4	18.0
Eastern	43.7	30.4	34.8	31.0	27.2
Northern	69.2	56.5	66.2	59.2	52.6
Upper East	88.2	69.9	79.2	71.4	61.1
Upper West	83.9	67.3	77.8	68.7	55.8
Volta	37.7	15.0	22.0	16.1	13.6
Western	27.3	8.5	12.3	9.7	8.5
National	**39.5**	**23.0**	**28.4**	**23.9**	**20.5**

Source: Authors’ model simulations

In this study we pay particular attention to the potential effect of agricultural soil degradation on poverty. A detailed discussion about how to reduce regional disparities in growth and poverty reduction in Ghana can be found in Al-Hassan and Diao (2007). Once the effect of agricultural soil loss is taken into account, the predicted declines in regional poverty are further slowed in the three northern regions (Scenario 2, Table 6). For example, the predicted poverty rate in 2015 in the three northern regions (the regions with the highest and slowest-declining poverty rates in the country) is raised by 10 percentage points when the effects of soil loss are considered in the model compared to the projections made without accounting for soil loss effects. This result further emphasizes the importance of sustainable land management measures in improving agricultural performance in Ghana.

5. POTENTIAL IMPACTS OF SUITABLE LAND MANAGEMENT PRACTICES IN GHANA

5.1 Sustainable land management practices in Ghana

SLM practices are the key to reducing agricultural soil loss and hence to overcoming the negative effect of land degradation on agricultural production. SLM can be implemented through both traditional and modern technologies. Given that the adoption rate of modern inputs such as fertilizer and irrigation is low in Ghana, especially in traditional staple crop production, we first examine the traditional SLM applied by Ghanaian farmers.

Several low-input technologies and conservation practices that can substantially reduce land degradation while enhancing productivity are currently applied by some Ghanaian farmers at the farm level. However, the large-scale adoption of these practices seems to be limited by many factors. The weak integration of SLM into key policies, strategies and action plans is an important policy and regulatory factor. An insecure land tenure system, difficulties in accessing credit, and poorly functioning output and input markets significantly lower the incentive for farmers to adopt such practices. The duplication of roles and responsibilities among institutions responsible for land management and administration are also important factors. Moreover, limited knowledge on the extent, impact and costs of land degradation, and on the benefits of SLM, together with a lack of systematic information on the requirements of SLM practices and the applicability of such practices to the diverse agro-ecological zones of Ghana, further constrain the dissemination of suitable land management practices (World Bank, 2006).

The SLM techniques in soil and water conservation traditionally applied to degraded lands in Ghana have mostly encompassed moisture and fertility management measures including afforestation/agro-forestry, mulching, cover cropping and contour vegetative barriers, and relatively inexpensive physical structures such as ridge-furrow systems, stones lines, tied-ridging and contour bunds. Stone lines, tied-ridging and contour bunds, for example, are run-off/erosion control measures. Stone lines and bunds are often constructed on rather flat slopes on fields already under cultivation or on strongly crusted and barren soils in order to rehabilitate them. Stone bunds are semi-permeable structures that do not concentrate runoff but check it and permit part of it to infiltrate. When properly installed, stone bunds can have a tremendous positive impact on soil properties and on crop production (Mando, 2000). For instance, it is estimated that in Burkina Faso, stone bunds alone could increase sorghum yields on very degraded soil from 350 kg/ha to 515 kg/ha and that yields could be further increased to 630 kg/ha by adding 1.7 ton/ha of organic manure, to 700 kg/ha by adding 150 kg/ha of inorganic fertilizers and to 850 kg/ha by adding both (Mando, 2000).

Mulching, cover-cropping and contour vegetative barriers, on the other hand, are soil structure/soil fertility improvement measures. For example, mulching, which involves leaving either straw or some other organic matter on a field, is effective in improving soil physical properties that obstruct water runoff and increase water infiltration, and also protects the soil against heavy rains, preventing land crusting and contributing to soil organic matter and nutrients.

There are several economic benefits associated with mitigating land degradation using these SLM techniques. Quansah (2001) has reviewed results of several studies on soil, water and fertility conservation practices in ameliorating soil loss in various agro ecological zones and their effects on crop yields in Ghana (see Table 7).

Table 7 summarizes several of the traditional SLM interventions used in the various agro ecological zones of Ghana to ameliorate agricultural soil loss, and their effects on crop yields. For instance, the application of organic matter in the Guinea Savanna, Transition and Semi deciduous forest zones could reduce soil loss and increase crop yields by more than 50 percent. Again, zero-tillage with herbicide application in various agricultural ecological zones could increase (crop) yields by more than 50 percent over the traditional slash and burn approach, increasing net financial benefits by between 58 and 98 percent (Boa Amponsem et al., 1998).

Table 7: Benefits of specific interventions (case studies) to ameliorate soil degradation in Ghana

INTERVENTION	ECOLOGICAL ZONE	RESULT
1.Cover crops Mucuna	Transition/Semi deciduous forest	Controlled weeds and increased soil nitrogen by 0.14% to 0.18%, increased maize grain yield over control by 86% (Osei Bonsu et al. 1995; Agyenim Boateng, 1997)
Groundnut	Guinea Savanna	Reduced soil loss by 94% and run off by 70% (Bonsu 1980)
	Semi deciduous forest	Reduced soil loss by 66% and run off by 24% (Quansah et al. 2001)
Bambara nut,	Semi deciduous forest	Reduced soil loss by 57% and run-off by 38%
Cowpea	Semi deciduous forest	Reduced soil loss by 79% and run off by 38% (Quansah et al. 2001)
2. Strip Cropping Maize-cowpea Maize-groundnut	Transition Zone	Reduced soil loss by 92% and run-off by 70% (Quansah et al. 2001)
3.Zero Tillage	Sudan savannah Transition, Semi deciduous Forest	Reduced soil loss by 80-99% and run off by 76-99% (Bonsu and Obeng 1979)
4. Zero Tillage with weedicide	Sudan savannah Transition, Semi deciduous Forest	50% higher yield compared to traditional slash and burn, with net financial benefit of 58-98% (Boa-Amponsem et al. 1998)
5. Mulching	Guinea Savanna Transition Semi deciduous Forest	Reduced soil loss by 90% (Bonsu and Obeng 1979; Quansah et al. 1997)
6.Contour /Vegetative barriers	Semi deciduous forest	Controlled soil erosion and conserved moisture to increase maize yields (GGDP 1993)
7.Liming (Acid soils	High rain forest	Reduced soil loss when liming rate increased from 1 ton/ha to 5 ton/ha (Bonsu 1979)
8.Organic Matter	Guinea Savanna Transition	Reduced soil loss and increases crop yields (Bonsu and Obeng 1979; Quansah et al. 1997)
	Semi deciduous Forest Guinea Savanna	Yield for maize increased from 1.94 ton/ha to 3.16 ton/ha
9. Crop rotation Groundnut maize, Cowpea Maize,		Reduced soil loss and increased yield (Sauerborn et al. 2000) Increased the yield of maize from 2.11 ton/ha to 4.82 ton/ha and 4.75 ton/ha, respectively

Source: Integrated soil management for sustainable agriculture and food security, Quansah 2001

In addition, augmenting these traditional SLM practices with modern soil enhancing treatments such as fertilizers can increase soil productivity and hence crop yields even further. According to the Ghana Grains Development Project (GGDP; 1992), the combination of traditional farming practices and fertilizer use can increase maize yield by 50–200 percent in the forest zone of Ghana.

5.2 Assessing the economy-wide benefits of SLM practices

We simulate the impacts of SLM practices through either their effect on agricultural soil loss, which indirectly affects yield, or on the yield directly. We define the SLM practices that mainly focus on controlling soil loss as “conventional measures”; these practices include methods such as improving vegetation cover that protects the soil against direct rain. We assume that the effect of a conventional measure on the yield of a crop is mainly through the reduction in soil loss, though the plant residues and mulch also improve soil quality by improving the structure and macro-nutrient content of the soil, which can increase crop yield. Scenario 3 is designed to include such conventional measures, under the assumption that soil loss will be reduced by 90 percent in Ghana by 2015, the level estimated by Osei Bonsu et al. (1995) and Agyenim Boateng (1997) for the case of mucuna as cover crops (Table 6). We also simulate the farm practices aimed at increasing yield through the improvement of soil quality, such as the application of organic and inorganic fertilizers in combination with SLM practices. We define this second group of farm practices as “modern SLM” and simulate its effect in Scenario 4. In this scenario, in addition to the 90 percent soil loss control assumed in Scenario 3, the average yield of the eight crops is assumed to increase by 20–55 percent by 2015, compared with the yield level in the same year with soil loss but without conventional or modern SLM; this assumed increase is close to the lowest increase in the estimation of the GGDP (1992).

Scenario 3: Controlling for Agricultural Soil Loss Only

In this scenario, the conventional measures of controlling soil loss result in slowing agricultural land degradation, although the soil quality continues to decline to a modest degree. Under this scenario, the yield levels of the eight crops in 2015 are very close to (but still slightly lower than) those predicted without taking soil loss effects into consideration (Scenario 1, the base-run).

Since there is no significant increase in soil quality, and hence yield, of the eight crops, the aggregate effect of conventional measures is to keep the current growth trends sustainable: by 2015, the level of real AgGDP is almost the same as that predicted in the base-run simulation without considering soil loss effects. Compared with Scenario 2, which does include soil loss effects, the accumulated gain in AgGDP between 2006 and 2015 in Scenario 3 is almost equivalent to the economic cost of soil loss. Although we did not estimate the cost of SLM to farmers due to a lack of data, the model results suggest that SLM practices can overcome the negative effect of soil loss and reverse the declining trends in land productivity, but without significant additional profit. Considering that most conventional SLM practices require mainly labor rather than cash investment, and given that family labor is the dominant labor input among most small holder farmers, such practices are feasible for most farmers, especially in the areas already facing land constraints and having few non-farm employment opportunities.

Controlling soil loss through conventional SLM practices also reduces the negative effect of agricultural soil loss on poverty. However, because SLM practices are introduced into the economy gradually, the national poverty level in 2015 is predicted to be slightly higher than that in the base-run without considering soil loss (Figure 2). Moreover, the poverty rates in the three northern regions in 2015 are higher in this scenario than in the base-run (Table 6). However, compared with the poverty rates of the three poor regions in 2015 predicted under Scenario 2, the corresponding rates predicted under Scenario 3 are about 6–9 percentage points lower.

Scenario 4: Improving Soil Quality to Increase Crop Yield

In Scenario 4, in addition to the conventional measures to control soil loss, we assume that the yields of the eight crops steadily rise due to the combination of conventional SLM practices with the use of modern practices through 2015. With 1 to 4 percent of average annual growth rate in the yield at the national level, the yield level of the eight crops simulated in 2015 is about 20–55 percent higher than that of the same year's yield levels under Scenario 2, which accounted for soil loss effects (Table 4).

Under Scenario 4, the real AgGDP in 2015 is US$1.4 billion higher than that predicted under Scenario 2 in which the marginal soil loss effect on land productivity is taken into account. The accumulated gains (compared with the Scenario 2 level) are US$6.4 billion over the period 2006-2015. This increase in food crop production would significantly improve the food security situation in the country. Not only would the predicted supply of most food crops meet the increased demand in the domestic market, surpluses would occur in some crops, such as yam, groundnuts and beans, which can then be exported provided additional measures are implemented to further reduce transportation and transaction costs in the country.

The national poverty rate is lowered under Scenario 4 (Figure 2). While the national poverty rate in 2015 is 8 percentage points lower than that under Scenario 2 (with soil loss consideration), the positive effect on poverty reduction is even higher in the north (Table 6): in the three northern regions, the poverty rate in 2015 is 14–22 percentage points lower under Scenario 4 than under Scenario 2.

6. CAVEATS AND CONCLUSIONS

Our analysis using an EMM model developed for Ghana empirically confirms concerns regarding agricultural land (soil) degradation and its impacts on economic growth and poverty in the country, and supports calls for urgent policy action to mitigate these effects. Crop level effects of agricultural soil loss, relative to the baseline scenario of no soil loss, are significant. For example, soil loss effects are predicted to lower maize and sorghum yields in 2015 by 38 and 42 percent, respectively, compared to the case where no soil loss occurs. Moreover, increases in agricultural soil loss reduce the aggregate AgGDP. The cumulative loss in AgGDP between 2006 and 2015 is predicted to be US$4.2 billion, equivalent to approximately 5 percent of the total AgGDP in the 10-year period. The effect of agricultural soil loss on poverty at the national level is also significant, equivalent to an increase in the 2015 poverty rate of 5 percentage points compared to the case with no soil loss. Among the 10 regions of Ghana, poverty levels are predicted to fall much less in the three northern regions that currently have much higher poverty rates.

Sustainable agricultural land management is the key to reducing agricultural soil loss and hence to overcoming the negative effects of land degradation on agricultural production (crop productivity), income growth, and poverty reduction. The adoption of conventional SLM practices by farmers to reduce agricultural soil loss can help reverse the declining trend of land productivity without significant additional profits, while use of a combination of conventional and modern SLM practices (e.g., organic and inorganic fertilizers) generates a total benefit of US$6.4 billion in the next 10 years. Compared to the outcome if no measures are used to mitigate the effects of agricultural soil loss, the use of a combination of conventional and modern SLM practices is predicted to increase the AgGDP in 2015 by US$1.4 billion. The increase in food production using these measures would significantly improve food security in the country. While the national poverty rate in 2015 is 8 percentage points lower than that in the scenario with soil loss consideration, the positive effect on poverty reduction is even higher in the northern regions, where the poverty rate falls by 14–22 percentage points.

There are two major caveats in this paper. The first is related to the estimation of the on-site impact of soil loss on land productivity. There is no consensus among researchers with regard to the effect of soil erosion on agricultural production and soil productivity (van Baren and Oldeman, 1998), although most researchers agree that soil erosion is a serious problem. The difficulty of precisely measuring the effect of the loss of a unit of soil on the yield of a crop arises from the fact that there is no direct, clear-cut relationship between erosion and productivity (Perrens and Trustum, 1984; Erenstein, 1999). Most assessments of soil erosion and land productivity are based on systematic analysis of data from field experiments, and estimated effects from the loss of a unit of soil are quite different among scholars (see, for example, Table 3 and Adama 2003 cited in this paper). The model developed in the present work applies the relatively modest impact of past erosion-induced yield loss for Africa in Biggelaar et al. (2004), and hence may underestimate the impact of soil loss on agricultural production in Ghana. However, the alternative approach of applying the data from field experiments to the entire agricultural land of Ghana (for the 8 crops) may have significantly overestimated the impact of soil loss, as soil may move from one plot to another (off-site effects). In the present simulation study, such off-site effects are not explicitly taken into consideration.[6]

The second caveat is that the study did not quantitatively estimate the costs of sustainable management of agricultural soil and increased use of chemical fertilizers. The gains simulated in the model for both conventional and modern SLM practices are actually the gross revenue, and net benefits to farmers should be smaller. Indeed, the costs associated with implementing SLM must be carefully considered in order to understand why many SLM practices have yet to be widely used in Ghana. While encouraging evidence exists for some technologies and a few exploratory case studies provide helpful information, a lack of quantitative data on the costs of specific SLM practices at the crop level prevents incorporation of such data in the model.

The above caveats notwithstanding, the findings of the present study have important implications for agricultural modernization, and hence poverty reduction, in Ghana. Land degradation, including soil and soil fertility degradation, is a major factor underlying the low agricultural productivity of Ghana. Although land degradation is recognized as a major development issue, sustainable land management has not yet received the desired attention due to a number of critical barriers. Strategies that enhance the mainstreaming of SLM in smallholder farms include government policy directions and a promotion of, through different bundles of incentives, sustainable land management practices and technologies that suit the varying ecological conditions of Ghana.

Modernizing agriculture in Ghana to reduce rural poverty starts with the promotion of conventional SLM practices at the farm level, which are cost effective as they involve minimum cash investment. Given that family labor is the dominant labor input among most smallholders

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[6] This assumption is commonly used in assessments of the aggregate effect of soil loss on crop production.

such conventional SLM practices are feasible for most farmers. However, combining modern SLM techniques and conventional SLM practices is a win-win strategy that both reduces soil erosion and increases land productivity.

Farmers require outside support to successfully introduce agricultural soil and water conservation techniques. Any support program of the government, international communities and non-government organizations will involve costs in addition to the financial costs already incurred by the farmer. The cost of any such program depends on many factors but the net returns per hectare from SLM interventions are expected to be large and the cost-benefit analysis would remain strongly positive with additional (discounted) costs (see ISSER/DFID/WB, 2005).

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APPENDIX

1. List of agricultural commodities and nonagricultural subsectors in the EMM model

Agriculture:

Cereals: **maize**, rice, wheat, **sorghum/millet**;
Roots and tubers: **cassava**, **yam**, **cocoyam**;
Oilseeds and pulses: **groundnut**, **beans and other pulses**;
Cash crops: sugar, tobacco, vegetables for export, vegetables for domestic demand, pineapple;
Tree crops: cocoa, coffee, plantains, coconut, tree nuts, oil palm, fruits for export, fruits for domestic demand;
Livestock: beef, goat and sheep meats, poultry, pork, other meats, milk, eggs, fish;
Industrial crops and agricultural processing: cotton, rubber, wood, cocoa processing, fish processing, other processing;

Note: The bold crops are those having soil loss-yield loss information.

Non-agriculture:

Mining, agriculture-related manufacturing, other manufacturing, electric and water, construction, transport, trade, finance, government, community and other services

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