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How well do tree plantations comply with the twin targets of the Clean Development Mechanism?

The case of tree plantations in Tanzania

Abstract:
This paper studies the effect of a CDM tree-planting project on carbon sequestration and urban and rural income distribution, taking economy-wide impacts into account. Carbon sequestration in agricultural soil is considered in addition to the carbon in the tree farm itself. The study points to that project designs that raise the general investment level may add substantially to the project's carbon capture by stimulating the productivity of agriculture, thus binding more carbon in soil. As demand for crops is rising, the mode of agricultural production turns more intensive and improved plant growth leaves more plant residues for uptake as soil organic carbon. As for the income effect, the non-poor benefit more than the poor in economic terms, except when the project is hosted by the rural poorest. Foreign owned projects withdrawing the project surplus may turn out to reduce the income of urban poor and does not enhance agricultural productivity and beyond-project carbon sequestration.

Keywords: CDM, afforestation, poverty reduction, CGE, Tanzania

JEL classification: D58, O13, Q52, Q56, Q58

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1. Introduction

Capturing and storing carbon through afforestation has attracted considerable interest as a feasible way to mitigate global warming. The cost is generally lower than in projects targeting emission reductions from fossil fuel combustion. Further, studies point to that carbon sequestration in forests is cheaper in developing countries than in industrialized countries (Richards and Stokes 2004). The Clean Development Mechanism (CDM) under the Kyoto Protocol provides developing countries with an opportunity to reduce carbon emissions and trade certified emissions reductions (CER) to countries with CO_2 reduction obligations. The CDM opportunity is supposed to serve two purposes, i.e. enhance development in addition to mitigate climate change.

The mitigation efficiency of the CDM mechanism has been strongly debated for various reasons. One concern is whether CDM projects actually are additional to a baseline of social, technological and economic development and thus brings in genuine emission reductions. Another concern relates to whether the project will suffer from leakages, i.e. lead to carbon emission outside the defined project border. The general issue of carbon leakage is discussed by Chomitz (2000, 2002) and Aukland et al. (2003), whereas Schwarze et al. (2002) focuses leakage particularly in forest based GHG mitigation projects and Garcia- Olivia and Masera (2004) deal with issues related to carbon sequestration in soil.

There has been less focus on the capacity of CDM projects to reduce poverty, although many point to CDM as a good opportunity for enhanced development. Whether the different designs or modalities of CDM projects actually will serve the twin targets of carbon sequestration and poverty reduction is, however, not yet well understood, and so far the development issue associated with CDM is hardly analyzed in empirical terms. As a consequence, the scale of trade in certified emission reductions (CERs) from CDM projects as reflected in the flow of carbon payment is taken by default as indicator of the development impact as well as climate mitigation effect. The study of a CDM treeplanting project reported below aims at providing a more holistic approach to questions concerning the capacity of CDM projects to fulfil their dual target.

In the first commitment period (2008-2012) of the Kyoto Protocol, carbon uptake in trees is included in the portfolio of compliance activities. Afforestation and reforestation are accepted as credible, but carbon sequestration in other types of vegetation and soil is not yet a CDM project option. Among forestation projects, tree plantations so far seem to have a better esteem than community forests because monitoring is less demanding for plantations than for tree planting in small scale farming.

Large-scale plantations may also have the capacity to insure towards sequestration failure through buffer funds of carbon credits.

Certified emission reductions (CER) from afforestation projects are not accepted in the EU carbon trading system. There is so far only one afforestation projects among approved CDM projects. In the pipeline there are 12 afforestation and reforestation projects generating less than a percentage of total 2012 CER (UNEP-Risø 2008). The scale of forestry projects is likely to increase, however, and forestry projects are also a part of the international market for environmental services that evolves parallel to the Kyoto process, driven by private demand or government initiatives from countries outside the Kyoto Protocol. The efficiency of carbon mitigation projects outside the Kyoto-framework is of course just as important an issue as for those that may emerge within the Kyoto Protocol.

The purpose here is to study the potential effects of establishing a CDM tree plantation project in Tanzania on carbon sequestration and on the income level of various rural or urban socio-economic groups. Tanzania is a signatory of the Kyoto Protocol and registered as a CDM host country, but no project is registered in Tanzania so far (UNEP Risø 2007). The country is rich in land and the mitigation capacity embedded in the Tanzanian Forest Action Plan, if implemented, would accumulate to about 215 million tons CO_2 over three decades (Makundi 2001). Within softwood and hardwood plantations carbon sequestration can be obtained at a cost of USD 0.3-0.6 per ton carbon as estimated by Makundi (2001). Currently, there are plantations both under private and public ownership in Tanzania. Private owners already provide options for carbon offsets that are targeting future international carbon trade.

If CDM tree plantations can reduce poverty in addition to sequestering carbon, they would indeed be useful for a poor agricultural country like Tanzania, one of the poorest countries in the world. In Tanzania, estimated per capita income in 2005 was USD 330. According to the Household Budget Survey of 2000/2001, 19 percent of the population are below the national food poverty line and altogether 36 percent are below the national basic needs poverty line (NBS 2002).

Whereas project characteristics of tree plantations in Tanzania have been studied (Makundi 2001) the economic repercussions and social effects of such CDM projects have not been outlined. There are several reasons why it is necessary to look beyond the forested plot for a more complete understanding of the project efficiency in terms of economic outcome and carbon capture. The allocation of land for additional tree plantations may crowd out agricultural activity. As a consequence, food prices may rise, affecting the rural landless and urban poor, while increasing the flow of land rent to urban and rural landowners. Further, tree plantations will create employment opportunities, which most likely will benefit the poorer groups of rural households. However, available labour for other activities will be in shorter supply and rural households' income growth may turn out to exceed or fall below what project employment and associated wage payments promise. Finally, it matters who is the project host and consequently how the carbon premium is distributed. Effects on income distribution and growth turn out differently depending upon the ownership. With government ownership, political decisions determine the saving and expenditure pattern in the wake of the carbon premium. With private ownership, the carbon premium may float to foreigners, to domestic high-income urban or rural households or to poor households if the plantation is a joint effort at village level. The indirect effects may be different depending on how the carbon premium is spent, as the households have different levels of income and patterns of consumption. As a consequence of market repercussions, the carbon cycle outside the plantation borders may also be affected. Hence, the final effect of a project depends on the economic framework conditions and how the markets work, for instance if there are limited resources of labour and land or not.

The significance of economy-wide effects in afforestation projects has been studied by Adams et al. (1993) for the USA. When simulating the US agriculture with tree planting for carbon sequestration as an option for farmers, Adams et al. included effects on the timber market of lower prices and increased supply. The representative consumer in the US thus carries the cost of trees crowding out food production, but enjoys the benefit of falling timber prices for housing and other products. The study show that the effect of afforestation on consumer surplus is negative and further that the effect is substantial and highly sensitive to the ambition of the carbon sequestration program. It also follows that the cost of carbon sequestration is considerably lower when timber is harvested than not, as declining timber prices soften the impact of increasing food prices. Consequently, as shown by Adams et al (1993) for the US, cost of carbon sequestration depends on consumer preferences, how relative prices change and on supply side adjustments. These results signal that CDM projects within forestry and agriculture may also generate substantial indirect economic effects, possibly also with implications for national carbon emissions. For a poor country it may be particularly useful to consider if such projects actually contribute to poverty reduction or not.

The CDM introduces incentives and verification criteria for carbon sequestration, but there are no particular incentives or criteria for fulfilling a poverty reduction target. The CDM project host will benefit from transfers of external funds through the carbon premium, but there is still reason to question the effect on poverty reduction since inflow of foreign exchange does not necessarily increase the income of the population below the poverty line.

Although the potential for carbon sequestration through tree planting seems considerable, some caution may be necessary for environmental reasons. Plantations cause concerns over the expansion of land under monoculture, mainly over loss of biodiversity. There is also the problem that trees may affect water retention capacity negatively. Trees have deeper roots than other vegetation and are able to absorb and transpire water even in dry periods. A general reduction in the groundwater table may thus harm food crops and other vegetation with less deep root systems. Hence, forestation in particular of fast growing species frequently found in plantations may increase the social and environmental scale of drought (DFID, 2005).

Can it really be necessary to look at the macro-effects of a single tree-planting project? Yes, because the point of interest in this context is the dimension of the spillovers in the whole economy in relation to the magnitudes of the project’s on-site effect. A CDM project has a specific role to play in climate policy and economic development. If economy-wide analyses show reasons for concern over impact on income distribution and carbon sequestration, the project criteria should be reconsidered and possibly overhauled to secure compliance with the basic targets of the CDM. Further, if CDM carbon sequestration projects shall be of more than marginal interest in climate policy, the scale of land use change must also be non-negligible and will thus generate substantial repercussions both in economic and environmental terms.

As far as we know, the study presented below adds new information along several dimensions to the literature on CDM efficiency. First, our study takes into account the market repercussions within the host country when resources like labour and land are allocated to CDM tree plantations. Further, we trace economy-wide effects on income, income distribution and carbon leakage associated with the inflow and distribution of carbon payment to potential project hosts. To do so, we apply a computable general equilibrium model (CGE) for Tanzania developed at the International Food Policy Research Institute (Löfgren et al. 2002). The model is disaggregated in agricultural activities and household segments, and further developed in this study to keep account of the carbon cycle associated with land use. A particularly interesting result is that the plantation induces a negative carbon leakage in the same order of magnitude as within the CDM plantation project itself due to increased (uncompensated) carbon sequestration in agricultural land.

2. A CDM tree-farming project in Tanzania

Tanzania already has tree plantations covering about 80,000 ha owned by the government. The main genera planted are *Pinus* and *Cupressus*. In addition there are about 100,000 ha of private woodlots and plantations (NFP 2005). A part of the more recently afforested area is already targeting the emerging international market for carbon emissions rights and plans are announced for additional plantations covering almost 100,000 ha.

To approach the question of carbon efficiency and capacity to reduce poverty we incorporate a Pinus patula tree plantation project in a CGE model for Tanzania. The investments in tree-planting cover land and labour expenditures according to a typical time profile of planting and management. It takes 20 years before trees in the plantation project become mature. Along the project development path, annual carbon uptake is calculated following the natural rate of tree growth. By assumption, no timber harvest is taking place in the project period.

In this study we are looking at economy-wide consequences, hence we do not consider the private financial arrangements or profitability for carrying out the plantation projects. We assume that the financial aspects are solved by private or public agents and motivated by the expected project profitability resulting from the carbon premium.

The tree plantation we have in mind is an expansion of the 40,000 ha Sao Hill forest plantation in Southern Tanzania. Growth characteristics of the Pinus patula plantation is taken from observations on 99 plots in Sao Hill (Chamshama and Philip 1980). The average annual aboveground biomass accumulation and carbon accumulation was found to be 11.7 Mg per ha and 5.9 Mg per ha respectively. The cost of plantation establishment was set to 225 USD per ha based on Sathaye et al. (2001).

Whereas the existing plantation delivers logs to Southern Paper Mill and Sao Hill Sawmill, the hypothetical CDM plantation project depicted here is only meant for carbon storage, thus making sure that the project has no other income sources than the carbon premium and that there is no leakage through timber markets. We implement this new plantation activity in a standard CGE model (Löfgren, et al., 2002; Thurlow, J. and Wobst, P., 2003) with base year 2000 and enterprises, households and government as decision makers. Among a total of 43 production sectors there are 21 agricultural sectors (crops) and a separate sector for forestry and hunting combined.

The CGE model assumes maximizing behaviour by producers and consumers. Each sector produces a single good and the output is formalized as a Leontief aggregate of value added and use of intermediates. The value added element is a CES function of the primary input factors land, labour and produced capital. This means that there is substitution between land, labour and capital, but not between land/labour/capital combined and a more intensive agricultural practice represented by higher use of intermediates like fertilizer and pesticides.

Heterogeneity of land and labour makes the return to input factors differ across sectors. Land and labour allowances are exogenous and factor prices flexible. Households receive wage income and revenue from land and produced capital assets. Household demand is represented by a linear expenditure system (LES) based on a Stone utility function (Stone 1954, Dervis et al.1982). Public consumption per capita is fixed and surplus government income equals government saving. Foreign saving is exogenous and the domestic price level adjusts to balance the external account. Import of commodities is determined as a price sensitive CES aggregate of demand of the foreign and domestic varieties in line with the approach of Armington (1969). A similar relation determines how producers allocate their supply between domestic and foreign demand. The world market prices are fixed.

The inflow of foreign exchange in terms of carbon premium is creating a slack in the external balance, making room for an increase of imports. Rural household groups participate in plantation work and thus receive additional wage income. By assumption, all plantation work is carried out by labour from rural households below food poverty line.

The total level of investments is basically assumed to be policy given and thus exogenous, whereas private saving rates are adjusted by a common factor to generate the necessary amount of domestic finance to support the given rate of capital accumulation. Saving rates vary across household income groups and are adjusted by the same percentage points in this process. The economy operating on these terms can be characterized as investment driven. We first study the impact of the CDM plantation project under an investment driven closure rule, then under a savings driven alternative where household saving rates are fixed and factor income is adjusted to achieve the same investments path.

A particular useful model property for our purpose is that households are split in rural and urban categories, each further disaggregated into 6 urban and 6 rural household groups based on income level and education of head of household. The poorest households are those below the food poverty line, followed by households above the food poverty line, but below basic needs poverty line. The non-poor households (approximately 60 percent of the population) are divided in 4 groups according to income and educational level of head of household.

The baseline scenario assumes annual growth in real investments of about 4 percent and factor neutral technical change of 1 per cent per year in all production sectors. The corresponding growth in GDP amounts to 4 percent per year on average over the period 2001-2020. More details about the baseline scenario are presented in Appendix 1.

For studying the overall carbon efficiency of the project, we implemented a carbon cycle module covering both aboveground and belowground carbon for each agricultural activity. For agricultural crops the carbon module calculates change in carbon stock both in biomass and soils, but the carbon sequestration of these sinks are not included in the CDM project. As a consequence, there are no carbon incentives influencing farmers' behaviour. Every year 4 percent of the carbon stock in the soil is released to the atmosphere, while soil organic carbon from current crop residues is added to the stock. Soil organic carbon generated from the roots and residue of crops left in the soil in one year enters the soil carbon stock the following year. The amount of roots and residues are crop specific and proportional to the yield per ha land.

The carbon accumulation in the plantation is rewarded equally much per tonne every year and only the amount of carbon sequestered in trees is included. The annual addition to the carbon stock of the tree stand is compensated by a premium of 30 USD per tonne C, corresponding to about 8 USD per tonne CO_2. A low price was chosen to reflect the higher uncertainty associated with CERs from land use, land use change and forestry (LULUCF) projects. Currently, carbon is traded for slightly above 20 EURO per ton CO_2 (73 EURO per ton carbon) in the market for EU allowances (January 2008).

We compare the prospects along the economic baseline scenario with 5 different designs of CDM plantation projects. The different plantation initiatives use the same amount of resources in terms of land and labour, and plant the same amount of trees and receive the same carbon premium. However, they differ in terms of project ownership, and distribution of income from the CDM project activity.

The carbon premium is assumed to come from the international carbon market and add to the inflow of foreign capital, which is exogenous by assumption. Common for all scenarios is further that there is no timber harvest from the plantation during the project’s lifetime of 20 years. In that way there is no reason for concern over carbon leakage through the timber market. In all the scenarios 1-5, the wage income earned through plantation work is allocated to poor rural households below food poverty line, hence all direct expenditure (except land rent) target the poorest households.

The carbon premium is paid annually on the basis of carbon accumulated in the tree stands. The project design means that a total carbon premium of 1 244 billion Tanzanian shilling (BTsh) is received by the project host and 11.4 BTsh or about one percent of the project value is paid as wages over the 20 years project lifetime.

A premium of USD 30 paid per tonne carbon and the low on-site plantation costs allow for solid return. Figures 1 and 2 illustrate the income and cost flows of the plantation given this level of carbon premium. The carbon premium inflow is determined by the annual biomass growth rate of the tree stand. The land rent is fixed according to existing private plantation's compensation for use of government land.

Figure 1. Time profile of carbon payment. 2001-2021. BTsh

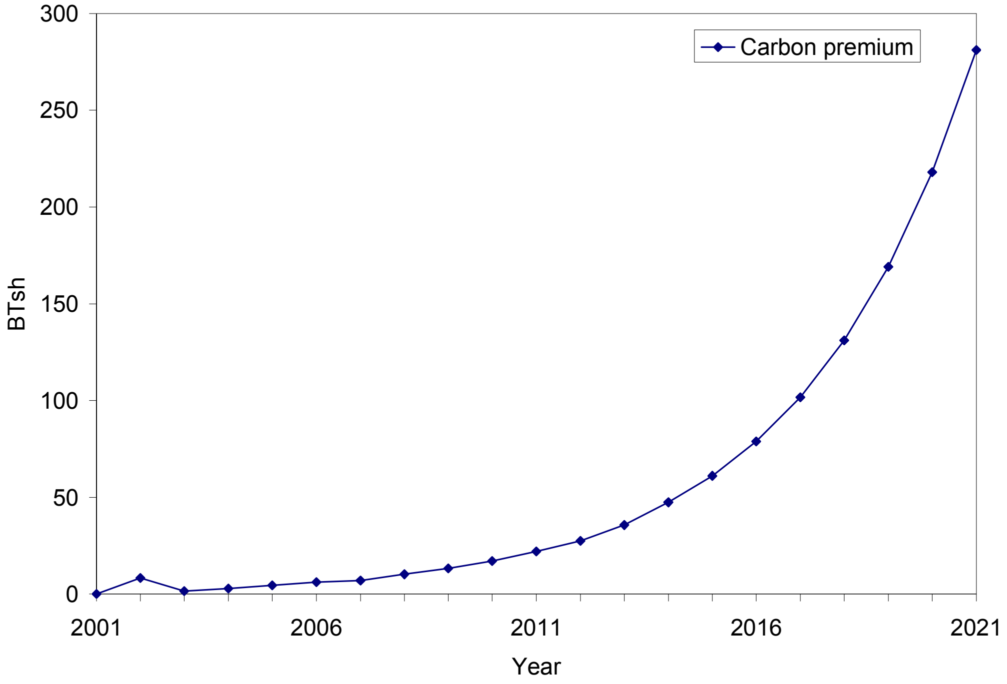


Figure 2. Labour cost and land rent. 2001-2021. BTsh

As is clearly seen from these figures, the carbon premium is low in the beginning, but escalates towards the end of the period. The costs are mainly associated with initial planting followed by some sequences with thinning. The time profiles of income and costs tend to make the surplus measured as net present value lower the higher the discount rate of the project host. However, in our study the focus is not on the decision to undertake the project and how this decision is influenced by the prospect to harvest profit now or in the future. The project is undertaken by assumption, and our purpose is to trace the repercussions and associated effects on income distribution and net carbon mitigation. In our results we present income growth of household segments accumulated over the project horizon without discounting. This can mimic the perspective of a social planner who is indifferent to distribution between generations. When comparing the results of various income groups we also ignore the differences in marginal utility of consumption. The reader may, however, attach subjective values to the income growth obtained by different income strata.

3. Scenarios

Scenario 1: CDM plantation as private farm initiative

In this case the afforestation is undertaken as private farm projects, where the farmers receive the carbon premium. All land-owning farmers participate proportionally to their share in land, and carbon premium is allocated to farm household groups according to their share in land rent. This mimics the case when the CDM plantation area is large in scale and thus accessible to most farmers. Consequently scenario 1 assumes that even low-income rural households owning some land succeed in establishing tree stands that are credited for carbon uptake. As shown in table 1, the rural non-poor receive the dominant share of land rent and will dominate the carbon trade, but rural poor own as much as 25 percent of the land and are thus also assumed to be actively involved in the CDM activity.

Table 1. Share of land rent received by household group. 2000. Per cent

Rural households	
Poor below food poverty line	11.0
Poor above food poverty line[1]	14.5
Non-poor	65.4
Urban households	
Poor below food poverty line	0.9
Poor above food poverty line[1]	0.6
Non-poor	7.6

[1] Below basic need poverty line.

Scenario 2: Plantation project hosted by urban-based landowners

Non-poor urban citizens received almost 8 percent of the total land rent in the base year. Their land holdings are likely to be larger and provide easier monitoring and verification of CDM projects. Large estates may tend to underutilize land due to labour monitoring costs in labour intensive crop production (Binswanger and Rosenzweig 1986, Heltberg 1998). Given increased profitability introduced by the carbon premium, large estates may consider tree planting particularly attractive. The plantation project in scenario 2 is assumed to be hosted by the two wealthiest household groups among the urban non-poor. This scenario differs from scenario 1 only by distributing the carbon premium to other private income strata with a markedly different expenditure pattern.

Scenario 3: The Tanzanian government hosts the project

Here the government pays the cost of establishing the plantation and receives the carbon premium. The surplus is earmarked for increased investments allocated to sectors according to the base year practice. This scenario is the only scenario that spends the whole carbon premium (net of plantation management cost) to increase investments. In all other scenarios the level of investments stays constant, whereas additional income is spent on private consumption.

Scenario 4: A foreign investor hosts the project

In this case the surplus from the CDM project is returned to international investors. Only the plantation management expenditure in terms of labour costs and land rent remains in Tanzania. This scenario resembles a situation where the government hosts the projects, and use the surplus from the carbon premium to pay down on foreign loans rather than on investments as in scenario 3. The difference would be that when the government pays down on foreign loans the external balance would improve as future foreign loan services would be somewhat reduced.

Scenario 5: Private initiative of poor rural villages

In this scenario we look for the result if the tree-planting initiative deliberately targets poor farmers. The poorest rural households are project owners and receive the whole plantation surplus. This kind of project is frequently regarded as difficult and expensive to monitor. However, if forestation is widely used for carbon sequestration, remote sensing could even out the differences in monitoring costs between large, centrally situated and small, remote plantations in that respect. If undertaken jointly with development assistance, a difference in management costs could also be overcome.

4. Results

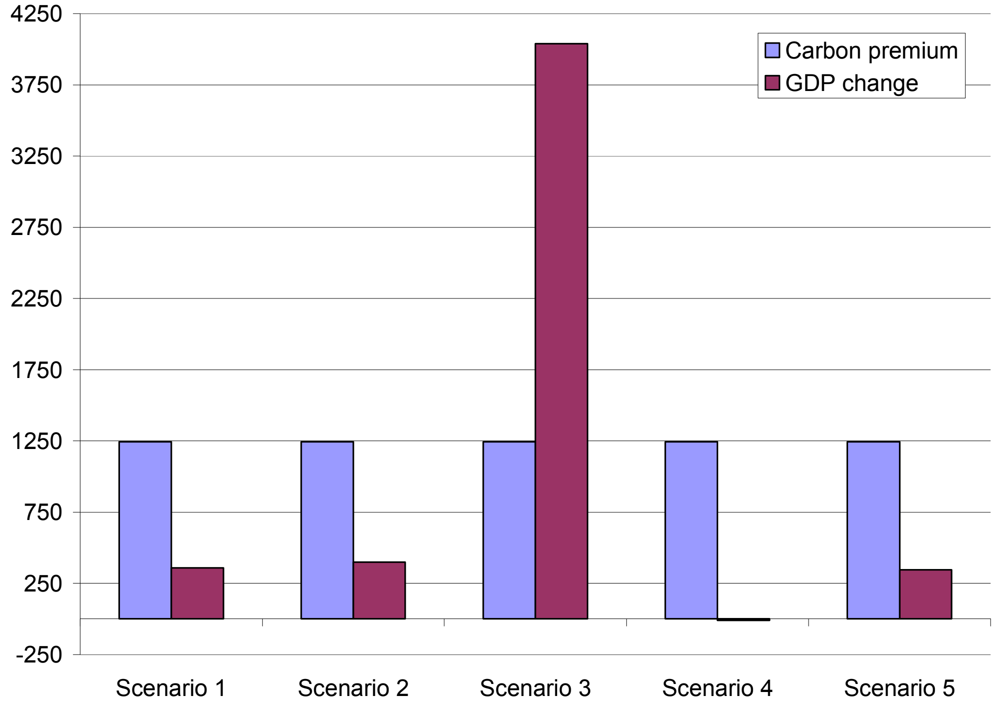
Before discussing the results in detail, we consider the various mechanisms that drive the outcome. The labour stock and the area of agricultural land are assumed fixed at the aggregate level. If we ignore the transfer of carbon premium and just think of the plantation as a politically enforced project, the new plantation crowds out labour and land so far utilized by other activities. The activity level in other sectors is slightly reduced due to the increased competition for labour and land outside the plantation. Further, when land and labour are withdrawn from the rest of the economy, the marginal return on produced capital will fall and settle somewhat below the level in the BAU scenario. There is no produced capital in the forest plantation. Hence, the produced capital generates less return and the overall return to produced capital is falling. The inefficiencies imposed by crowding out land and labour from other sectors may tend to reduce equilibrium wage and land rent.

When the carbon premium enters the economy, two main effects add to the picture. First it increases income of the CDM project host(s). This benefits rural poor and non-poor and urban households to various degrees, depending on ownership of factors and the spillovers associated with the spending behaviour of the CDM project hosts. Total household saving is not affected, as long as the domestic investment level is given (politically determined) and foreign saving is fixed by assumption (see section 4.3 for an alternative closure rule). Hence, higher household income increases consumer demand and may change the composition of total demand, production and external trade. The various household groups have specific consumption characteristics. The poorest will primarily increase demand for food, whereas the urban better-off will to a larger extent increase consumption of manufactured goods, some of them imported. Then there is a second main effect on the economy as the inflow of foreign currency as carbon premium creates a slack in the external balance and the import increases to fill the gap. This is driven by the appreciation of the domestic currency, i.e. the exchange rate falls and each dollar transfers to less Tanzanian shilling - a disadvantage to the exporters, but beneficial to importers of consumer and investment goods. Cheaper investment goods from abroad contribute to higher real investments and improved productivity.

4.1 Poverty reduction

Figure 3 shows the footprint of the carbon premium on gross domestic product (GDP). Scenario 3 stands out in terms of GDP growth, which is three times as large as the value of the project measured as carbon. This neat multiplier effect illustrates that the Tanzanian economy is capital constrained and that investments are likely to yield a reasonable return. This is why a foreign owned project that withdraws the project surplus does not increase GDP at all (scenario 4). The money spent for plantation management is simply too little to make additional economic growth visible – investments are fixed and the income transfer is negligible. In scenarios 1, 2 and 5 investments are also fixed, but the project income remains with private households in Tanzania. GDP rises, but only about a third of the project value. Thus, we may conclude that the project value is not a good indicator of economic impact.

Figure 3. Accumulated GDP growth and carbon premium. 2001-2021



The GDP growth represents additional value added that is distributed to households as owners of the primary factors labour, land and capital. In addition to factor income growth, households may also receive transfers from abroad as carbon premium. The detailed distribution of factor income by household group is given in Appendix 3.

Table 2. Factor income[1] growth. 2001-2021. BTsh

	Base year	Scenarios				
		1	2	3	4	5
Wage income	99669	329	260	2404	2	362
Land rent	17811	37	-11	261	0	53
Profit	45710	42	-23	358	-1	62
Total	163189	408	226	3022	2	477

[1] Factor income received by households, transfers not included.

Table 3. Factor contribution to total factor income[1)] growth. 2001-2021. Percent

	Base year	Scenarios				
		1	**2**	**3**	**4**	**5**
Wage income	61	81	115	80	122	76
Land rent	11	9	-5	9	21	11
Profit	28	10	-10	12	-43	13
Total	100	100	100	100	100	100

[1)] Received by households.

Table 2 shows how GDP growth is allocated to the production factors labour, land and produced capital. All scenarios share the common feature that wage income growth is the dominant element of total factor income growth reflecting that Tanzania is a very labour intensive economy. The wage income growth is considerable compared with the project wage expenditure for all domestic projects . Even without the multiplier effect of higher investments as in scenario 3, the wage income growth amounts to 25-35 times the wage expenditure in the CDM project itself.

Table 3 shows how the additional factor income is allocated in relative terms. Distributing CDM plantations in proportion to land holdings (Scenario 1) allocates income to factors in a similar way as a government plantation using the surplus for additional investments (Scenario 3), although their effects on GDP level differ considerably. Scenario 2 channels more than total income growth in absolute terms to labour but creates a loss in profit and land rent. In scenario 2 the carbon premium is earned by urban rich, who direct their demand growth towards manufacturing, services and imported goods. The agriculture is left behind, and land rent is falling somewhat. Profit is reduced as imports crowd out domestic produce. Scenario 5 returns the lowest share of factor income growth to labour. On the margin, all scenarios allocate more to labour, less to profit and, with some variation, about the same to land rent as the base year distribution.

Whereas tables 2 and 3 present changes in factor income, the total effect on household income also includes their share in the carbon payment if hosting the CDM project. Figures 4-6 illustrate total income changes by household segment. Poverty is most pervasive in rural areas, and it is useful to start with a look at how the rural versus urban income develops. As shown in Figure 4, scenarios 1, 3 and 5 are those that mainly channel income to the rural economy. The higher investments in scenario 3 also allocate income to the urban economy through investment goods demand mainly supplied by manufacturing industries. Hence urban households receive about a third of total income growth when the government hosts the projects and uses the surplus for investments. When urban rich hosts the CDM project (scenario 2), there is practically no benefits to the rural economy.

The fact that scenarios 1,3 and 5 favour the rural economy might raise expectations that the poor will benefit considerably from these CDM project designs. Figure 5 shows, however, that the larger share of income growth goes to non-poor households in scenarios 1 and 3. Scenario 2 leaves practically nothing to the poor. Only scenario 5, which by project design is targeting the rural poor, succeeds in getting the income through to the poor.

As seen from Figure 6, it is even clearer that only a very small share of income growth trickles down to the poorest below food poverty line. Even though the plantation work is carried out by the rural poorest, their total income growth is only 15 percent of the CDM project value.

When urban rich or foreigners host the project (scenario 4), there is hardly any income growth for the rural poorest below food poverty line. It seems necessary to involve the rural poorest as hosts to succeed in getting the benefits through and reduce the extreme poverty as is done in scenario 5. In that case, the benefit to the poorest even exceeds the total project value. However, the income growth of the urban poor below food poverty line still remains negligible in that case.

Figures 4-6 referred to above show real income effects in base year prices by household segment. Households of various income levels have different consumption patterns. The CDM project imposes changes in relative prices, which hit the household segments differently. There are two drivers behind the price changes. One is the distribution of carbon premium among households and the associated shift in aggregate demand. The other is the appreciation of the Tanzanian shilling as the carbon payment in foreign currency enters the economy. Prices on imported goods for private consumption and investments fall, but food prices increase. Rural households comprising the majority of the poor experience that consumption growth in real terms is lower than income growth. For urban households the tendency is more ambiguous. Detailed tables are found in Appendix 3.

Figure 4. Income growth of rural and urban households. 2001-2021

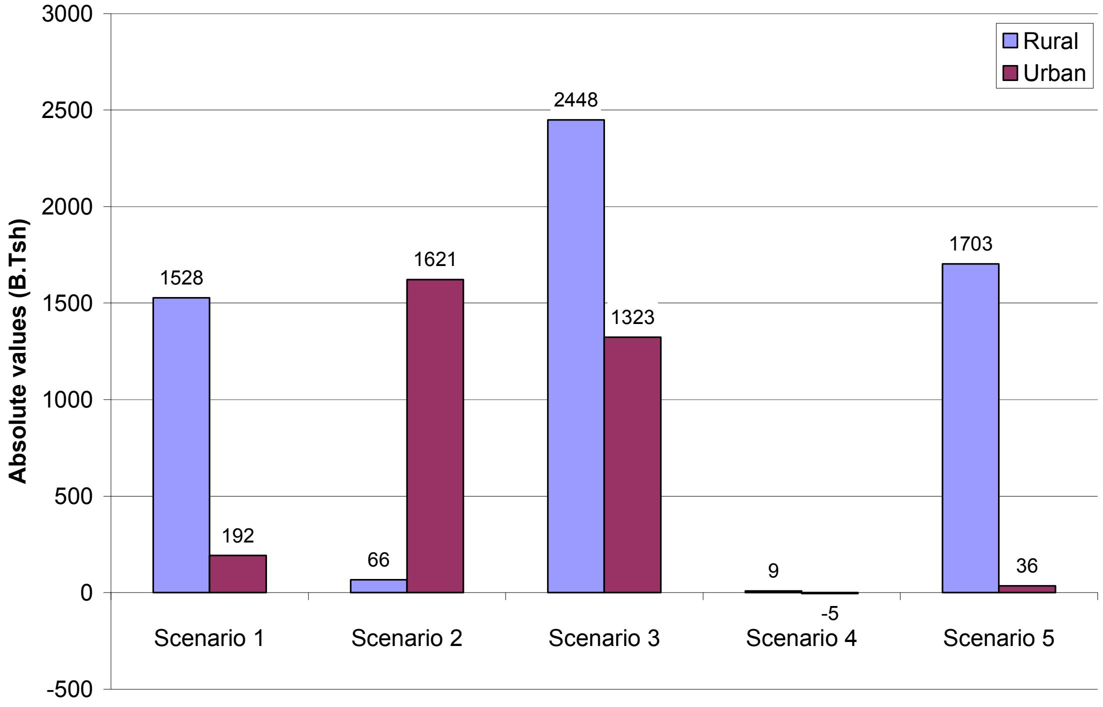


Figure 5. Income growth of poor and non-poor households. 2001-2021

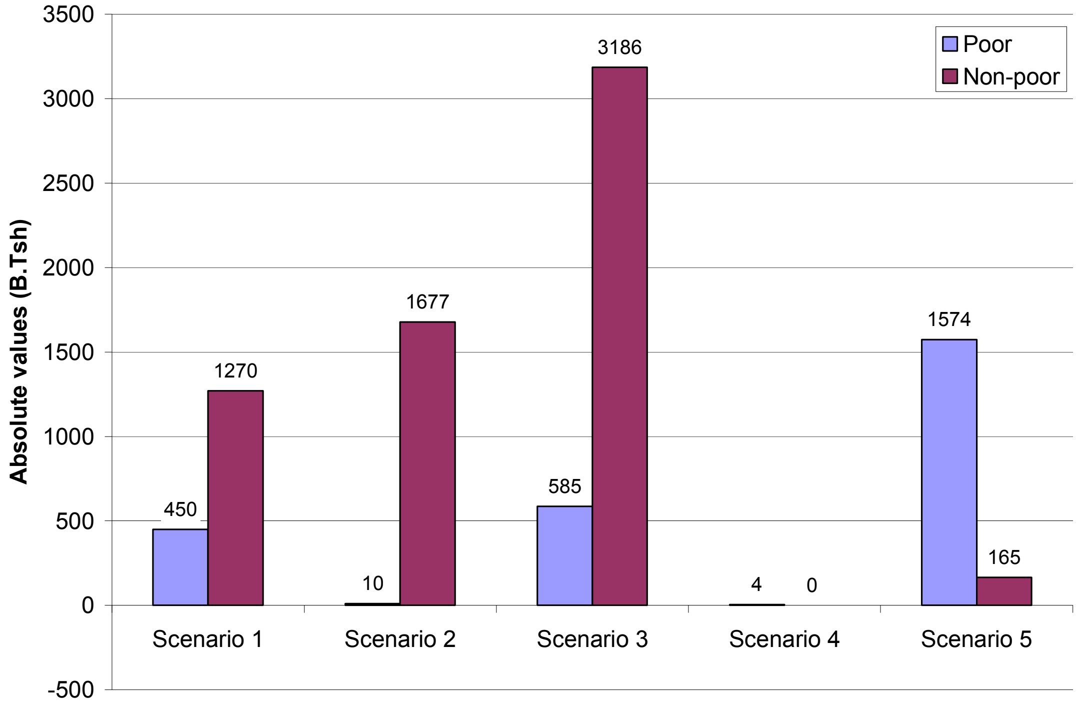
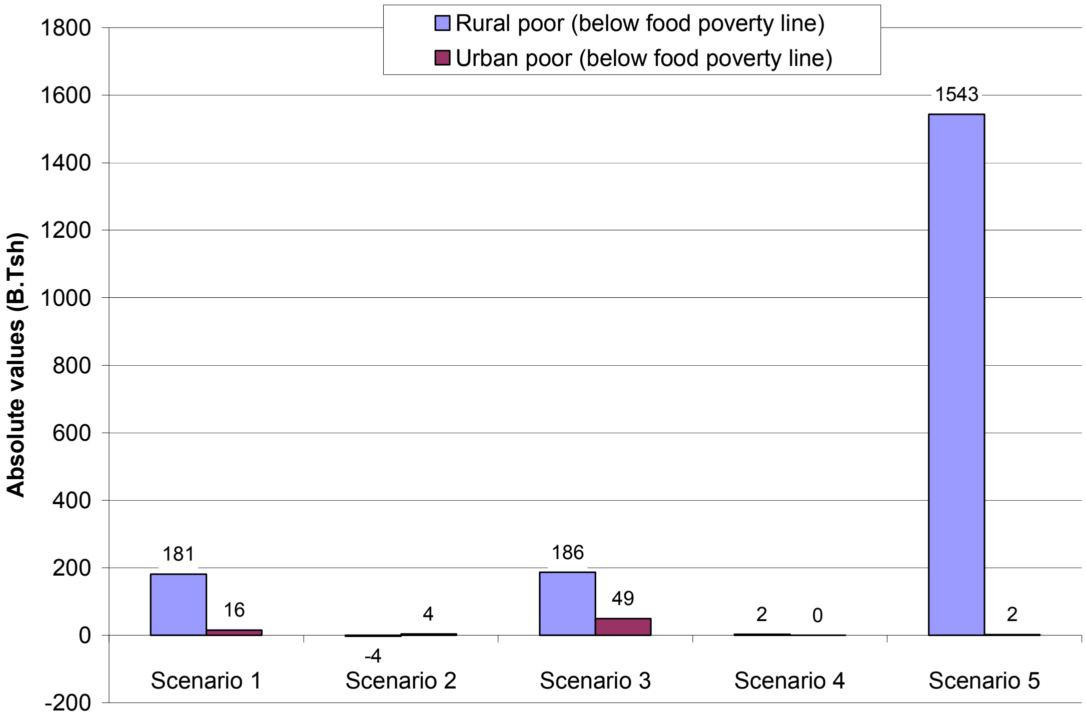


Figure 6. Income growth of urban and rural households below food poverty line. 2001-2021



4.2. Net carbon effect

The carbon stock at the plantation site is monitored and compensated within the project. However, the project also has indirect effects on the economy and thus also on emissions or sequestration of carbon in other land use. Our study tracks the effect on the stock of soil organic carbon in agricultural land due to increased demand and higher yields. Higher prices allow for more intensive farming and more plant residues are returned to the soil per unit land every year.

In Scenario 3 the soil carbon sequestration is actually 20 percent larger than in the plantation itself (Table 4). Moreover, scenarios 1, 2 and 5 bind another 60-90 percent carbon in soil as compared with what is accumulated in the plantation itself. Hence, there is a considerable negative leakage in the project. There is particularly a build up of carbon in soil used for cash crops. The main cash crops are the perennials coffee, tea and tobacco with substantial use of imported agrochemicals. The appreciation of the domestic currency following the inflow of carbon premium lowers the cost of imported inputs. This effect dominates over the reduced incentives for cash crops due to the reduction in export prices in domestic currency. Hence the scale of cash crop farming rises more than food production. The cash crops are more efficient in carbon binding than the food crops under current agricultural practices. However, the food crops also improve carbon binding capacity per ha land due to demand growth, price increases and more intensive use of fertilizer. The enhanced productivity through more intensive agriculture leaves more plant residues to the ground as organic carbon. The highest build-up of carbon in soils occurs in scenario 3 when the government is host and uses the carbon premium to increase investments. These result points to the potential synergy effects between climate mitigation and economic growth in poor agricultural economies.

The results also illustrate the potential for carbon sequestration embedded in general policies for economic development. Increasing productivity in agriculture may contribute to reverse the carbon flow from agriculture, making food production a net absorber of carbon.

Note that so far in this study farmers are not compensated for their contribution to carbon mitigation. If they had been able to trade CERs similar to the plantation host, or somehow compensated for this effect, the carbon dynamics might be accelerated.

Table 4. Soil carbon accumulation 2001-2021. Mill. tonnes

	Scenarios				
	1	**2**	**3**	**4**	**5**
Total	25.94	22.73	31.07	14.16	26.56
Plantation	14.10	14.10	14.10	14.10	14.10
Agricultural soil	11.84	8.63	16.98	0.06	12.46
Ratio of soil to plantation sequestration	0.84	0.61	1.20	0	0.88

The substantial negative carbon leakage of 60-120 per cent found in this study clearly contrasts the results obtained in earlier economy wide studies of CDM projects based on improved energy efficiency in coal use. Studies by Böhringer et al. (2003) and Glomsrød and Wei (2005) point to considerable carbon leakage through the coal market. Böhringer et al. estimated around 50 percent leakage following CDM investments in more efficient coal combustion in coal-fired power plants in India. Glomsrød and Wei found that coal cleaning might even increase the total CO_2 emissions as reduced coal volume per thermal unit and high transportation cost shares in the end-user price of coal led to marked cost reductions to coal users. Both studies illustrate the rebound effect taking place as increased energy efficiency implies economic gains and lower fuel prices that in turn stimulate energy use. Thus, fossil energy efficiency projects involve a kind of subsidy to the user of the energy carrier involved, as also pointed out by Stern (2007).

The Kyoto Protocol's CDM Executive Board has downplayed the role of the rebound effect by neglecting the so-called secondary leakages through markets. When considering the striking contrasts between the phenomenon of leakage in fossil energy efficiency projects and forestation projects observed in this study, such a position might undermine many efficient options for mitigation in terms of carbon sequestration and poverty reduction associated with land use projects.

In the energy efficiency projects it is particularly important to remember that developing countries have high income elasticities for energy goods and energy intensive services like transportation. A project on fossil energy efficiency will rebound through the fossil energy market and the urban economy - while a land use change or forestry project will mainly encourage the rural economy with a low fossil intensity in demand.

The results of Scenario 3 using the CDM project surplus for investments invites to consider the role of economic policy in carbon mitigation more closely. The low input/low output agriculture in many developing countries contains a vast potential for higher yields and enhanced carbon sequestration in soil. The soil could be reactivated as a carbon sink through fertilizer subsidies and taxes that adjust the income distribution. The monitoring of such carbon mitigation strategies might not be more costly and difficult than in specific and numerous private CDM projects. Programs for fertilizer subsidies were practiced in Tanzania, but abandoned as part of the structural adjustment policies during the 1990s partly due to the inefficiencies in distribution by agricultural parastatals. Considering the substantial climate mitigation potential of a more productive agriculture in Africa, fertilizer subsidies might serve as an important vehicle for climate mitigation as well as poverty reduction. The introduction of a subsidy should be compatible with a more efficient private market and distribution system. Subsidies on food crops would possibly be even more efficient as high-income producers of export crops like coffe and tobacco would not harvest the main share of the fertilizer subsidies (although that could be adjusted through an export tax). A food crop "carbon premium" would reach a higher share of less well-off farmers. For the poorest, the problem of a full up-front payment for fertilizer would still challenge their very strict cash constraints and problems with carrying the whole risk if the harvest fails. The level of fertilizer use in food production is generally low in Southern Africa. Hence the local pollution aspects are minor. However, fertilizer cause emissions of greenhouse gases (N_2O) which must be considered to secure a net climate mitigation effect.

It is important to have in mind that the effect of a reduction in the fertilizer price due to appreciation of the Tanzanian shilling is not fully absorbed in farm behaviour in our study. The reason is that the model uses fixed proportion of fertilizer and other material inputs of farms, thus underestimating the tendency to higher yields and productivity. A model with substitution between fertilizer and other input variables would come closer to the actual effect on agricultural productivity and carbon sequestration in soil. This effect is more directly described by a study of Wiig et al (2001) based on a CGE with nitrogen cycle and endogenous soil productivity and land use for Tanzania. Devaluations carried out as part of the structural adjustment policies resulted in a increase in land use of about 20 percent, reflecting the higher price on fertilizer and the substantial pressure towards more extensive agriculture.

4.3. Alternative closure rule

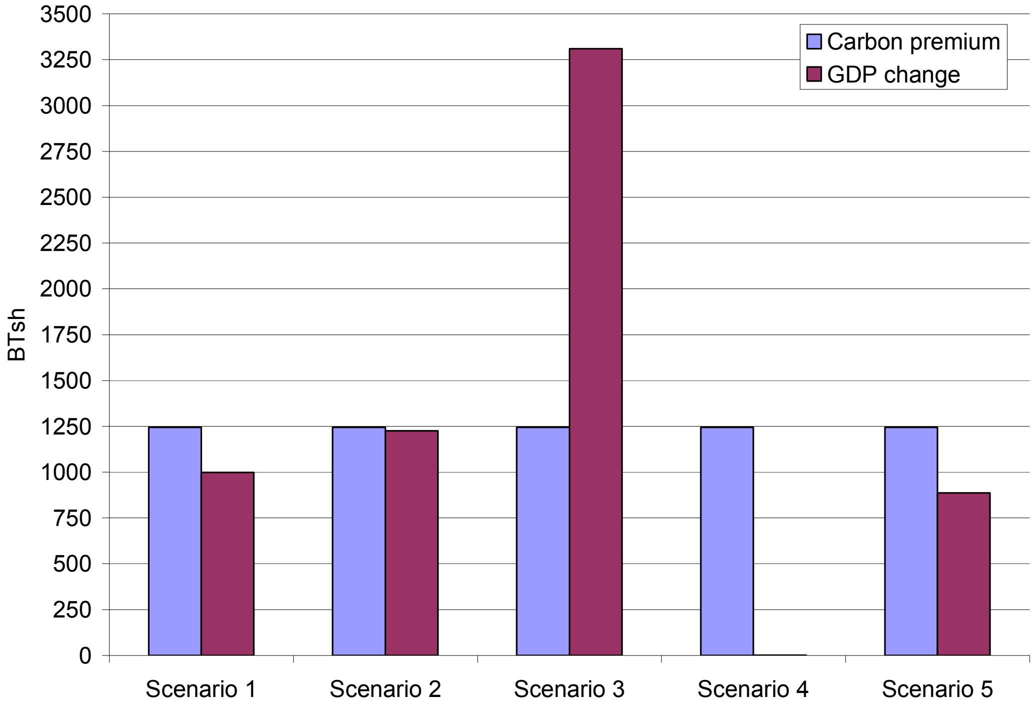
It may easily be forgotten in the CDM project context that the overall constraint for the economy are decisive for the result of economic interventions. For instance will the presence of constraints on the external balance lead to another result than if the country enjoys flexibility in terms of access to foreign loans.

So far in this study it is assumed that the government controls the investment level through public investment programs or via public investments banks. The economy might alternatively operate under different framework conditions that have consequences also in terms of climate mitigation. Below we illustrate the impact of implementing the CDM project in a savings driven economy rather than an investment driven economy as discussed above. In the case of a savings driven economy, investments are no longer determined politically, but depend on the saving decisions made by households. With different saving rates among household groups the income distribution via return to the primary factors land, labour and produced capital, is the mechanism behind the general propensity to save. Total saving will then be sensitive to the change in structure of production and the tax base. Below we consider if the effects of the CDM plantation project in a savings driven economy deviate from in an investment driven economy. Two rigidities are still with us - the allocation of land ownership is fixed and the allocation of investments still follows the base year sector distribution.

The key to understand the relation between the income distribution and level of saving is the wage to rent ratio. Basically the economy-wide wage/rent ratio varies to clear the capital market. The wage rate and return per unit capital and land will adjust to maintain the wage expenditure to rent-ratio by sector. In our savings driven scenario, the return to produced capital is scaled to match the level of the baseline scenario with fixed investment. The wage to land rent ratio will thus have to adjust to provide the required amount of saving in the savings driven alternative.

Figure 7 shows the increase in GDP across scenarios 1-5. Overall the induced GDP is larger than in the investment driven alternative, only in scenario 3 the GDP growth is somewhat lower.

Figure 7. Accumulated GDP growth and carbon premium. Savings driven. 2001-2021



The effect of the CDM project in a savings driven economy on household segments are shown in figures 8-10. Scenario 1 is the only scenario where both the rural and urban population benefit more than in the case of an investment driven economy. By allocating the project surplus to households proportional to their shares in land rent, the wage to land rent ratio is shifted downwards and helps to clear the savings-investment market simply by scenario design. This moderates the efficiency loss associated with a larger reallocation of factors. However, it is mainly the non-poor who improve their situation. Only in scenario 3 the non-poor get less than in the investment driven case (Figure 8). Figure 9 shows a minor improvement for the rural poor below food poverty line compared with the investment driven case. Other scenarios are quite similar to the investment driven alternative, although scenario 2 comes out with higher and scenario 3 with somewhat lower total income growth. Scenario 5 generates a marketly higher income for the rural population as a whole, but this benefit does not reach the poor. The CDM under savings driven alternative is clearly more beneficial tot the non-poor than within a investment driven framework.

Figure 8. Income growth of urban and rural households. Savings driven. 2001-2021

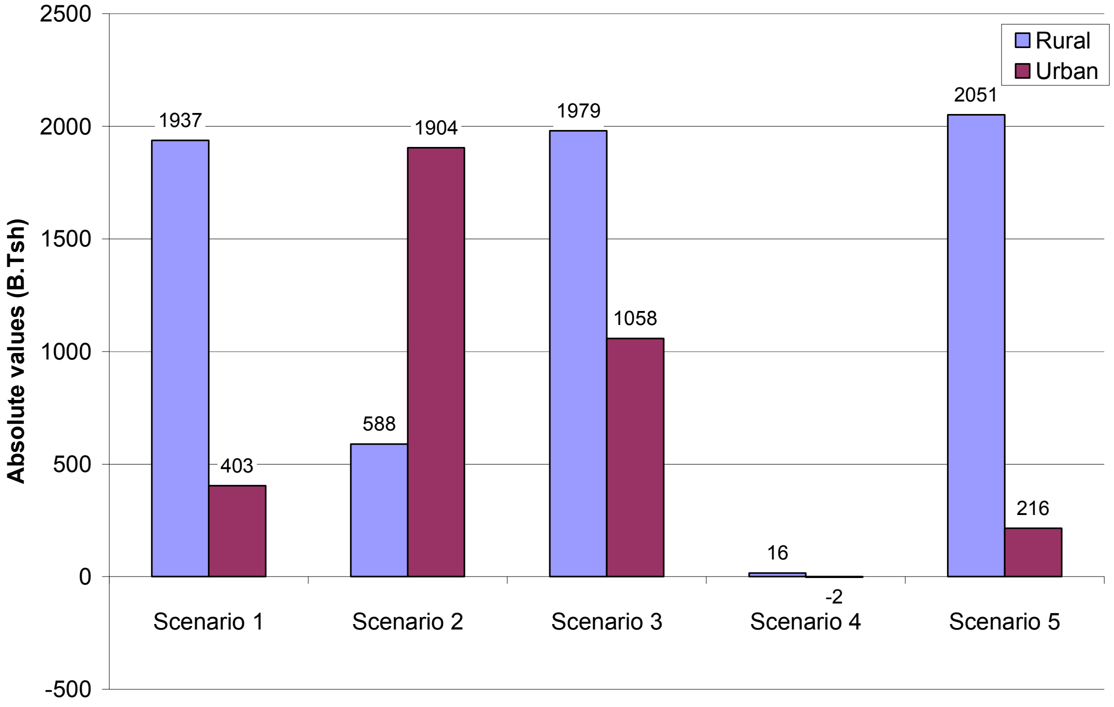
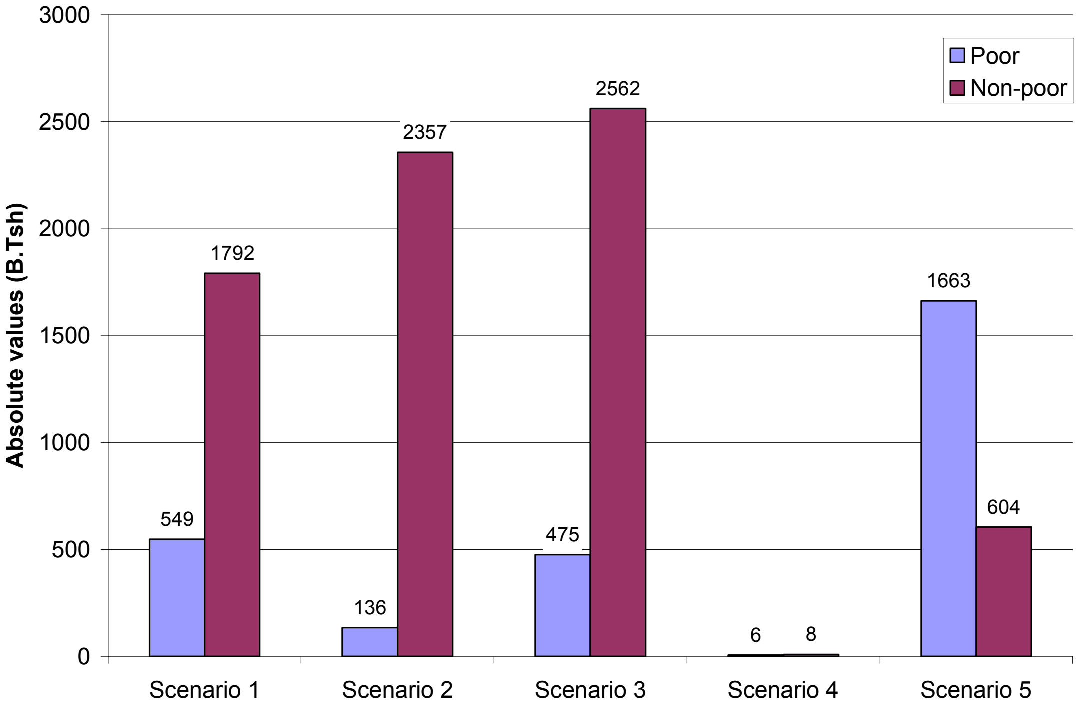
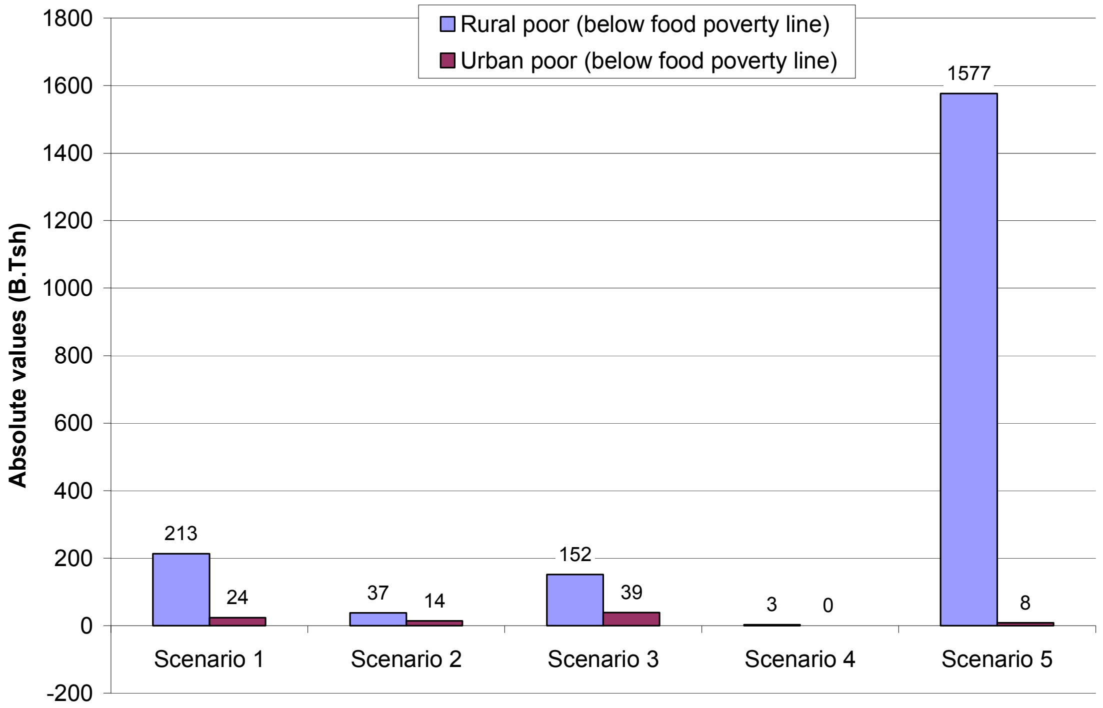


Figure 9. Income growth of poor and non-poor households. Savings driven. 2001-2021



Figur 10. Income growth of rural and urban households below food poverty line. Savings driven. 2001-2021



The factor income growth in the savings driven alternative is fairly homogenously allocated among factors (Appendix 4) and roughly corresponding to the base year factor income distribution, although labour is slightly better rewarded on the margin.

Table 10. Soil carbon accumulation. Savings driven 2000 - 2021. Million tons

	Scenarios				
	1	2	3	4	5
Total	27.2	24.3	30.3	14.2	27.6
Plantation	14.1	14.1	14.1	14.1	14.1
Agricultural soil	13.1	10.2	16.2	0.1	13.5
Ratio of soil to plantation sequestration	0.93	0.73	1.15	0.01	0.95

The project's capacity to absorbe carbon off-site is 7-12 per cent higher in scenarios 1, 2 and 5 in the case of a savings driven economy than in the investment driven alternative. With a government-hosted project (scenario 3) the off-site carbon uptake by agricultural soil is somewhat lower than in the investment driven alternative. These results reflect that GDP increases more in Scenarios 1, 2 and 5, slightly less in scenario 3. The agriculture responds to growth by increasing productivity and soil carbon sequestration.

5. Final remarks

A main purpose of the CDM is to mitigate emissions of greenhouse gases. Our study for Tanzania indicates that tree plantations under domestic ownership interact with the economy in a way that enhances the carbon mitigation effect well beyond the project obligations. The income growth of domestically hosted projects leads in various degrees to increasing demand for agricultural products, thereby stimulating the rural economy. Further, the appreciation of the Tanzanian shilling following the inflow of carbon payment makes use of imported fertilizer and pesticide cheaper. The agriculture becomes more productive and the higher yields in agriculture causes substantial additional carbon accumulation in soil. This effect increases total carbon sequestration 60-120 per cent above the plantation on-site effect, making the difference in total carbon sequestration across domestically hosted projects significant. If the plantation is foreign owned and revenue is returned abroad, there is no carbon sequestration additional to the plantation itself.

In terms of total income growth, the plantation project earmarking the surplus for domestic investments seems to be superior. Moreover, in this scenario the rural population enjoys the largest income growth. However, the benefits to the very poor are very modest even in this case. Only when the poorest are actively targeted, they harvest the highest benefit. A foreign owned project hardly increase the income level. To approach both the twin targets of the CDM, the projects seem to need domestic hosts.

The results of this study point to that CDM projects that capture identical amounts of carbon and receive the same amounts of carbon premium might give highly different effects on economic growth, income distribution and climate mitigation. It seems worth while to further study if there are systematic differences in indirect effects and total benefits from fossil fuel related projects and land use projects.

There is reason to argue that our results have relevance for other poor economies mainly relying on low input-low output agriculture. Under these circumstances there is a large potential for higher yields, and a CDM project can vitalize the rural economy and extract this potential for productivity rise and further carbon accumulation in soil. A substantial negative leakage may thus turn out to be the rule rather than the exception for land use projects in such economies.

Income from CDM projects will be spent on both energy and food items. In poor agricultural economies food has a higher income share and will dominate in the resulting consumption growth, thus improving agricultural productivity and carbon sequestration. CDM projects targeting poor people’s land use may thus seem to yield more carbon mitigation for the same input than energy-related projects primarily reaching the urban economies with higher fossil fuel intensity. So far, there has been much concern over carbon leakage in land use projects. However, a few percentage carbon leakage from plantations due to local peoples' harvest of primarily wood litter seems negligible as compared with the massive beneficial effects of project generated economic repercussions on agricultural productivity and soil carbon sequestration.

A conclusion from our study could be that the cost-efficiency of the CDM portfolio could increase by being more balanced and focus less on energy, more on land use options for carbon mitigation and rural development. Land use projects in combination with bio-energy undertakings may seem particularly beneficial. It seems useful to increase work on identification of agricultural practices that bind carbon and can easily be monitored or driven by economic incentives. The potential for additional mitigation effects of land use projects also invite to considering general economic policies to enhance climate mitigation and reduce poverty simultaneously.

There are many simplifications in our stylized approach. However, substantial economy-wide effects are identified - effects that are usually ignored in the on-site projects records and evaluations. A complete picture of CDM project efficiency should also include those issues to ensure proper verification of traded carbon emission rights.

References

Adams, R.M., D.M. Adams, J.M. Callaway, Ching Cheng Chang and B. McCarl (1993): Sequestering carbon on agricultural land: Social costs and impacts on the timber market. *Contemporary Policy Issues*, Vol XI, January 1993.

Armington, P.A. (1969): A theory of demand for products distinguished by place of production. IMF Staff Papers 16 (1): 159-178.

Aukland, L., P. Moura-Costa and S. Brown (2003): A conceptual framework and its application for addressing leakage: The case of avoided deforestation. *Climate Policy* **3**, 123-136.

Binsvanger, H.P. and M. Rosenzweig (1986): Behavioural and Material Determinants of Production Relations in Agriculture. *Journal of Development Studies* **22** (3), 503-539.

Böhringer, C., K. Conrad and A. Löschel (2003): Carbon Taxes and Joint Implementation. *Environmental and Resource Economics* **24**, 49-76.

Chamshama, S.A.O. and M. Philip (1980): Thinning Pinus Patula plantations at Sao Hill, Southern Tanzania. Division of Forestry, Faculty of Agriculture, Forestry and Veterinary Science, University of Dar es Salaam, Record no 13, 16 pp.

Chomitz, K.M. (2000): Evaluating Carbon Offsets from Forestry and Energy Projects: How do they Compare? World Bank Paper 2357, WB, Washington DC.

Chomitz, K.M. (2002): Baseline, leakage and measurement issues: how do forestry and energy projects compare? *Climate Policy* **2**, 35-49.

Dervis, K., J. de Melo and S. Robinson (1982): *General equilibrium models for development policies*. Cambridge University Press. New York.

Garcia-Olivia, F. and O.R. Masera (2004): Assessment and measurement issues related to soil carbon sequestration in land use, land use change, and forestry (LULUCF) projects under the Kyoto Protcol. *Climatic Change* **65**, 347-364.

Glomsrød, S. and T. Wei (2005): Coal cleaning: A viable strategy for reduced carbon emissions and improved environment in China? *Energy Policy* **33**, 525-542.

Heltberg, R. (1998): Rural market imperfections and the farm size-productivity relationship: Evidence from Pakistan. *World Development* **26** (10), 1807-1826.

Makundi, W.R. (2001): Potential and costs of carbon sequestration in the Tanzanian forest sector. *Mitigation and Adaptation Strategies for Global Change* **6**, 335-353.

NBS (2002): Household Budget Survey 2000/2001. Final report, National Bureau of Statistics, Dar es Salaam.

NFP (2005): Current status by different forest land management category. http://www.nfp.co.tz/studies_report/land_management/land_category.htm

Ramsey, F.P. (1928): A Mathematical Theory of Saving. *Economic Journal* **38**, 543-559.

Richards, K.R. and C. Stokes (2004): A review of forest carbon sequestration cost studies: A dozen years of research. *Climatic Change* **63**, 1-4.s

Sathaye, J.A., W.R. Makundi and K. Andrasko (2001): Carbon mitigation potential and costs of forestry options in Brazil, China, India, Indonesia, Mexico, the Philippines and Tanzania. *Mitigation and Adoption Strategies of Global Change* **6**,185-211.

Schwarze, R., J.O Niles and J. Olander (2002): Understanding and managing leakge in forest-based - greenhouse- gas mitigation projects. *Phil.Trans. R. Soc. Lond. A* **360**, 1685-1783.

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

Stone, J.R.N. (1954): Linear expenditure systems and demand analysis: An application to the pattern of British demand. *Economic Journal*, **64**, 511-27.

Stone, J.R.N. (1956): Quantity and Price Indexes in National Accounts. OECD, Paris.

Thurlow, J. and P. Wobst (2003): Poverty-focused Social Accounting Matrices for Tanzania, Trade and Macroeconomics Discussion Paper No. 112, International Food Policy Research Institute, Washington, D.C.

UNEP-Risq (2007): http://cdmpipeline.org/cdm-projects-type.htm

The soil carbon module

For all agricultural activities a carbon cycle covering above and belowground carbon is included in the model. For the plantation project, only the amount of carbon sequestered in trees is included. For agricultural crops, we include carbon both in biomass and soils. Every year 4 percent of carbon stock (*CS*) in the soil is released to the atmosphere, whereas soil organic carbon (*SOC*) in crop residues from the current crop is added to the stock. Soil organic carbon in one year (*t*-1) generated from the root and residue of crops left in the soil, enters the carbon stock in the soil the next year (*t*). Roots and residues are crop specific and proportional to the yield (harvest (*X*) per land unit (*KL*).

$$CS_{i,t} = (1-0.04)CS_{i,t-1} + SOC_{i,t-1}$$

$$SOC_{i,t} = exxs_i \cdot \frac{X_i}{KL_i} \cdot \left(0.15 \cdot retain_i \cdot \frac{1-hs_i}{hs_i} + 0.35 \cdot \frac{1}{hs_i srs_i} \right)$$

hs= food share of food and stover
srs= proportion of food and stover to roots
retain = proportion of stover kept in soil
exxs = crop specific calibration factor

The model is based on data from Young (1989): 35 per cent of the carbon in roots and 15 per cent of carbon in stover is transferred to the soil organic carbon pool. The model furthermore accounts for the portion of stover retained in the field, the harvest index of the crop and the portion of roots as compared to aboveground biomass.

Young A. 1989. Agroforestry for soil conservation CAB International, , Wallingford, Oxon 0X10 8DE, UK, 276 pp.

Appendix 2

The reference scenario (BAU)

The idea behind the construction of the baseline or business as usual (BAU) scenario in this case is to create a development path where the economy remains close to its base year condition so that the development over time is only included to take into account the full time horizon of the plantation project. The implementation of the project is intended to be the only difference between status quo and the development path with the CDM project. The tree growth and carbon compensation are time dependent, hence we have a BAU scenario advancing over 20 years and adjust the major economic variables that lay the foundation for the baseline economic development over the project horizon. .

Population growth

The population growth is set to 2.5 percent per year. According to (http://www.unicef.org/infobycountry/tanzania_statistics.html), total population of Tanzania in 2003 was 36 977 000. The annual population growth was 3.2 percent during 1970-1990 and 2.7 percent during 1990-2003.

Investments

According to national accounts 2002 (National Bureau of Statistics Tanzania), the annual growth in real investments averaged 1.2 percent during 1992-2002, 3.9 percent 1995-2002, and 4.7 percent 1997-2002. The investment growth rate has been quite unstable. During 1992-2002 real investment kept declining in the first five years and then increased over the next five years. Over these 10 years GDP kept rising with yearly growth rates from 0.3 percent in 1993 to 6.2 percent in 2002. Considerable restructuring of the Tanzanian economy has taken place over these years, with considerable implications for productivity of capital assets.

As shown in the SAM for Tanzania in 2000, the total capital stock was 3415 billion Tanzanian shillings (Tsh). At the same time, total investment is 1237 billion Tsh (in national accounts 2002, it was 1281 Tsh), accounting for 36 percent (37.5 based on NA data. On the other hand, GDP in 2000 is 7236 billion Tsh. Then capital-GDP ratio is 0.47, which implies that one more unit capital is expected to produce about two units of GDP if the ratio is stable in long run. Then we can expect the capital stock to increase only 2 percent per year if GDP grows 4 percent per year. Based on the relation capital stock (t+1) = capital stock (t) - deprecation (t) + investment (t), the depreciation could be 30 percent or more of capital stock.

Technological change

The factor neutral technological improvement in production is assumed to be one percent per year for every production activity. This corresponds to GDP per capita average growth rate during1990-2003 of only one percent annually in Tanzania provided by www.unicef.org,.

Simulated GDP growth path

To form the baseline over the project horizon we let the annual level of investments grow at about 4 percent per year. Factor neutral technical change is assumed to be one percent per year in all production sectors. Population growth rate and the associated rate of growth in the labour stock is set to 2.5 percent per year in average for the whole period. The government expenditure is assumed to grow at the same rate as the population. These assumptions lead to a development path caracterised by a growth rate declining from 6.3 percent per year in 2001 to 3.0 percent per year in 2020. This corresponds to an average growth rate of 4.0 percent per year over the whole period.

Inflation

Another feature of the economy in this country is the rather high inflation. Average annual rate of inflation at the period (1990-2003) is as high as 17 percent, which unfortunately cannot be reflected by our model since the CPI is the numeraire with value 1 constant over time. Generally the agricultural goods prices increase while the industrial goods prices decline, reflecting the assumption that the exogenous final demand (or real investment) is the same each year while the demand for consumption keeps growing over time. The exchange rate rises, which implies a lower value of local currency.

Adjusting the Frisch parameter (ω) in LES

The elasticity of the marginal utility of expenditure (Frisch parameter) is a constant under many additive utility specifications including the LES system applied here (Frisch 1959, Sato 1972). In our model version the Frisch parameter for each household group is modified to take into account that the composition of demand is changing when household income is rising.

Investment driven alternative

Table A3.1 Income[1] and consumption growth by factor and household group. Investments driven[2]. 2001-2021. 2000-prices. B.Tsh

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
Wage income	99668.54	329.49	259.75	2403.69	2.43	361.76
Rural HH	64104.23	198.43	134.96	1503.97	2.45	225.02
Poor below food poverty line	5205.34	14.02	7.34	114.21	0.35	16.68
Poor below basic need poverty line, above food poverty line	7080.38	20.17	11.40	157.10	0.49	23.69
Non-poor	51818.51	164.24	116.22	1232.66	1.61	184.65
Urban HH	35564.30	131.06	124.80	899.71	-0.02	136.74
Poor below food poverty line	1064.41	2.99	1.84	24.29	0.05	3.48
Poor below basic need poverty line, above food poverty line	1589.93	4.93	3.49	36.91	0.04	5.56
Non-poor	32909.97	123.13	119.46	838.52	-0.11	127.70
Land rent	17810.84	36.91	-11.15	260.85	0.41	53.38
Rural HH	16191.30	33.55	-10.13	237.13	0.37	48.52
Poor below food poverty line	1965.77	4.07	-1.23	28.79	0.05	5.89
Poor below basic need poverty line, above food poverty line	2575.46	5.34	-1.61	37.72	0.06	7.72
Non-poor	11650.07	24.14	-7.29	170.62	0.27	34.91
Urban HH	1619.54	3.36	-1.01	23.72	0.04	4.85
Poor below food poverty line	158.16	0.33	-0.10	2.32	0.00	0.47
Poor below basic need poverty line, above food poverty line	113.33	0.24	-0.07	1.66	0.00	0.34
Non-poor	1348.05	2.79	-0.84	19.74	0.03	4.04

Table A3.1 (cont.)

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
Profit	45709.58	41.54	-23.05	357.78	-0.85	62.17
Rural HH	41566.00	38.19	-21.42	323.81	-0.74	57.27
Poor below food poverty line	4871.48	4.84	-2.90	36.63	-0.06	7.35
Poor below basic need poverty line, above food overty line	6511.94	6.21	-3.60	49.91	-0.10	9.37
Non-poor	30182.59	27.15	-14.92	237.27	-0.58	40.56
Urban HH	4143.57	3.35	-1.63	33.97	-0.11	4.90
Poor below food poverty line	312.71	0.35	-0.23	2.19	0.00	0.55
Poor below basic need poverty line, above food overty line	248.38	0.22	-0.12	1.96	-0.01	0.33
Non-poor	3582.49	2.77	-1.28	29.82	-0.11	4.02
HH income	222674.53	1719.61	1686.75	3771.62	3.69	1738.58
Rural HH	152577.84	1527.78	65.72	2448.41	9.09	1702.52
Poor below food poverty line	12746.74	181.01	-3.69	186.27	2.31	1543.17
Poor below basic need poverty line, above food overty line	17392.60	241.66	1.01	259.64	2.33	29.87
Non-poor	122438.50	1105.12	68.40	2002.51	4.46	129.48
Urban HH	70096.69	191.82	1621.04	1323.21	-5.40	36.06
Poor below food poverty line	2894.25	15.62	3.74	49.03	-0.19	1.62
Poor below basic need poverty line, above food overty line	5270.52	11.42	8.81	90.52	-0.55	-0.89
Non-poor	61931.93	164.79	1608.49	1183.66	-4.67	35.34

Table A3.1 (cont.)

Household groups	**Baseyear level**	**Scenario**				
		1	**2**	**3**	**4**	**5**
HH real consumption	200085.83	1612.12	1651.75	2790.53	1.61	1596.87
Rural HH	138606.00	1348.99	131.70	1814.53	5.16	1485.41
Poor below food poverty line	11894.93	155.98	-5.08	143.72	1.69	1422.08
Poor below basic need poverty line, above food poverty line	15683.09	201.70	3.49	179.55	1.44	2.56
Non-poor	111027.97	991.30	133.29	1491.26	2.03	60.78
Urban HH	61479.83	263.14	1520.05	976.00	-3.55	111.46
Poor below food poverty line	2775.16	16.19	5.60	44.57	-0.20	2.40
Poor below basic need poverty line, above food poverty line	4843.23	12.92	13.27	71.23	-0.52	0.31
Non-poor	53861.45	234.02	1501.18	860.20	-2.83	108.74

1) Undiscounted real income.

2) Scaled marginal saving rates by household group. No carbon premium to carbon sequestration by agriculture.

Table A3.2. Average income growth per capita per year. 2001-2021. Tsh

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
Wage income	117100.62	387.12	305.18	2824.09	2.86	425.03
Rural HH	93572.69	289.65	196.99	2195.34	3.57	328.46
Poor below food poverty line	37688.62	101.50	53.12	826.95	2.51	120.79
Poor below basic need poverty line, above food overty line	56556.47	161.14	91.04	1254.86	3.89	189.20
Non-poor	122860.10	389.42	275.56	2922.61	3.83	437.80
Urban HH	214163.14	789.21	751.50	5417.94	-0.10	823.44
Poor below food poverty line	58025.67	163.22	100.42	1323.94	2.67	189.82
Poor below basic need poverty line, above food overty line	82091.62	254.75	180.35	1905.70	2.17	286.97
Non-poor	256407.39	959.33	930.74	6533.04	-0.83	994.95
HH income	261620.43	2020.37	1981.77	4431.28	4.34	2042.66
Rural HH	222717.26	2230.10	95.93	3573.93	13.27	2485.16
Poor below food poverty line	92291.18	1310.59	-26.72	1348.64	16.69	11173.12
Poor below basic need poverty line, above food overty line	138928.11	1930.29	8.04	2073.92	18.60	238.60
Non-poor	290297.93	2620.19	162.18	4747.88	10.58	307.00
Urban HH	422112.29	1155.14	9761.64	7968.19	-32.53	217.16
Poor below food poverty line	157779.06	851.41	203.83	2672.80	-10.14	88.31
Poor below basic need poverty line, above food overty line	272129.08	589.64	454.88	4673.86	-28.29	-46.11
Non-poor	290297.93	2620.19	162.18	4747.88	10.58	307.00

Table A3.2 (cont.)

Household groups	**Baseyear level**	**Scenario**				
		1	**2**	**3**	**4**	**5**
HH consumption	235080.95	1894.08	1940.64	3278.60	1.89	1876.16
Rural HH	202322.62	1969.11	192.25	2648.67	7.53	2168.25
Poor below food poverty line	86123.78	1129.37	-36.77	1040.61	12.24	10296.36
Poor below basic need poverty line, above food poverty line	125272.97	1611.13	27.87	1434.17	11.53	20.44
Non-poor	263243.92	2350.35	316.03	3535.74	4.80	144.10
Urban HH	370222.77	1584.56	9153.51	5877.31	-21.40	671.17
Poor below food poverty line	151286.70	882.81	305.17	2429.55	-10.85	130.84
Poor below basic need poverty line, above food poverty line	250067.09	667.19	685.01	3677.82	-26.95	16.11
Non-poor	419644.07	1823.28	11695.98	6701.96	-22.06	847.24

Table A3.3. Average income growth per capita per day. 2001-2021. TSh

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
Wage income	320.82	1.06	0.84	7.74	0.01	1.16
Rural HH	256.36	0.79	0.54	6.01	0.01	0.90
Poor below food poverty line	103.26	0.28	0.15	2.27	0.01	0.33
Poor below basic need poverty line, above food overty line	154.95	0.44	0.25	3.44	0.01	0.52
Non-poor	336.60	1.07	0.75	8.01	0.01	1.20
Urban HH	586.75	2.16	2.06	14.84	0.00	2.26
Poor below food poverty line	158.97	0.45	0.28	3.63	0.01	0.52
Poor below basic need poverty line, above food overty line	224.91	0.70	0.49	5.22	0.01	0.79
Non-poor	702.49	2.63	2.55	17.90	0.00	2.73
HH income	716.77	5.54	5.43	12.14	0.01	5.60
Rural HH	610.18	6.11	0.26	9.79	0.04	6.81
Poor below food poverty line	252.85	3.59	-0.07	3.69	0.05	30.61
Poor below basic need poverty line, above food overty line	320.82	1.06	0.84	7.74	0.01	1.16
Non-poor	795.34	7.18	0.44	13.01	0.03	0.84
Urban HH	1156.47	3.16	26.74	21.83	-0.09	0.59
Poor below food poverty line	432.27	2.33	0.56	7.32	-0.03	0.24
Poor below basic need poverty line, above food overty line	745.56	1.62	1.25	12.81	-0.08	-0.13
Non-poor	1321.98	3.52	34.33	25.27	-0.10	0.75

Table A3.3 (cont.)

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
HH consumption	644.06	5.19	5.32	8.98	0.01	5.14
Rural HH	554.31	5.39	0.53	7.26	0.02	5.94
Poor below food poverty line	235.96	3.09	-0.10	2.85	0.03	28.21
Poor below basic need poverty line, above food poverty line	343.21	4.41	0.08	3.93	0.03	0.06
Non-poor	721.22	6.44	0.87	9.69	0.01	0.39
Urban HH	1014.31	4.34	25.08	16.10	-0.06	1.84
Poor below food poverty line	414.48	2.42	0.84	6.66	-0.03	0.36
Poor below basic need poverty line, above food poverty line	685.12	1.83	1.88	10.08	-0.07	0.04
Non-poor	1149.71	5.00	32.04	18.36	-0.06	2.32

Savings driven scenarios

Table A4.1 Income1) growth by factor and household group. 2001-2021. Bill. TSh

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
Wage income	99857.15	692.21	730.65	1978.81	9.12	669.45
Rural HH	64226.10	428.61	433.80	1236.20	6.73	420.24
Poor below food poverty line	5215.19	31.91	30.57	93.78	0.69	31.85
Poor below basic need poverty line, above food poverty line	7093.77	44.58	43.09	129.16	0.95	44.38
Non-poor	51917.13	352.12	360.14	1013.25	5.09	344.01
Urban HH	35631.06	263.61	296.85	742.61	2.39	249.21
Poor below food poverty line	1066.43	6.76	6.74	19.93	0.12	6.68
Poor below basic need poverty line, above food poverty line	1592.94	10.57	10.81	30.39	0.15	10.34
Non-poor	32971.68	246.27	279.30	692.29	2.12	232.19
Land rent	17842.25	81.28	46.55	218.81	1.45	90.76
Rural HH	16219.85	73.89	42.32	198.91	1.31	82.51
Poor below food poverty line	1969.24	8.97	5.14	24.15	0.16	10.02
Poor below basic need poverty line, above food poverty line	2580.00	11.75	6.73	31.64	0.21	13.12
Non-poor	11670.62	53.16	30.45	143.12	0.95	59.37
Urban HH	1622.40	7.39	4.23	19.90	0.13	8.25
Poor below food poverty line	158.44	0.72	0.41	1.94	0.01	0.81
Poor below basic need poverty line, above food poverty line	113.53	0.52	0.30	1.39	0.01	0.58
Non-poor	1350.43	6.15	3.52	16.56	0.11	6.87

Table A4.1 (cont.)

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
Profit	45753.50	103.29	57.69	296.51	0.55	114.17
Rural HH	41606.14	94.11	51.72	268.56	0.53	104.35
Poor below food poverty line	4876.35	11.19	5.42	30.55	0.09	12.69
Poor below basic need poverty line, above food overty line	6518.33	14.84	7.70	41.50	0.10	16.64
Non-poor	30211.46	68.08	38.60	196.51	0.34	75.03
Urban HH	4147.36	9.18	5.98	27.95	0.01	9.81
Poor below food poverty line	313.04	0.74	0.27	1.85	0.01	0.87
Poor below basic need poverty line, above food overty line	248.62	0.56	0.32	1.62	0.00	0.62
Non-poor	3585.70	7.88	5.39	24.48	0.00	8.33
HH income	222948.25	2340.57	2492.23	3036.70	14.14	2266.50
Rural HH	152774.68	1937.37	588.45	1978.92	16.35	2050.96
Poor below food poverty line	12765.58	213.42	37.37	151.97	2.96	1576.64
Poor below basic need poverty line, above food overty line	17417.53	285.84	57.02	212.30	3.20	66.32
Non-poor	122591.57	1438.11	494.06	1614.65	10.20	408.00
Urban HH	70173.57	403.20	1903.77	1057.78	-2.21	215.54
Poor below food poverty line	2896.93	23.50	13.87	39.20	-0.07	8.28
Poor below basic need poverty line, above food overty line	5274.07	25.80	27.35	71.64	-0.37	11.36
Non-poor	62002.57	353.89	1862.56	946.94	-1.78	195.90

Table A4.1 (cont.)

Household groups	**Baseyear level**	**Scenario**				
		1	**2**	**3**	**4**	**5**
HH real consumption	200287.21	1834.88	1940.56	2643.13	8.76	1782.17
Rural HH	138751.96	1520.50	353.01	1688.32	10.27	1629.17
Poor below food poverty line	11909.62	175.93	20.32	125.97	2.19	1442.71
Poor below basic need poverty line, above food poverty line	15701.01	219.25	26.09	168.97	2.04	16.62
Non-poor	111141.33	1125.33	306.60	1393.38	6.04	169.84
Urban HH	61535.25	314.38	1587.55	954.81	-1.51	153.00
Poor below food poverty line	2777.39	22.32	13.48	37.20	-0.10	7.56
Poor below basic need poverty line, above food poverty line	4845.62	19.13	21.34	64.68	-0.40	5.53
Non-poor	53912.24	272.92	1552.74	852.94	-1.01	139.91

1) Undiscounted, accumulated real income.

2) Fixed marginal savings rates. Marginal return to capital scaled to match the investment driven alternative.

Table A4.2 Income growth per capita per year. TSh. 2001-2021

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
Wage income	117322.22	813.28	858.44	2324.90	10.72	786.53
Rural HH	93750.58	625.63	633.21	1804.47	9.83	613.42
Poor below food poverty line	37759.96	231.03	221.33	679.02	4.99	230.59
Poor below basic need poverty line, above food overty line	56663.41	356.10	344.19	1031.72	7.61	354.47
Non-poor	123093.93	834.85	853.88	2402.39	12.07	815.64
Urban HH	214565.15	1587.39	1787.59	4471.89	14.38	1500.71
Poor below food poverty line	58136.06	368.74	367.32	1086.48	6.49	364.10
Poor below basic need poverty line, above food overty line	82247.44	545.91	558.35	1569.06	7.64	533.88
Non-poor	256888.22	1918.72	2176.06	5393.76	16.53	1809.04
HH income	261942.02	2749.94	2928.12	3567.82	16.62	2662.91
Rural HH	223004.59	2827.98	858.96	2888.62	23.87	2993.77
Poor below food poverty line	92427.60	1545.26	270.56	1100.33	21.40	11415.47
Poor below basic need poverty line, above food overty line	139127.27	2283.25	455.46	1695.78	25.53	529.75
Non-poor	290660.86	3409.71	1171.41	3828.29	24.19	967.35
Urban HH	422575.22	2427.99	11464.26	6369.82	-13.31	1297.95
Poor below food poverty line	157924.94	1281.26	755.84	2137.03	-3.82	451.49
Poor below basic need poverty line, above food overty line	272312.48	1332.27	1412.14	3699.10	-18.85	586.29
Non-poor	483073.02	2757.22	14511.53	7377.77	-13.83	1526.31

Table A4.2 (cont.)

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
HH consumption	235317.55	2155.81	2279.96	3105.42	10.29	2093.87
Rural HH	202535.68	2219.47	515.29	2464.43	14.99	2378.09
Poor below food poverty line	86230.11	1273.81	147.12	912.09	15.88	10445.75
Poor below basic need poverty line, above food poverty line	125416.11	1751.29	208.36	1349.69	16.26	132.77
Non-poor	263512.68	2668.11	726.95	3303.66	14.32	402.68
Urban HH	370556.47	1893.15	9559.99	5749.74	-9.07	921.36
Poor below food poverty line	151408.37	1216.88	734.64	2027.78	-5.40	412.35
Poor below basic need poverty line, above food poverty line	250190.75	987.93	1101.73	3339.53	-20.50	285.48
Non-poor	420039.77	2126.39	12097.63	6645.38	-7.88	1090.06

Table A4.3. Average income growth per capita per day. 2001-2021. TSh

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
Wage income	321.43	2.23	2.35	6.37	0.03	2.15
Rural HH	256.85	1.71	1.73	4.94	0.03	1.68
Poor below food poverty line	103.45	0.63	0.61	1.86	0.01	0.63
Poor below basic need poverty line, above food overty line	155.24	0.98	0.94	2.83	0.02	0.97
Non-poor	337.24	2.29	2.34	6.58	0.03	2.23
Urban HH	587.85	4.35	4.90	12.25	0.04	4.11
Poor below food poverty line	159.28	1.01	1.01	2.98	0.02	1.00
Poor below basic need poverty line, above food overty line	225.34	1.50	1.53	4.30	0.02	1.46
Non-poor	703.80	5.26	5.96	14.78	0.05	4.96
HH income	717.65	7.53	8.02	9.77	0.05	7.30
Rural HH	610.97	7.75	2.35	7.91	0.07	8.20
Poor below food poverty line	253.23	4.23	0.74	3.01	0.06	31.28
Poor below basic need poverty line, above food overty line	381.17	6.26	1.25	4.65	0.07	1.45
Non-poor	796.33	9.34	3.21	10.49	0.07	2.65
Urban HH	1157.74	6.65	31.41	17.45	-0.04	3.56
Poor below food poverty line	432.67	3.51	2.07	5.85	-0.01	1.24
Poor below basic need poverty line, above food overty line	746.06	3.65	3.87	10.13	-0.05	1.61
Non-poor	1323.49	7.55	39.76	20.21	-0.04	4.18

Table A4.3 (cont.)

Household groups	Baseyear level	Scenario				
		1	2	3	4	5
HH consumption	644.71	5.91	6.25	8.51	0.03	5.74
Rural HH	554.89	6.08	1.41	6.75	0.04	6.52
Poor below food poverty line	236.25	3.49	0.40	2.50	0.04	28.62
Poor below basic need poverty line, above food poverty line	343.61	4.80	0.57	3.70	0.04	0.36
Non-poor	721.95	7.31	1.99	9.05	0.04	1.10
Urban HH	1015.22	5.19	26.19	15.75	-0.02	2.52
Poor below food poverty line	414.82	3.33	2.01	5.56	-0.01	1.13
Poor below basic need poverty line, above food poverty line	685.45	2.71	3.02	9.15	-0.06	0.78
Non-poor	1150.79	5.83	33.14	18.21	-0.02	2.99

Table A4.4. Factor income[1)] growth. Savings driven. 2001-2021, BTsh

	Base year level	Scenario				
		1	2	3	4	5
Wage income	99857.154	692.21	730.648	1978.806	9.122	669.447
Land rent	17842.25	81.28	46.55	218.81	1.45	90.76
Profit	45753.498	103.288	57.691	296.511	0.547	114.168
Total	163452.902	876.775	834.892	2494.125	11.114	874.377
Percent						
Wage income	61.1	78.9	87.5	79.3	82.1	76.6
Land rent	10.9	9.3	5.6	8.8	13.0	10.4
Profit	28.0	11.8	6.9	11.9	4.9	13.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

1) Received by households.

GDP growth and plantation income and expenditure

Table A5.1. Total GDP changes under various scenarios. 2001-2021. BTsh

Scenario No.	Total carbon premium	Total GDP change	
		Savings driven	Investment driven
Scenario 1	1244	998	359
Scenario 2	1244	1226	399
Scenario 3	1244	3311	4039
Scenario 4	1244	1	-10
Scenario 5	1244	887	344

Table A5.2. Carbon premium and plantation cost.2001-2021. BTsh

Year	Carbon premium	Land rent	Labor cost
2001	0.00	0.16	1.97
2002	8.35	0.16	1.62
2003	1.56	0.16	1.23
2004	2.75	0.16	0.86
2005	4.48	0.16	0.28
2006	6.12	0.16	0.07
2007	6.92	0.16	0.86
2008	10.23	0.16	0.07
2009	13.21	0.16	0.07
2010	17.06	0.16	0.07
2011	22.03	0.16	0.07
2012	27.36	0.16	0.86
2013	35.61	0.16	0.86
2014	47.35	0.16	0.07
2015	61.09	0.16	0.07
2016	78.80	0.16	0.07
2017	101.64	0.16	0.07
2018	131.09	0.16	0.07
2019	169.08	0.16	0.07
2020	218.05	0.16	0.07
2021	281.21	0.16	0.07
Total	1243.99	3.39	9.47