GREENHOUSE GAS EMISSIONS AND MITIGATION STUDIES IN TANZANIA: AN OVERVIEW

M. J. Mwandosya, P. Victus , H. E. Meena
Centre for Energy, Environment, Science and Technology
Karume Road, P. O. Box 5511, Dar es Salaam, Tanzania

Abstract. In order to help the Government of Tanzania meet its obligations under the UNFCCC, the Centre for Energy, Environment, Science and Technology was commissioned to undertake studies on greenhouse gas sources and sinks in Tanzania and the technological and other options for the mitigation of greenhouse gases in Tanzania. The study on sources and sinks was aimed at identifying and quantifying anthropogenic sources of atmospheric emissions of greenhouse gases in the country. It developed GHG inventories for the industry sector, electricity generation, household and commercial energy use, transportation activities, foresty and land use and the agricultural and livestock sector. The study on mitigation options identified the technologies that are associated with the mitigation of GHG emissions in the various sectors of the economy. It developed a long-term macroeconomic scenario which takes into consideration the mitigation of greenhouse gas emissions, the main objective being achieving mitigation without compromising the development endeavors of the nation.

1. Introduction

In a world where developing countries are beset with an array of problems which at times test the very basis of existence of some of these nations, climate change would appear at first glance to be an 'esoteric' subject, a concern for the future for those whom poverty is a thing of the past. There are also those who hold the opinion that the developed countries had utter disregard, knowingly or unknowingly, of the 'global commons'. At early stages of development and long thereafter, concern for the environment was secondary to the drive for industrialisation. Indeed, considering historic and present emissions of greenhouse gases, developed countries are responsible for 2/3 of the emissions due to anthropogenic activities and therefore the associated forcing potential. The responsibility for 'cleaning up the mess', it is argued, is therefore that of the developed countries. Should or should not developing countries be involved in issues of climate change? We submit that they should do so, and take a proactive role for that matter. Reasons for doing so are many and include, among others, those given in the following paragraphs.

The atmosphere is indivisible. Even the most developed nations have no control over the complex forces of nature which govern the diffusion of emissions in the atmosphere and circulation of air masses. In terms of emissions the atmosphere is one global common. Developing countries, Tanzania included, are part, (albeit a small part) of that global common. What happens elsewhere in that global common has an effect and impacts on our countries. In respect of climate change therefore we are and should be an interested party.

The International Panel on Climate Change (IPCC) admits that there are many uncertainties in the predictions of climate change, especially with regard to the timing, magnitude and regional patterns of climate change. Even with these uncertainties, evidence points to a changing climate. Climate variability being experienced by many countries is an illustration in the short term of impacts of long-term climate change. Droughts, floods, extreme temperatures and tropical typhoons are but some of the manifestations of climate variability. The ability of countries like Tanzania to withstand or to adapt to the impacts of these variations is at best minimal. It is precisely because of this inability to cope or adapt that developing countries need to understand, and participate in order to find out, what may or may not be going on in the atmospheric system. There is a need therefore for developing countries to formulate cross-sectoral and sectoral policies which achieve developmental objectives and also lead to mitigation of emissions and take into account vulnerability of countries to climate variations and climate change. It should therefore be possible for nations to explore policy options and strategies which achieve the goals of economic development and poverty alleviation while contributing to the stabilisation of the climate.

Climate change studies are about understanding complex phenomena and their impact on mankind. By their very nature, they are inter-disciplinary and multi-disciplinary in character. They provide an opportunity for unification and application of natural sciences, social sciences and engineering. They provide an avenue for exploring and exploiting important synergy among sectors. Energy and agricultural strategies, for example, if they are geared towards sustainable development, will involve rational choices and rational

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utilisation of natural resources which should result in reduction of emissions of greenhouse gases.

Furthermore, now that Tanzania and other developing countries are Parties to the United Nations Framework Convention on Climate Change (UNFCCC), its requirements provide a basis for our participation in climate change studies and policy formulation. The UNFCCC is a legally binding document providing a normative guide to all the Parties with regard to responsibilities of each and to each other.

2. Source and Sinks of Greenhouse Gases in Tanzania

In order to assist the Government meet its obligations under the UNFCCC, the Centre for Energy, Environment, Science and Technology (CEEST) was commissioned to undertake a study on greenhouse gas (GHG) sources and sinks in Tanzania. The main purpose of the study was to identify and quantify anthropogenic sources of atmospheric emissions of greenhouse gases in the country. In particular, the study was aimed at increasing the quantity and quality of base-line data available in order to further scientific understanding of the relationship of greenhouse gas emissions to climate change. Furthermore, the study aims at the identification of policy and technological options that could reduce the level of emissions in the country. The study is being funded by the Global Environment Facility (GEF) through the United Nations Environment Programme (UNEP), and by the International Development Research Centre (IDRC). Presented below is a summary of preliminary findings regarding the emissions of greenhouse gases in Tanzania (CEEST, 1994).

2.1 GHG EMISSIONS FROM ENERGY END USE BY INDUSTRY

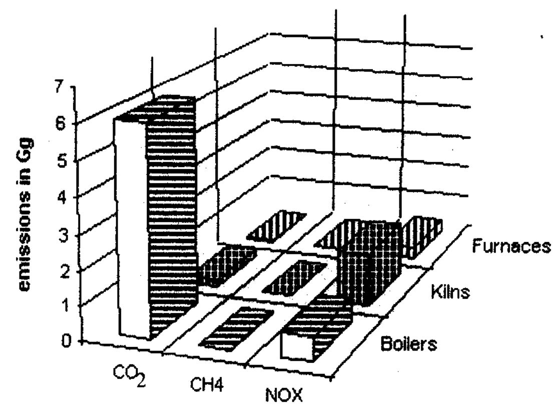
The industry sector has been surveyed for energy use in its various subsectors. Using the International Standard Industrial Classification (ISIC), the industry sector has been broken down into six subsectors: food, beverage and tobacco; textile, leather and sisal; metal and engineering; chemicals; wood and wood products and printing; and non-metal and mineral products. Also included in the study is the cottage industry, representing energy use in the non-formal rural industry.

Using a number of assumptions and emission factors, the estimation of greenhouse gas emissions from stationary combustion sources has been made using the basic formula as provided in IPCC/OECD (1992) and IPCC/OECD (1994). The estimates are shown in Fig. 1 for formal industry.

2.2 GHG EMISSIONS FROM MOBILE COMBUSTION

The transport sector accounts for approximately half of all petroleum consumed in the country, using about 400,000 tonnes of diesel, petrol, aviation gasoline and jet kerosene per year. Freight movement within Tanzania is estimated to be 2500 million tonne-km per annum. An existing truck fleet of about 14,000 trucks (over three tonnes) carries nearly 60% of the freight. Passenger transport services amount to about 5500 million person-kilometres annually. There are approximately 250,000 motor vehicles on the road.

Figure 1. Greenhouse gas emissions from industry in 1990.



Tanzania does not have emission control regulations. There are no emission standards nor emission control policies, and also no mandatory vehicle inspection and maintenance requirements. Mobile combustion emissions have been estimated from trunk roads, urban roads and non-road uses. Light-duty passenger cars, heavy duty vehicles, farm and construction equipment, railway locomotives, ocean going ships, boats and aircraft have been considered. The United States Environmental Protection Agency classification of vehicles and motorcycles has been adopted. All motor vehicles imported into the country have been assumed to be without emissions control.

Based on the aforementioned assumptions, the estimate of emissions from mobile combustion (Fig. 2) is based on relationships provided in IPCC/OECD (1992).

2.3 GHG EMISSIONS FROM THE AGRICULTURE SECTOR

We considered greenhouse gas emissions due to six activities in the agriculture sectors: CH_4 emission from rice cultivation; CH_4 emissions from enteric fermentation of domestic animals; CH_4 emissions from animal wastes; N_2O emissions from the use of nitrogen fertilizers; and CH_4, CO_2, NOx, and N_2O emissions from burning of agricultural crop wastes.

Production of methane in rice fields is a result of the decomposition of organic material by methonogenic bacteria. Methane escapes to the atmosphere mainly by diffusion through rice plants. Methane emission varies with a number of factors such as soil type, temperature, oxidation potential, pH, fertilizer use and water management.

Figure 2. Estimates of emissions from the transport sector in 1990.

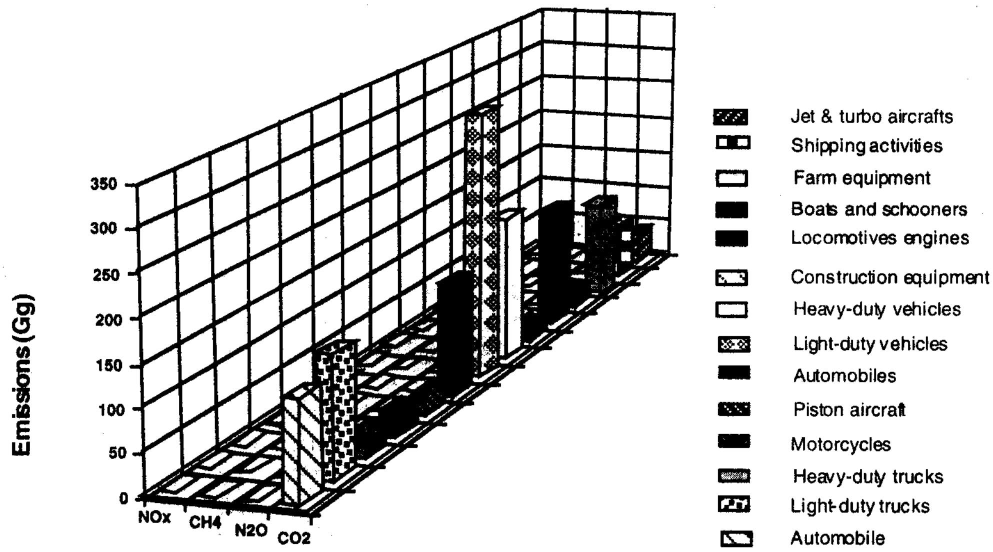
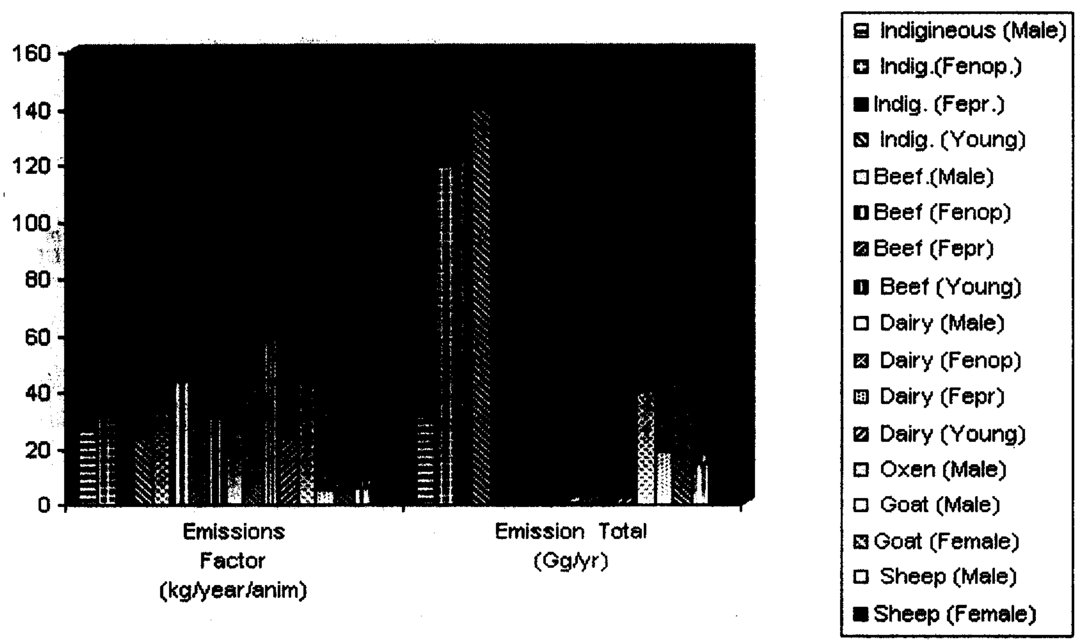


Figure 3. Methane emissions from ruminant livestock in Tanzania.



A simple methodology has been used to estimate methane emitted from rice fields in which a daily emission rate range is used to obtain annual emission. The recommended range for daily emission fluxes for methane emission from rice fields in Tanzania has been borrowed from an empirical relationship from Hangchou, China. From this relationship the annual estimate of CH_4 emissions due to rice cultivation is 0.07106 Tg CH_4. IPCC (1994) has further recommended seasonal average emissions factors according to water management regimes, taking into account average seasonal temperatures. Using this approach, the estimate of methane emission from rice cultivation is 0.0842 TgCH_4. It is recommended that country-specific emission factors be determined for emissions of methane from rice cultivation and that such factors as the fertilizer effect, soil type and temperature effects be incorporated.

Methane production in animals is part of the normal digestive process among livestock ruminants. The emission estimate of methane from enteric fermentation is based on defining various systems of feeding requirements for the animals. The total energy requirement of a ruminant is broken down into that required for its own maintenance, for growth, for pregnancy, for work and for milk production. Total methane emission will depend on a number of factors such as number and animal type, livestock management systems, the size, and feeding and production characteristics. Simplified relationships for the estimation of methane emissions are obtained based on estimation of the total feed energy intake by the animal and an estimate of the ratio of feed energy that is converted to methane. The animal categories, their numbers, and emission factors used in estimating the total methane emission from ruminants in Tanzania are shown in Fig. 3.

Methane from animal wastes is generated when organic material decompose anaerobically. The amount of methane produced will depend on the type of animal waste characteristics, in particular the amount of volatile solids present in the waste and waste management. Based on a number of assumptions, the estimated total methane emission from ruminants is 0.02617 Tg.

Fertilizers are an additional source of nitrogen to the soil and their application leads to an increase in the emission of nitrous oxide, which is influenced by natural processes such as temperature and precipitation and farm management practices such as fertilizer type, crop type, and irrigation. Emission coefficients are usually given as a range and a medium of the range. The estimated emission of nitrous oxide from the use of fertilizers in 1990 was 1050 tonnes.

The burning of crop wastes leads to the emission of carbon dioxide, methane, carbon monoxide, nitrous oxide and nitrogen oxides. Only three crops have been considered: cotton, sugarcane and paddy. Greenhouse gas emission from their burning is estimated on the basis of the amount of carbon burned and the emission ratios of the gases. To calculate emissions of CH_4 and CO, emission ratios which have been obtained specifically for Tanzania were used. Emission ratios for nitrogen/carbon are borrowed from IPCC/OECD (1992). Estimates of greenhouse gases from crop waste burning are shown in Fig. 4.

2.4 EMISSIONS AND UPTAKE OF GREENHOUSE GASES IN LAND USE AND FORESTRY

Land-use changes often result in changes in the quantity of biomass on land and produce a net exchange of greenhouse gases. Since biomass is about 45% carbon by weight, clearing by burning leads to instantaneous release of carbon dioxide. Methane, carbon monoxide, nitrous oxide and nitrogen oxides are also released. Soil disturbance through conversion of forests to pasture or cropland also leads to a release of soil carbon through oxidation of organic matter contained in the soil.

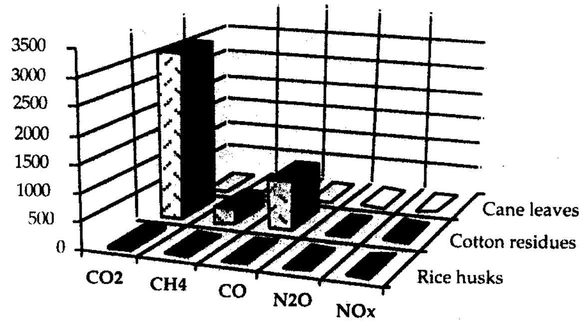
In estimating greenhouse gas emissions from land use changes, the following activities are important: forest clearing for permanent cropland or pasture; conversion of natural grassland to cultivated or pasture; abandonment of managed lands; and forest management, including human interactions with forests.

The following broad assumptions have been used in estimating the release of carbon dioxide and other non-carbon trace gases:

- In the conversion of forests to cultivated land, not all cleared above-ground biomass is burned. About 75% of the cleared biomass is collected as woodfuel.

- Approximately 20% of the cleared biomass is burned in the field, 10% of which remains on the ground as charcoal.

Figure 4. Emissions of GHG due to crop wastes burning ('000 tonnes).



The remaining 5% of above-ground biomass, such as foliage and twigs, decays in the fields over an average period of 10 years, releasing 1/10th of its carbon content annually.

Approximately half of the soil carbon is lost linearly over 25 years when forests are cleared and converted to cultivated soil.

Based on the quantity of CO_2 released from on-site burning of above-ground biomass, trace gases are released instantaneously. A nitrogen/carbon ratio of 0.01 has been used.

- In converting grasslands into cultivated land, the carbon density of the above-ground vegetation remains approximately the same. Carbon stock changes are therefore due to soil carbon.

- In cases where abandoned managed land has regrown, carbon dioxide uptake is due to the re-accumulation of soil carbon and regrowth of above-ground biomass.

Based on these and other assumptions, estimated emissions and removals of greenhouse gases due to land use changes are as shown in Table 1.

3. GHG Mitigation Study

A study of the technical options for mitigation of greenhouse gas emissions in Tanzania is being carried out by CEEST. Tasks being performed under this study include: identifying technologies that are associated with GHG emissions for various sectors; identifying technical possibilities of minimising GHG emissions; identifying the best and new environmentally-benign technologies available for Tanzania and their mitigation potential and cost; investigating various options for GHG abatement to achieve emissions reductions; exploring the link between energy efficiency and mitigation of GHG emissions; proposing technology, strategies and policy options to mitigate the GHG emissions based on abatement cost curve; recommending possible targets for GHG mitigation or stabilization, particularly in the national energy policy; and building an indigenous capacity in the assessment of climate issues.

These tasks were conducted under the following categories:

- the energy sector, covering energy forecast and energy supply analysis;

- the industrial sector, covering demand-side analysis and energy efficiency;

- cement and pulp plants, as well as waste disposal management;

- the transportation sector, covering demand-side analysis and energy efficiency;

- the agricultural sector, covering efficiency in agricultural practices and livestock feeding;

- the forestry sector, covering land use and forestry, land tenure, afforestation and reforestation;

Table 1. GHG emissions and removals from land use changes and forestry in Tanzania, 1990 (Gg).

Sources and sinks	CO_2	CH_4	CO	N_2O	NOx
Forest clearing for permanent agricultural land	733.30	9.32	81.56	0.06	1.51
Grassland conversion for agricultural land	15375.00				
Abandoned managed land	-5809.00				
Accessible natural forests	55675.00				
Shifting cultivation	4021.00	2.68	23.42	0.02	0.43
Man-made flooded lands		0.04			
Savanna burning		63.00	1662.	2.00	21.00
Total	70495.30	75.04	1766.9	2.08	22.94

- the household and commercial sector, covering demand-side analysis; and
- macroeconomic analysis, energy pricing and marginal cost analysis and evaluation of abatement scenarios.

The main objective is to evaluate the costs of the options to limit emissions of greenhouse gases, and to help to develop a mitigation strategy which could be implemented by the Government in the context of its commitments under the UNFCCC.

Mitigation analysis is a complex task which a needs considerable amount of data and involves the use of various analytical tools. The approach of the Tanzania Country Study (Fig. 5) follows the methodological guidelines developed by the UNEP Collaborating Centre on Energy and Environment (1994) in the context of the UNEP project on GHG Abatement Costing Studies.

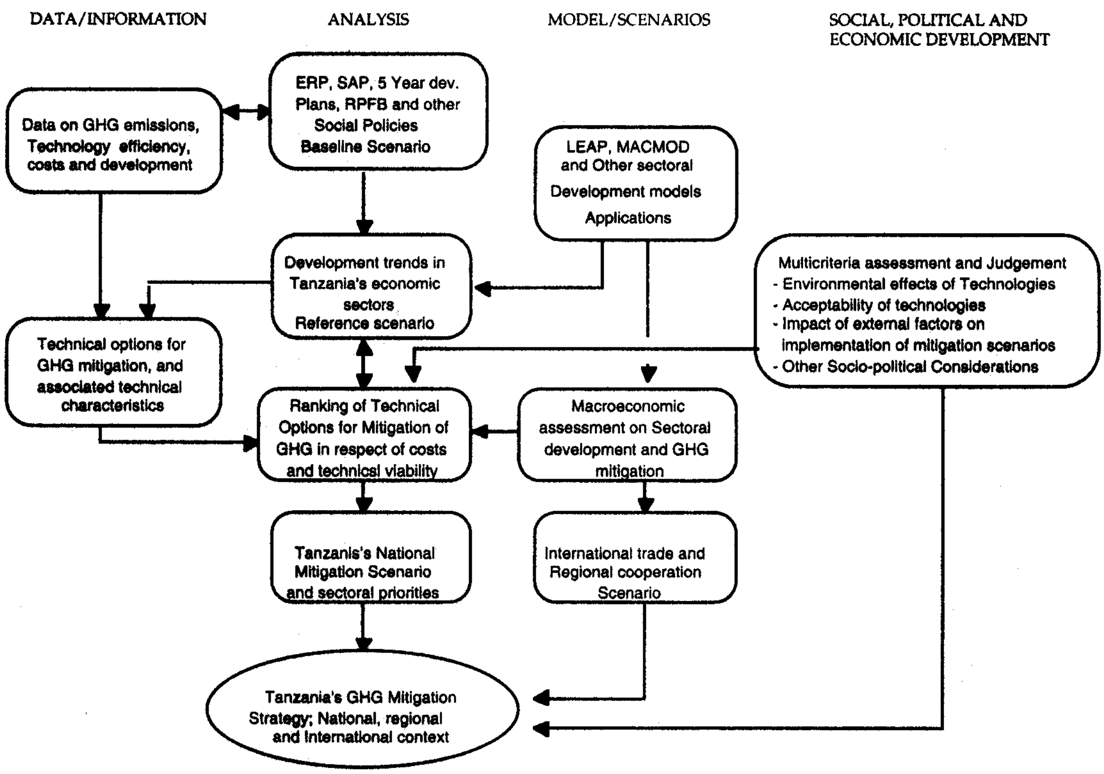
3.1 MAIN DETERMINANTS OF THE SCENARIOS

The scenarios are built in the context of Tanzania's economic development (Planning Commission, 1993) (Bureau of Statistics, 1993). Constraints in the baseline trend are considered in building up the mitigation scenarios. Tanzania's economy, like that of most developing countries, has a strong dependence on external factors. How these factors will evolve in the future is a complex question whose answer lies beyond the scope of the present analysis. For the purposes of scenario construction two types of trends concerning the external environment were assumed:

- improvement of terms of trade, favourable conditions for debt servicing, and increasing flows of external assistance are essential conditions for a successful materialisation of a balanced growth scenario;
- periodic fluctuations in the terms of trade, as well as in the short-term rescheduling arrangements for debt servicing, are more compatible with an accelerated structural reforms scenario.

We envision four potential long-term development options for Tanzania. These options are considered in relation to the

Figure 5. Structure of Mitigation Analysis Procedure.



current development levels as well as short- and long-term policies and plans. The scenarios are Balanced Growth, Accelerated Structural Reforms, Inconsistent, and Business As Usual (Fig. 6). In the context of this study the Inconsistent and Business As Usual scenarios are ruled out. For a developing country the Business As Usual scenario is impossible because the economy is still at a growing stage. The Inconsistent scenario is undesirable for any developing economy. Below is a brief description of the scenarios for Tanzania where the driving forces and environment within which the economy grows are considered.

Balanced Growth Scenario: Structural reforms are implemented at a gradual pace, and priority is given to a balanced regional development within the country. There is improvement in the terms of trade and better conditions for loans and repaying debt.

Accelerated Structural Reforms Scenario: Comprehensive and accelerated economic and institutional restructuring occurs, and the government gives priority to development of export zones. Debt service continues to exert heavy pressure on the economy, and there is no substantial improvement in the terms of trade.

Regional Cooperation Scenario: same as the Balanced Growth scenario, and there is enhancement of economic and political cooperation among neighbouring countries.

3.2 A COMPOSITE SCENARIO AND SECTORAL TRENDS

From the standpoint of GHG mitigation analysis, what is important in the context of long-term scenarios is the behavior of the socio-economic sectors. Decisions about which mitigation options should be pursued in the future depend on the constraints and opportunities that sectoral development offers to the diffusion of different technologies. Therefore, the development characteristics of economic sectors define the potential space for the successful implementation of mitigation strategies.

A combination of the Structural Reforms and the Balanced Growth scenarios results in a composite development scenario which is more relevant for Tanzania and also incorporates the regional cooperation aspect. In a simplified way, the most likely scenario for the long-term development of Tanzania can be characterized by the predominance of structural reforms in the short-term, followed by a more balanced growth strategy in the long-term. Regional cooperation includes initiatives like the East African Community and the Southern African Development Community. Other cooperation initiatives include multilateral and other international bodies.

The cooperation aspect comes about from the fact that GHG mitigation cannot be addressed in isolation from national development objectives and goals. In most cases economic

Figure 6. Four potential development scenarios for Tanzania.

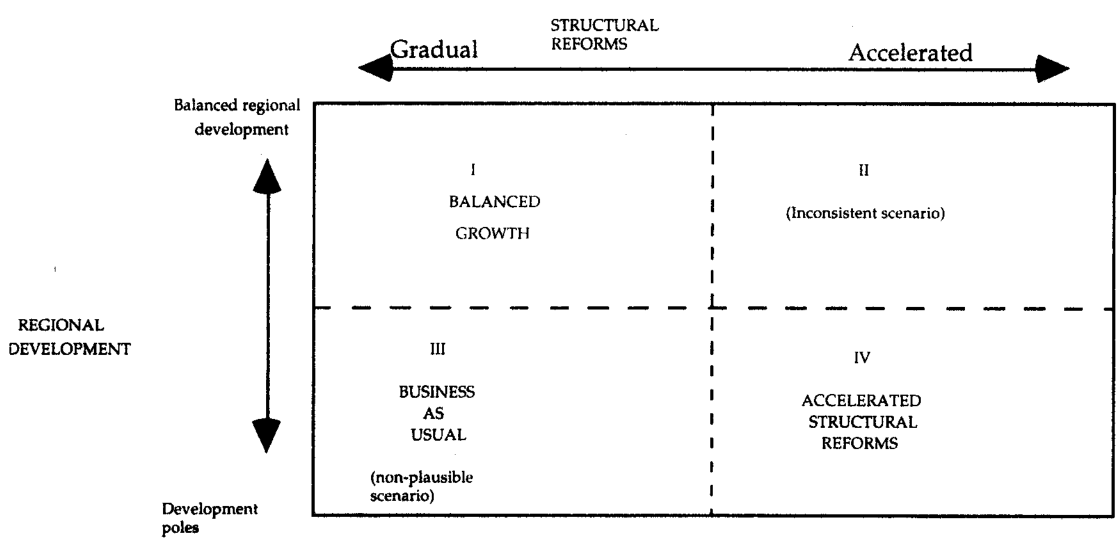


Table 2. Mitigation Options Analyzed for Tanzania.

Sector	Option	Description
Energy Supply	Advanced electricity generation technologies	Installation of 230 MW of combined-cycle power plants instead of simple cycle gas turbines
	Efficiency improvements	Increase the efficiency of existing power generation systems by repowering and improvements in transmission and distribution systems
	Charcoal production	Improve the conversion efficiency of charcoal kilns
	Coal mining	Optimise the methane release from coal mines
	Renewable technologies	Development of renewable energy technologies: solar energy, photovoltaics, wind turbines, biomass, geothermal.
Industry	1. Cement Production	
	Production management	Installation of automatic control system for reducing the amount of fuel used and improving production efficiency
	CO2 recovery system	Installation of CO_2 recovery system. Recovered CO_2 can be used for other industrial applications
	Fuel switching	Substitution of fuel oil by natural gas in two production plants
	Production mix	Production of blended cements such as pozzolanic cements, blast furnace slag cement and Portland cements in order to reduce the amount of fuel used for calcination and the amount of lime per unit of cement produced
		Optimisation of the recovery boiler in order to reduce both the amount of lime and energy use
	2. Pulp and Paper	
	Efficiency improvements	
	Recovery of CO_2	Recovery of CO_2 from calcination by absorption
		Energy efficiency improvements in existing plants including maintenance, steam production and management, cogeneration and motor systems.
	3. Other Industries	
	Energy efficiency improvements	
Transport	Vehicle efficiency	Improvements of vehicle technical efficiency
	Improve system efficiency	Improvements in traffic flow, increase vehicle load factor, improve vehicle maintenance, traffic operation, training and management
	Modal split	Rehabilitation and further development of rail system
	Urban transport	Implementation of city train in Dar es Salaam
Household and Services	Electrical appliances	Efficiency improvements on electrical appliances
	Cookstoves	Increase energy efficiency of biomass use in cookstoves
	Waste management	Waste management including landfills and waste water treatment

Table 2. Continued on next page.

Table 2. Continued.

Sector	Option	Description
Agriculture and Livestock	Agricultural practices	Reduction of methane and carbon emissions through better practices related to fertiliser application, rice cultivation, and loss of soil organic carbon from cultivated soils
	Livestock husbandry	Better livestock husbandry including better breeding and feeding practices
Land Use and Forestry Sector	Forest management	Forest management includes: i) maintaining the existing stocks through forest protection and conservation; and ii) expanding carbon sinks by means of afforestation, reforestation, enhanced regeneration and agroforestry practices
	Grasslands and rangelands	Grasslands and rangelands options are focused on maintaining or increasing carbon sequestration through better soil management, and sustainable agricultural practices

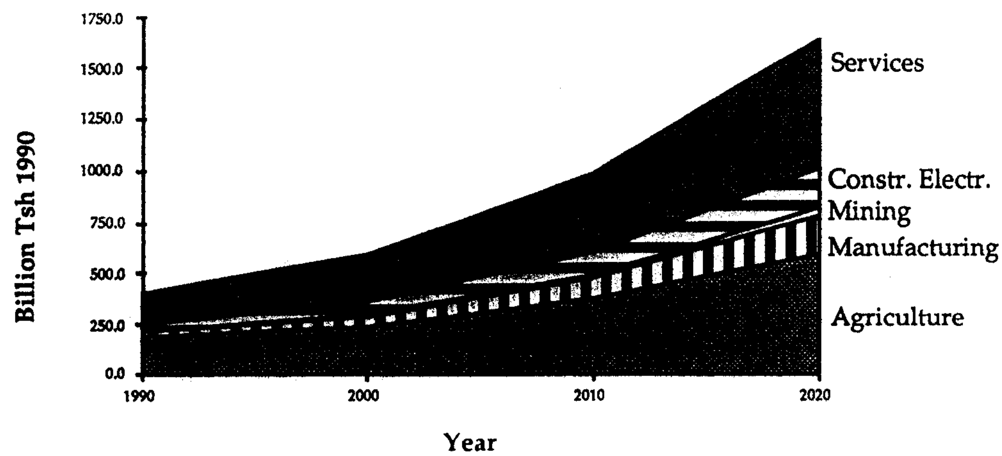
development is associated with technological development, and economic cooperation is associated with technology transfer.

Fig. 7 shows the composite scenario for economic growth in Tanzania. An annual rate of increase in GDP of 4.7% is estimated for the period 1990-2020. GDP per capita is expected to double. Agriculture output will greatly increase, but its share in the total product is expected to fall from 47% in 1990 to around 36% in 2020. The share of manufacturing, construction and electricity sectors is expected to increase from 14% to 23%.

3.3 MITIGATION OPTIONS

Table 2 provides a summary of the mitigation options being analyzed in the study. The priority or influence of different economic sectors in attaining the scenario objectives varies. When evaluation of the options is made, each assessment criterion is emphasized differently in the different sectors. For example the acceptance criterion is stressed in agriculture, which is a more traditional sector than industry, whereas this criterion might be less important in the energy supply sector. The ranking and costing of the mitigation options is an on-going activity.

Figure 7. Long-term GDP trends.



4. Concluding Remarks

A preliminary study has been carried out to determine sources and sinks of greenhouse gases in Tanzania. Initial results indicate that land use changes and forestry and the energy sector contribute the largest share of greenhouse gas emissions in Tanzania. The results are based mainly on default emission factors. There is need for more research to establish country-specific emission factors, especially in agriculture, livestock and land-use sectors.

Climate vulnerability and climate change studies are interdisciplinary in character. They provide an avenue for interdisciplinary cooperation and institutional collaboration for research. Furthermore, international and bilateral cooperation evolves more and more around environmental protection. Mechanisms such as the Global Environmental Facility and Joint Implementation for mitigation of greenhouse gases are increasingly becoming tools for economic cooperation. There is a need, therefore, for scholars in developing countries to be in the forefront in research in climate change in order to, among other reasons, provide informed advice to governments as they negotiate the implementation of various protocols and conventions that relate to climate change.

The preliminary work on the greenhouse gas mitigation study has explored the various mitigation technologies, and their characteristics and costs. On-going activities include sensitivity and marginal cost analysis of the options.

Since mitigation analysis has to incorporate technological developments and efficiency in production, it is intended to link these with scenarios in national development plans and sectoral policies. Furthermore, since one of the development scenarios for Tanzania involves regional collaboration, there is a need to study the impact of regional collaboration on development of Tanzania, as well as to seek ways of implementing mitigation options through regional collaboration and technology transfer.

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