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AFRICAN GREENHOUSE GAS EMISSION INVENTORIES AND MITIGATION OPTIONS: FORESTRY, LAND-USE CHANGE, AND AGRICULTURE

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1. Background and objectives

Human-induced change in the composition of the atmosphere seriously threatens the global climate. In an effort to address this threat, 161 nations signed the United Nations Framework Convention on Climate Change at the Earth Summit in Rio de Janeiro in June 1992. The ultimate objective of this international agreement is to *achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.* As of the first session of the Conference of the Parties (March/April 1995), 128 nations had ratified the Convention. Parties to the Convention commit to numerous obligations, including commitments to: *develop national inventories of anthropogenic emissions using agreed, comparable methodologies*; and to *formulate and implement national programs containing measures to mitigate, and to facilitate adaptation to, climate change.* Several bilateral and multilateral programs, including the United States Country Studies Program (U.S. CSP) and the United Nations Environment Programme/Global Environment Facility Country Case Studies Project (UNEP), have been established to provide technical and financial assistance to developing countries and countries with economies in transition in meeting their commitments under the Convention.

From 29 May to 2 June 1995, a workshop cosponsored by U.S. CSP and UNEP was held near Johannesburg, South Africa to address emission inventory development and emissions mitigation in an African context. The workshop focused on forestry, land-use

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change, and agriculture because these "sectors" play a major role in generating greenhouse gas (GHG) emissions from the continent, provide promising opportunities for emission mitigation, and are a vital component of African growth and development. The primary objectives of the workshop were to:

- Promote the exchange of information based on participants' experience in preparing national inventories and assessing mitigation options
- Further the development of consensus among experts on emission estimation and mitigation methods suitable for African countries
- Identify priority needs for support in testing and using the methodologies
- Identify and discuss possible options for mitigating emissions in Africa
- Promote cooperation and coordination among participants and institutions involved in climate change studies in Africa

The workshop was attended by 64 governmental and nongovernmental scientists and policy experts from 18 African and 5 non-African nations. There were 20 presentations by specialists dealing with methodological and scientific aspects of emission estimation or mitigation, 9 presentations reporting the experiences of African countries in conducting inventories or mitigation assessments, and 6 presentations from organizations providing financial, technical, or logistic support to the inventory and mitigation assessment process. Three working groups were formed to discuss and make recommendations on (1) Forestry and Land-Use Change, (2) Vegetation Burning, and (3) Livestock.

This workshop statement presents the main conclusions of discussions in plenary and in working groups, followed by the three working group summaries. The formal publication resulting from the workshop contains this statement, as well as individual papers contributed by participants (see inside front cover for details).

2. Main conclusions

The workshop reemphasized the importance of non-point sources of GHGs (i.e., forestry, land-use change, vegetation burning, and ruminant animals, in contrast to "point sources" such as fossil energy combustion) in the emission inventories of African countries, and pointed out a number of obstacles which stand in the way of their accurate estimation. In general, the inventory methods contained in the *IPCC Guidelines for National Greenhouse Gas Inventories* (UNEP/OECD/IEA/IPCC, 1995) for non-point sources are not as well-developed and tested as those for point sources. In most cases the methods themselves are acceptable, although the scope of the methods should be expanded to allow for more detailed and comprehensive assessments and for inclusion of additional gases. More importantly, the data needed to implement the methods are either unavailable or inadequate, and the default values provided by the IPCC are too general for accurate assessments.

The workshop participants noted that the completion of national emission inventories is not, in general, a high priority in countries confronted by an urgent need to develop, but that the process of emission estimation could be complementary to development imperatives. For instance, the inventory process has highlighted the poor state of national-

level statistics in many African countries. These statistics, which include items such as the distribution of agricultural practices, the state of forests, and the sizes of livestock herds, have uses far beyond the preparation of emission estimates. Participants agreed that these statistics should be routinely maintained by national governments because the same statistics that are needed to produce a GHG inventory are also necessary for effective development planning.

The analysis of mitigation options must be closely linked to emission inventory assessment. Most importantly, mitigation options must be consistent with, and complementary to, development objectives in order to be viable.

Greater coordination among the various agencies providing support for inventory and mitigation activities, as well as between these agencies and other governmental and nongovernmental entities, is needed to effectively leverage limited resources. In addition, more collaboration among countries on a regional basis should be promoted.

In particular, participants agreed that there should be more African involvement in further development and implementation of inventory and mitigation methodologies.

3. Individual working group reports

3.1. Forestry and Land-Use Change

Co-Chairs: Youba Sokona & Paul Drichi
Rapporteurs: Barbara V. Braatz & Greg Gaston

3.1.1. Emission inventory scope

Forestry and land-use change is one of the most significant sectors in Africa, both in the context of GHG emissions and as a critical part of African development and planning. This sector is a major source of GHG emissions in many African countries primarily because of rapid rates of deforestation and forest degradation from cropland establishment and timber and fuelwood collection. It also presents opportunities for emission mitigation through both reducing emissions and increasing sinks. Forests and other woody biomass stocks play a critical role in the energy sector, as fuelwood and charcoal are the principal sources of energy for many countries in Africa. This sector is also an important source of food, fodder, construction material, and medicinal plants, provides jobs and income as well as foreign exchange, and plays a critical role in biodiversity conservation.

Despite general agreement that harvest and removal activities far outpace the reestablishment of forests and other woody biomass stocks in most of Africa, explicit proof is lacking in many regions. At the same time, extrapolations that predict no forests in Africa in the near future are unlikely. A thorough GHG emission inventory can be a very useful tool for defining forest resources, rates of use, and land-use changes; and the same data that are needed to produce an accurate inventory are also necessary for effective development planning. However, at present, inventories for this sector are highly uncertain

due to complexities associated with emission-producing activities, inventory methodologies, and the data needed to implement methodologies.

Overall, the sources and sinks in the forestry and land-use change sector are fairly well defined in the *IPCC Guidelines*, although two issues require further clarification. The first is "carbon uptake" and the discussion in the *Guidelines* of how this should be tracked in the calculations. The second is the connection between this sector and the energy sector. In particular, accounting for non-CO_2 emissions from woodfuel use in the energy sector and CO_2 emissions from woodfuel that contributes to forest clearing in the Forestry and Land-Use Change sector is confusing.

Although this sector is meant to cover all land-use change activities, as well as all activities that affect woody biomass stocks, there are several activities that are particularly important to Africa, but that are not discussed in detail in the *Guidelines*. In particular, trees on small farms can be a sink of carbon when they are growing and a source of carbon when they are harvested for use as fuelwood. Conversion of non-forest natural vegetation (e.g., rangelands, savannas) to croplands is another potentially important source of carbon. The *Guidelines* would be improved by more detailed treatment of these activities. At the same time, because of difficulties associated with collecting data (particularly historical data), there will always be a trade-off between greater detail in emission assessments and the available resources with which to collect and analyze data. The relative magnitudes of sources and sinks should be considered when planning and implementing how to allocate resources to an inventory assessment.

Changes in soil organic carbon and belowground biomass as a result of land-use change contribute significantly to carbon flux. At present, soil carbon is only partially included in the IPCC methods, while belowground biomass is not included at all. These components of overall carbon stocks should be considered in further improvements in the *Guidelines*, although data limitations will likely continue to impede full implementation.

3.1.2. Emission inventory data

Completion of a comprehensive inventory for forestry and land-use change requires both a wide variety and a large amount of data, both for the inventory year and for historical years. Specific data required to complete an inventory for this sector include: statistics on areas and rates of change for different land-use types, biomass densities, wood consumption statistics, and soil carbon and nitrogen data. With few exceptions within the African continent, many of the necessary data are lacking, or, if available, are of uncertain quality. Simply identifying the agency responsible for collecting and storing relevant data may be difficult. While public institutions should, in theory, be willing to share data, this is often not the case. Data from the private sector can be particularly difficult to acquire. Also, data bases within individual countries have been found to be inconsistent, and the agencies or groups responsible for collecting these data often do not assess the reasons for these inconsistencies. Although national surveys, monitoring, and data base processing and development are clearly needed, time and resource constraints will always limit improvements. At the same time, the utility of emission inventory data to national

development planning must be emphasized. Several countries have already performed thorough surveys for national emission assessments. Existing national data bases that have been developed for other purposes can be adapted for use in inventory assessments.

International data bases are often inaccurate and of poorer quality than those available in-country. The FAO data sets, some of which are used as default values in the *IPCC Guidelines*, have a number of problems. For example, the FAO biomass density data contain estimates of forest (tree) biomass only, rather than whole ecosystem biomass (e.g., understory vegetation, litter, etc.), and areas and rates of change statistics for some countries have been found to be inconsistent with national data. In addition, comprehensive and comparable soils data in Africa are lacking.

Remote sensing data are a potential source of information on rates of land-use change. However, while remote sensing data provide systematic and synoptic information suitable for assessing land-cover/land-use changes, a great variety of other data are required to produce comprehensive and accurate emission inventories.

Commercial forest inventories provide estimates of potential harvestable timber, but their use for biomass density estimation is limited. Specifically, timber inventories contain a bias towards large trees of commercial species, ignoring small trees and shrubs and noncommercial species. Therefore, use of these data to assess biomass densities results in underestimates. Similarly, commercial timber harvest statistics do not include all the harvesting that occurs in the informal sector, such as wood for pit props, fuelwood, and rural construction.

Clear definitions of forest and other land-cover types, and land-use classification systems are needed. The forest classification system adopted in the *IPCC Guidelines* is not well defined, and is too generic to be usefully applied to the wide variety of forest types across the African continent. The problem with definitions is partly addressed by the fact that countries are encouraged to use whatever classification system is most appropriate when developing emission inventories, with the stipulation that they clearly define this classification system in order for their inventory to be transparent and verifiable. Clear definitions of national classification systems will also facilitate sharing of data across national boundaries.

The applicability and clarity of the *Guidelines* would be improved with more comprehensive conversion factors, and clearer units. In particular, the *Guidelines* only provide one default value for wood density, which can vary significantly by species. In addition, units should be more clearly defined.

3.1.3. Emission inventory methodology

Four methodological issues associated with the *IPCC Guidelines* need to be addressed in this sector. First, the methods ignore international exports of forest products. In the fossil energy sector, however, exports are subtracted from production so that fuels that are produced in one country, but consumed in another, do not contribute to emissions in the producing country. A similar step should be included in the forestry calculations so that forest product exports do not contribute to the producing country's estimated emissions.

This omission of exports in the forestry and land-use change sector is likely to result in overestimates of CO_2 emissions in Africa since several African countries are major exporters of roundwood.

Second, the methods treat all biomass removed from "managed forests and other woody biomass stocks" as an emission in the inventory year, rather than explicitly tracking the decay of wood products. This simplification is based on the assumption that annual biomass removals are replacements for biomass stocks that have been discarded and are decaying in the inventory year. Although data limitations make it difficult to track annual fluxes from the decay of forest products, the realism of this methodological simplification should be assessed when a country undertakes an inventory assessment. Specifically, countries should assess (either qualitatively or quantitatively, depending on data availability) whether or not the sizes of forest product pools are changing significantly over time, and if so how rapidly. Data on population growth and materials substitution can be used to make this assessment.

The *Guidelines* employ a fairly simplistic compartmentalization of forestry and land-use change activities. The methods were designed to be simple to enable implementation with limited data, and the methods are essentially a framework within which countries are encouraged to develop as detailed emission estimates as available data and scientific understanding allow. However, the generic activities upon which the methods are based are not realistic, particularly in Africa where land uses are often complex and multidimensional.

There are many land-use practices in Africa that affect biomass and soil carbon stocks without an explicit land-use change. These activities affect land cover and could have a significant effect on GHG emissions, and therefore should be addressed in the inventory methods. For example, an increase in intensity of grazing (i.e., an increase in the number of cattle on a particular area) may result in reduced grass cover and increased soil erosion, and thereby enhance soil carbon emissions without an explicit land-use change.

3.1.4. Mitigation options

Forestry and land-use change provide opportunities for mitigation of emissions, but in order for any mitigation option to be viable, it must be linked to a country's overall development plan. For example, issues such as land tenure, agricultural productivity, resource development, and trade must be addressed when designing mitigation strategies. In fact, if mitigation options are presented to government policymakers solely as options to reduce GHG emissions, such options would never be implemented. Instead, analysts must determine which mitigation options are consistent with, and complementary to, national development plans, and focus on those.

Linkages between inventory and mitigation methodologies, as well as between the two processes of assessment, need to be strengthened. Inventory and mitigation methodologies have, in general, been developed separately and therefore there are inconsistencies between them. Also, since an inventory sets the baseline for a mitigation assessment, the process of assessing mitigation options must build upon the inventory. Ideally, the individuals who

compile a national inventory would also be involved in the national mitigation analysis to ensure continuity and consistency.

In order to adequately evaluate mitigation options in this sector, including reforestation, afforestation, and agroforestry, accurate and comprehensive cost data are needed. Documentation of past experiences with similar projects, particularly in the Sahel, are a valuable source of information with which to assess the viability of various options.

3.1.5. Programmatic issues

Country studies programs have contributed significantly to capacity building in African countries, but there are several areas for improvement–for the donors as well as the recipient countries. Donors often do not communicate effectively with one another, so that linkages between programs do not exist. As a result of this lack of communication, efforts may be duplicated. At the same time, recipient countries have a responsibility to inform donors of previous and ongoing work in this area. As they design and implement projects, donors and recipient countries must address the need for a multidisciplinary approach. In addition, both donors and recipients need to recognize the value of local expertise, and build on this expertise in order to strengthen and broaden local capacity.

There are also managerial and organizational problems associated with project implementation on the part of recipient countries, including the selection of appropriate institutions and individuals for project implementation and follow-up. Other problems include limited access to data, bureaucratic bottlenecks in the dissemination of information and results, and lack of managerial commitment to projects.

Resources for these types of country study projects are often insufficient. More resources are needed to address climate change issues, especially in order to maintain the momentum developed during initial assessments.

3.1.6. Conclusions

- *Scope.* Forestry and land-use change is an important source of GHG emissions in Africa, provides promising opportunities for emission mitigation, and is a vital component of African economic growth and development.
- *Methods and Data.* Reliable data with which to accurately assess GHG emissions and uptake due to activities in this sector are lacking. Improvements in methodology will not address this problem. Improving the quantity, quality, and accessibility of data must be a priority.

Numerous collateral benefits can accrue to a country from assembling the data necessary to conduct an accurate inventory of GHG emissions and sinks. Reliable and recent information on land-use change and forestry can be a great benefit to development activities. Remote sensing data are a potential source of information on rates of change in land cover and land use.

- *Mitigation Options.* Mitigation options within the forestry and land-use change sector must be consistent with, and complementary to, national development plans in order to be viable.

- *Programmatic Issues.* Country studies must emphasize "team building" both to effectively leverage existing resources and to develop in-country capacity. These studies should be seen as an opportunity to develop and utilize interdisciplinary teams.

There is a serious lack of regional cooperation in climate change studies that has been a barrier to effective use of local expertise in neighboring countries. This problem results from a lack of recognition on the part of the donors as well as recipient countries of the potential benefits of this exchange and sharing of expertise. Cooperation among countries is a vital component of regional capacity building. Therefore, such barriers must be removed in order to effectively develop climate change studies in general, and emission inventories in particular.

There needs to be more African involvement with the development of the *IPCC Guidelines*. The special characteristics of Africa must be addressed by Africans.

3.2. Vegetation Burning

Co-Chairs: Augustine O. Isichei & Robert A. Delmas
Rapporteurs: Rebecca Holmes & Samir Amous

3.2.1. Emission inventory scope

Emissions of GHGs from vegetation burning are very important in Africa; in many countries, they may be the dominant source of emissions. Net pyrogenic emissions include CO, CH_4, NO_x, N_2O, non-methane hydrocarbons (NMHCs), and particles. (Carbon dioxide is currently not treated as a net emission because it is reabsorbed by regrowth of the vegetation.) Even in attempting to measure emissions from other sources, it is very difficult to avoid picking up the pervasive emissions from fires. Emissions in Africa are greatest from the moist, infertile broad-leafed savanna regions which lie between the tropical rainforests and the arid savannas and subtropical deserts.

There is no clear picture of whether savanna burning is increasing or decreasing as an emission source. Over the long term (approximately 50 years), savanna burning is likely to decrease as a result of progressive change in agricultural practices. Over the short term (one to two decades), savanna burning is likely to continue increasing due to population pressure and land-cover conversion. Without active intervention, major changes in the frequency of savanna fires are not expected. Slash-and-burn practices are likely to peak in the short term and then decrease significantly in the medium term (approximately 30 years) due to shortage of land, a result of high population growth rates.

Vegetation burning as defined in the IPCC methods should be broadened to include not just savanna, but any vegetation category that is frequently burned and fire-adapted (e.g., grasslands and thickets).

Some emissions, such as NMHCs and aerosols (i.e., airborne particles) are not currently included in the *IPCC Guidelines* for vegetation burning. Unburned savanna and forest vegetation is a significant biogenic source of NMHCs and NO_x, both of which are ozone precursors. Burning may increase emissions of these gases and concentrate them into a

plume with the other gases necessary for ozone formation. The IPCC methods could be improved by including aerosol emissions. Aerosol emissions from fires are likely to be significant both as antidotes to greenhouse radiant forcing (directly and indirectly through cloud nucleation) and as sites of ozone formation and/or depletion. Some data on aerosol emissions are available, but additional work is needed to characterize these emissions. The IPCC should also include NMHCs in the inventory methods to be consistent with the inclusion of other ozone precursors (CO and NO_x).

3.2.2. Emission inventory methodology and data

Savanna Burning. The basic methodology presented in the *IPCC Guidelines* (i.e., estimating emissions using data on area burned, fuel load, and emission factors) is appropriate. The method as presented is unnecessarily complicated, and could be simplified to an expression such as:

$$E = B \times BFB \times EF$$

Where	E	=	emissions
	B	=	biomass (dry matter)
	BFB	=	biomass fraction burned
	EF	=	emission factor (g/kg dry fuel)

Better data are available on emission factors than on fuel load and area burned, therefore research should focus on estimating areas and characterizing fuel loads. It is important to differentiate between different savanna types in calculating emissions. Fuel load and fuel type may vary significantly between different types of savannas varying in vegetation composition and structure, soil type, and climate. Reasonable fuel load estimates can be derived using simple algorithms relating fuel load to rainfall, soil quality, vegetation type, and herbivory, provided that these algorithms can be calibrated.

In estimating areas of savanna burned, remote sensing should be used, because anecdotal ground-based data are generally overestimates. Use of low-resolution remote sensing (such as one kilometer AVHRR) is cost-effective, but calibration of the fire counts against high-resolution images (e.g. LANDSAT, SPOT, or aerial photographs) is essential.

The model of combustible biomass growth and burning emissions developed for southern Africa (Scholes, 1995) could be applied to West Africa, but the production functions and fire detection algorithms would need to be recalibrated. Together, the Southern and West African versions of the model could be used to derive estimates of area burned and fuel load for all of Sub-Saharan Africa at a resolution satisfactory for national inventories.

The *IPCC Guidelines* assume that there is no net long-term change in carbon storage associated with savanna burning. However, there is strong evidence that if savanna fires were suppressed, woody biomass would increase and there would be an increase in carbon storage in both biomass and soil. Because the frequency of fires is not known to be changing significantly and consistently at an Africa-wide scale, it is not known if there is a net storage

or release of CO_2 from savannas. Some local savanna regions are clearly decreasing in carbon density due to overapplication of fire and other reasons; others are accumulating carbon due to fire exclusion. Major changes in carbon fluxes are not likely to occur in the short term, although relevant and adequate policies to reduce savanna fires could result in a large carbon sink.

The great majority of African fires are anthropogenic, and probably have been for many centuries. Therefore, all fires should be considered in calculating emissions, not only those considered "unnatural."

Slash-and-Burn Agriculture. Fuel loads for slash-and-burn agriculture vary greatly. Since the size of the individual plots being cleared is so small, remote sensing would not be a practical tool to measure their area or characterize the carbon stock. One alternative is to use remote sensing to identify areas where slash-and-burn agriculture is practiced, based on their characteristic texture, and use ground teams to estimate the fraction of the landscape in different stages of clearing and regeneration, the biomass associated with each, and the duration of the cropping and regrowth cycle. More detailed information is also required on the state of maturity of vegetation and the fallow cycle. In addition, countries should seek information from their national agricultural services, and also increase the frequency of national land-cover mapping to at least once every 10 years.

Agricultural Residues. Emissions from field burning of agricultural residue are not significant in comparison with emissions from other sources. Most agricultural residues produced in African countries are used for energy, animal feed, the pulp and paper industry, and construction. Thus, little is burned in the field, with the exception of cotton-plant residue and the pre-harvest burning of sugar cane. In general, however, there are few reliable data available on quantities of residues produced and the proportions burned in the field. The few estimates available are based on anecdote or expert opinion rather than survey data. Research on GHG emissions from this source is necessary, but is not a high priority.

Emission Factors. Several studies have been conducted in West and Southern Africa on emissions from forest clearing, savanna burning, biofuel combustion, and charcoal production. Good data are available on emissions from savanna burning, and relatively good data are available on emissions from other sources such as forest clearing. The estimated emission factors for savannas are comparable to the default values presented in the *IPCC Guidelines*. The *IPCC Guidelines* present similar factors for forests and savannas, which the newer evidence shows are significantly different; this should be corrected. In addition, the newly available data have reduced the uncertainty range in emission factors to +/- 15%, less than that presented in the *Guidelines*. Additional research on emission factors for savanna burning should not be a high priority, with the exception of certain poorly-quantified situations such as wet-season fires.

There is much greater uncertainty in estimates of area burned and fuel loads than in emission factors. In order to conduct a complete error analysis, information on uncertainty in all parameters would be required. The IPCC recommends analysis of uncertainty, but does not specify a methodology to conduct it or consistently provide error ranges for default

values. The IPCC should define an explicit approach to approximate the accumulation of errors in multiplicative and additive calculations.

Given the importance of emissions from charcoal production and biofuel combustion, and the fact that few data are now available on these emissions, research should be conducted. Relatively simple equipment and research programs will be sufficient to conduct this research and improve data on these emissions fairly rapidly. Individual national-level studies are not necessary; regional studies targeting a few countries in each region would provide representative regional data.

3.2.3. Mitigation options

- *Savanna Fire Suppression.* Savannas are burned for a variety of purposes, and savanna fires are a necessary part of ecological and agricultural processes. In addition, high rainfall seasonality makes savannas very fire-prone. As a result, complete suppression of fires is not a realistic option. However, some reduction in savanna burning frequency may be a viable mitigation option. This action would have two consequences: it would reduce emissions of GHGs and ozone precursors, and also result in net carbon uptake.

  African countries need to pursue options that will both reduce GHG emissions and be consistent with development goals. Because limiting savanna fires is expected to increase the stock of woody biomass, and because wood is used for a variety of productive purposes (e.g., construction, fuel), this option could have positive development effects. It would, however, have negative long-term effects on grazing potential.
- *Biofuel combustion and charcoal production.* There are many options for reducing GHG emissions through improvements in the efficiency of cookstoves and charcoal production processes. This can have two benefits: limiting direct emissions, and preserving carbon sinks through reduction in biofuel use. Field studies would be necessary to demonstrate these benefits.
- *Slash-and-Burn Agriculture.* New agriculture methods such as agroforestry and alley cropping are being tried, but have not been successful so far.
- *Mitigation costs.* Mitigation options such as forestation (to provide alternative fuel sources), sustainable management of existing indigenous woodlands, and more efficient wood stoves and charcoal production processes could have short-term startup costs, but have low or even negative costs in the long run. The costs of reducing savanna burning may be relatively low as well. Pilot projects to determine costs and results of these mitigation programs would be useful.

3.2.4. Programmatic issues

A few programs have contributed to improving emission estimates (e.g., SAFARI in South Africa for savanna burning data in South and Central Africa, DECAFE for West Africa). A few future campaigns already planned will give more information on emission factors (e.g., the next phases of SAFARI and EXPRESSO in Africa, and SCAR-C in South America). The proposed IGBP megatransects would greatly improve fuel load estimation.

Research priorities should be emissions from biofuels, areal extent of forest and savanna burning, and identification and cost assessment of mitigation options. Research to estimate the effects of limiting savanna fires on biomass accumulation and the ecology and usefulness of savannas is still needed. In the long term, it may also be possible to systematically collect data on fire occurrence at the continental scale with little incremental cost, using AVHRR systems already in place to study land cover.

3.2.5. Conclusions

- *Scope.* Vegetation burning is an important source of GHG emissions in Africa; in many countries, it may be the dominant source. No conclusion is possible on whether savanna burning is increasing or decreasing as an emission source. Slash-and-burn agriculture is likely to peak during the next two decades and then decline. The *IPCC Guidelines* should be expanded to include aerosol and NMHC emissions from vegetation burning.
- *Methods and Data.* The basic IPCC methodology for calculating emissions from savanna burning (i.e., estimating emissions from data on area burned, fuel load, and emission factors) is appropriate. Because better data are available on emission factors than on fuel load and area burned, future research should focus on estimating fuel load and areas. In estimating areas burned, remote sensing (low-resolution calibrated with high-resolution) should be used. Most African fires are anthropogenic, and all fires should be included in emission calculations. For estimating areas and carbon stock for slash-and-burn agriculture, remote sensing in combination with ground teams could be used. Agricultural residue burning is not a significant emission source in Africa, because most residues are used for energy, feed, and other purposes. Good data are available on emission factors for savanna burning, and relatively good data are available on emission factors for other vegetation burning. Vegetation emission factors presented in the *IPCC Guidelines* could be improved based on recent data. Research should be conducted on emissions from charcoal and biofuel production and use.
- *Mitigation.* Because savanna fires serve useful agricultural and ecological purposes, complete suppression is not an option for mitigation; however, it may be possible to reduce fire frequency. Other mitigation options include afforestation, sustainable woodland management, and more efficient cookstoves and charcoal production processes. These options may have low or negative costs in the long run. African countries need to pursue options consistent with their development goals.
- *Programmatic Issues.* Programs that have contributed to improving emission estimates include SAFARI for South and Central Africa and DECAFE for West Africa. Future campaigns, including SAFARI and EXPRESSO in Africa and SCAR-C in South America, will provide more information on emission factors. Research priorities include emissions from biofuels, areal extent of forest and savanna burning, and identification and cost assessment of mitigation options.

3.3. Livestock and Livestock Manure

Co-Chairs: Richard S. Muyungi & Andrew de Jode
Rapporteur: Michael J. Gibbs

3.3.1. Emission inventory scope

Overall, the scope for the livestock and manure sectors is well defined and understood. The activities included and the GHGs addressed are clear. Possible improvements include:

- *Additional GHGs.* Additional GHGs could be investigated related to emissions from manure management. In particular, in several African countries large piggery installations with high concentrations of animals are becoming increasingly common. In addition to releasing CH_4, the liquid manure management facilities at these installations are believed to release CO as well as various nitrogen-containing compounds such as N_2O and NO_x. The significance of these additional GHGs should be examined for potential inclusion in the methods and inventory.
- *Managed Wildlife.* In several African countries, wildlife is considered to be managed, as human intervention helps to maintain the number, balance, and health of wildlife in game reserves, national parks, and on communal and private lands. The CH_4 emissions from managed wildlife should be recognized in the emission inventory, and reported separately from the estimates for domesticated livestock. The IPCC should identify suitable methods for estimating emissions from managed wildlife in Africa, particularly ruminant wildlife.

Within Africa, the livestock sector is extremely important from an economic and social point of view. Most economies are highly dependent on livestock, and in many cases the majority of households keep some form of livestock. Livestock are used not only for milk, meat, and draft power, but also for cultural purposes and as a source of emergency finances. Within the GHG inventories represented among the working group, livestock are by far the most important source of CH_4 emissions. Additionally, livestock are expected to be a significant portion of the total GHG inventory for all gases for many African countries. Therefore, this sector is important in Africa for GHG emission inventories and (possibly) mitigation.

Various factors are leading to changes in emissions from livestock in the region. For example, in some areas animal numbers may be increasing due to the adoption of small scale zero-grazing (i.e., intensive) dairying. Balancing this trend, however, is the expectation that animal numbers may be declining among some pastoralist societies as they become more settled. The working group did not know the net result of the various factors contributing to changes in animal numbers, although FAO data values show a general trend of increasing animal numbers for the region in the most recent decade.

In addition to changing animal numbers, the emission factors for livestock may be changing. On the one hand, the small-scale zero-grazing dairying operations may have higher emissions per animal as each animal has a higher rate of production and hence feed intake. This fact is balanced by the improved diet condition of the animals which

tends to reduce CH_4 production per unit of feed intake. The net result of these two factors among this subpopulation of animals has yet to be determined. It is clear, however, that CH_4 emissions from manure management are increasing in the region as liquid manure management is becoming increasingly common among the small-scale zero-grazing dairy operations and large piggery installations discussed above.

3.3.2. Emission inventory methodology and data

Experience in preparing emission inventories suggests the following points:

- *IPCC Method.* Although generally complete and well described, the IPCC method needs to be clarified regarding the use of the more-detailed "Tier 2" equations for estimating emission factors. It needs to be made clear that the equations apply only to cattle, and not to other ruminant animals such as sheep and goats. Additionally, the proper equations for sheep, goats, and other animals should be provided in the methods.
- *Data Verification.* Critical data, such as livestock populations, are generally available from government reports and bulletins. Additional data collection from experts, in particular to characterize the livestock populations, is required. Considerable effort is required to verify the available data, and this verification activity is the most time consuming step of preparing the inventory. To augment the use of experts, limited field data collection may be appropriate to help verify the available data, in particular for those livestock populations that contribute most to the estimated emissions.

  Feed Characteristics. Because feed characteristics, particularly digestibility, influence the amount of CH_4 emitted, data describing feed consumed by livestock are needed. Identifying data for this estimate can be time consuming because regional and seasonal differences in feed characteristics need to be reflected. A feeding calendar can be used to identify the types of feed consumed by time of year, and this information can be used to reflect differences in feed characteristics seasonally.

Data collection and verification is the major activity required to conduct the inventory for this sector; the calculations themselves are relatively simple and straightforward. It is valuable to circulate an initial inventory for comment among livestock experts early in the inventory process with the expectation that the experts can provide needed feedback on the proper characterization of the livestock and livestock feeding conditions.

Obtaining data describing manure management practices can be difficult. In Africa, most manure is managed in dry systems (including manure used for fuel and construction), and emissions from these practices are extremely small. However, liquid systems are being used increasingly in small-scale zero-grazing dairies and piggeries and the manure handled at these installations may produce significant amounts of CH_4 in specific countries.

As discussed above, wildlife should be added to the inventory. Data on animal numbers should be available as these numbers are routinely collected for purposes of managing the wildlife. However, default emission factors and suitable equations for estimating "Tier 2" emission factors are required for the types of wildlife commonly managed. The types of wildlife to be included need to be determined based on consultation with experts in this area.

3.3.3. Mitigation options

Livestock and livestock manure emissions are suitable for mitigation in the African context. Mitigation strategies must be developed that correspond to the motivations and resources of those who manage specific sub-sectors of livestock populations. While mitigation opportunities appear to apply broadly to the entire livestock sector, this discussion focuses on the largest source of emissions in Africa, which is cattle. The major sub-sectors of the cattle population are as follows:

- *Dairy production:*
  - large scale commercial enterprises
  - small scale zero-grazing enterprises
- *Beef production:*
  - commercial ranching, often followed by fattening
- *Pastoralist production system:*
  - agro-pastoralist, partially settled and increasingly linked to the monetary economy
  - pure pastoralist, substantially independent from sedentary economic parameters

Within the African context, the dairy and beef sectors, both large and small scale, present opportunities for mitigation. Improvements in production efficiency, linked with infrastructure development and related market access, can be used to reduce enteric fermentation emissions.

The promotion and use of biogas digesters for energy production can be used to reduce the increasing emissions associated with manure management at piggery and small scale dairy installations. In addition, the biogas provides energy for lighting and cooking in the household. As an added benefit, the biogas energy displaces some amount of the household fuelwood requirement, thereby reducing pressures on forest resources which may otherwise contribute to CO_2 emissions as the result of forest degradation.

While there are opportunities to mitigate emissions from these sectors, the pastoralist sub-sector will be the largest source of livestock GHG emissions in many countries. The potential to mitigate emissions from this group is debatable. The following conclusions are possible:

- The extent of pure pastoralist production, generally isolated from sedentary economic parameters, is declining as partial settlement of these populations occurs and as pastoralists become increasingly integrated into the monetary economy.
- The partially settled agro-pastoralists appear to be suitable candidates for mitigation, although care must be taken to design mitigation approaches that recognize the motivations of, and resources available to, this sector.
- Subregional collaboration (e.g., in East Africa) to investigate mitigation options for the pastoralist sub-sector is warranted.

Overall, mitigation in the livestock sector is feasible and promising. However, it must be integrated with overall national development objectives for this sector. As such, the livestock development plans for each country are a useful starting point for identifying the *incremental* efforts appropriate for reducing emissions.

While not strictly barriers in all cases, key features of the livestock situation in Africa require attention as part of mitigation activities. These key features include:

- *Infrastructure.* Livestock emissions mitigation must be addressed from the overall development perspective. As such, one important component of any effort will be to ensure the satisfactory provision of adequate infrastructure to link livestock producers to key inputs as well as to markets. In some cases, existing livestock sector development efforts include infrastructure initiatives. These initiatives must be fulfilled in order for the opportunities for mitigation to be achieved.
- *Coordination with programs with mutual objectives.* There are a variety of development initiatives relating to improving the quality of life of rural people. The livestock sector initiatives will benefit by coordinating with programs that have mutual objectives.
- *Involvement and awareness.* Livestock initiatives require a commitment at all levels, including among policymakers, researchers, and producers. An inclusive process must be undertaken that identifies the mitigation approaches that are most appropriate for local conditions and that will provide a benefit to producers.
- *Overcome initial reluctance.* There is often initial reluctance to adopting new agricultural practices. Involvement and awareness on the part of producers during the formulation of mitigation options is necessary to lessen this reluctance. However, there is also a role for government initiatives to help overcome this reluctance. Avenues for accomplishing this objective may include, among others: conducting demonstration projects within key production districts; providing information and training programs; and providing temporary incentives for early adopters of new production techniques to offset potential risks.

3.3.4. Programmatic issues

A variety of national and international programs have been very important in the development of national inventories. Among the international programs, the *IPCC Guidelines* program has made a critical contribution to the overall consistency and quality of inventory efforts globally. Among funding organizations, the U.S. Country Studies Program, the UNEP/GEF Country Case Studies Project, and other key programs have enabled the countries to prepare materials as called for under the Framework Convention on Climate Change. In particular, the training components of these programs have been enormously valuable.

Several national programs are important for the completion of the inventory for the livestock sector. Ongoing efforts in various countries to develop a national livestock census are, of course, of particular significance. Additionally, Agriculture Ministries, or similar organizations, often have periodic bulletins relating to livestock conditions and production practices. Finally, production experts at research institutions or within the extension service are important for verifying data and providing advice on the characterization of production practices.

There are several gaps in the available programs:

- *Networking.* Improved networking among those preparing inventories would be extremely helpful so that data and insights could be shared. The workshop format is a particularly good method for communicating on these issues. Subregional workshops should be conducted; within the livestock sector there are very strong similarities in animal types and production systems within subregions, while there are larger differences among the subregions.
- *Regional Collaboration.* Regional collaboration can help develop key data required for emission inventories and mitigation. For example, region-specific or sub-region-specific emission factors need to be verified. A regionally-coordinated emission measurement program should be a high priority.
- *Involvement.* Increased participation by livestock experts in Africa is needed. Improved links should be developed between these experts and those conducting emission inventories. Increasing awareness and understanding of the links between the livestock sector and environmental issues is needed.

3.3.5. Conclusions

- *Scope.* Within Africa the livestock sector is extremely important from an economic and social point of view. Livestock appear to be responsible for a significant portion of the total GHG emissions for many African countries, making the sector important in Africa for both emission inventories and mitigation.

  The scope for the livestock and manure sectors is well defined and understood. Recommendations include: (1) additional GHGs from manure management could be investigated; and (2) CH_4 emissions from managed wildlife should be recognized in the emission inventory.

  Methods and Data. The IPCC methods could be clarified, although overall the methods are satisfactory. Data collection and verification are the most challenging aspects of conducting the inventory for this sector, and regional networking can provide useful discussions of data issues. Africa-specific emission factors must be developed and verified to ensure that the methods are adequate for the African context.

  Mitigation Options. Livestock and livestock manure emissions are suitable for mitigation in Africa. Mitigation strategies must be developed that correspond to the motivations and resources of managers of specific sub-sectors of the overall livestock populations. In particular, livestock emissions mitigation must be integrated with overall national development objectives for this sector. As such, the livestock development plans for each country are a useful starting point for identifying the *incremental* efforts appropriate for reducing emissions.
- *Programmatic Issues.* A variety of international and national programs are important for supporting the livestock emission inventory and mitigation analyses. There are three primary improvements that should be made in the available programs: (1) Improved networking among those preparing inventories would be extremely helpful so that data and insights could be shared. (2) Regional collaboration could help develop key data

required for emission inventories and mitigation. A regionally-coordinated emission measurement program should be a high priority. (3) Increased participation by livestock experts and producers in Africa is needed. Improved links should be developed among these individuals and those conducting emission inventories and mitigation analyses.

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