GREENHOUSE GAS EMISSIONS FROM VEGETATION FIRES IN SOUTHERN AFRICA

R.J. SCHOLES

Division of Forest Science and Technology, CSIR, PO Box 395, Pretoria 0001 South Africa.
(bscholes@forestek.csir.co.za)

Abstract. Methane (CH₄), carbon monoxide (CO), nitrogen oxides (NOₓ), volatile organic carbon, and aerosols emitted as a result of the deliberate or accidental burning of natural vegetation constitute a large component of the greenhouse gas emissions of many African countries, but the data needed for calculating these emissions by the IPCC methodology is sparse and subject to estimation errors. An improved procedure for estimating emissions from fires in southern Africa has been developed. The proposed procedure involves reclassifying existing vegetation maps into one of eleven broad, functional vegetation classes. Fuel loads are calculated within each 0.5 x 0.5° cell based on empirical relationships to climate data for each class. The fractional area of each class that burns is estimated by using daily low-resolution satellite fire detection, which is calibrated against a subsample of pre- and post-fire high-resolution satellite images. The emission factors that relate the quantity of gas released to the mass of fuel burned are based on recent field campaigns in Africa and are related to combustion efficiency, which is in turn related to the fuel mix. The emissions are summed over the 1989 fire season for Africa south of the equator. The estimated emissions from vegetation burning in the subcontinent are 0.5 Tg CH₄, 14.9 Tg CO, 1.05 Tg NOₓ, and 1.08 Tg of particles smaller than 2.5µm. The 324 Tg CO₂ emitted is expected to be reabsorbed in subsequent years. These estimates are smaller than previous estimates.

1. Introduction

Most of Africa has a strongly seasonal climate, with hot, wet summers and warm, dry winters. This kind of climate permits frequent fires, which in turn promote the growth of a fire-tolerant vegetation known as a savanna. Because many savannas are located on extremely infertile soils, frequent application of fire is essential to sustainable low-input pastoralism. Fire has been used for millennia to promote the growth of palatable forage and prevent the encroachment of trees (Goldammer, 1993), and in fact, most fires in Africa are ignited by people rather than by lightning. In the southern hemisphere, savanna fires are concentrated in the dry season, between April and October.

Savanna grass is approximately 45% carbon (C) on a dry-mass basis. When it burns, most of this C is released as CO₂. In general, this does not represent a net release of CO₂, however, because the vegetation regrows in subsequent years. On the other hand, it is a net source of a range of other radiatively active and O₃-forming trace gases and aerosols (particles), because these are not reabsorbed. If the fire frequency or fuel load are increased systematically, vegetation fires are a net source of CO₂ as well; conversely, if fires are suppressed, savannas become a major C sink as tree biomass and organic soil matter increase. The degree to which colonial and post-colonial fire regulations have altered the long-term frequency of fire is unknown. In some places fire may now be more frequent than it was previously, whereas in others, the reverse may be true. African savanna fires...
have a profound effect on the regional and global atmosphere (Crutzen and Andreae, 1990),
but there is little data to suggest that the magnitude of the impact has changed in recent
times.

The emissions of partial combustion products (CO, CH₄, and aerosols) are inversely
proportional to the degree of oxygenation during combustion (Ward and Radke, 1993).
The fine, dry grass fuels that predominate in savannas are highly oxygenated during
combustion and therefore release relatively small amounts of these gases. Emissions of
nitrogenous gases (predominantly NOₓ, but also small amounts of nitrous oxide (N₂O) and
several other gases) depend on the N content of the fuel (Lobert et al., 1991), which is
typically low (0.5–1%). Because of the vast area of Africa that burns, the gross trace gas
emissions are globally significant (Crutzen and Andreae, 1990; Levine, 1990; Lacaux,
Cachier, and Delmas, 1993) and could dominate the greenhouse gas inventories of large
but lightly industrialized African countries, such as Angola, Tanzania, and Zambia.

The general procedure for estimating emissions from biomass burning (which should
more properly be called vegetation burning, because biomass refers only to the living
material, and fires mostly consume dead material) is to divide the study region into
vegetation types and calculate the emission per type (OECD, 1991; UNEP et al., 1995).
In each type, the area (A:m²) mean fuel load (L:g m⁻²), combustion completeness (the
fraction of the biomass exposed to the fire that actually burns—C:nondimensional fraction),
and average time between fires (R:years) is estimated, usually based on expert opinion,
because few detailed measurements exist. The amount of biomass consumed per annum
(B:g yr⁻¹) in each vegetation class is then calculated from B = A R⁻¹ L C.

The emission factors (F:g emission product/g fuel) are typically estimated by measuring
the increase in a given gas relative to the increase in CO₂ in a smoke plume. This
measurement is then converted to a dry-mass basis by assuming a C content in the fuel
(41–45%) and an efficiency of conversion of fuel C to CO₂ (80–98%). The emission of
combustion products is then given for each gas by Eₐ = B Fₐ, which is summed over
the various vegetation classes. The method proposed by the Intergovernmental Panel on
Climate Change for calculating emissions from savanna burning follows this simple
approach (UNEP et al., 1995). The disadvantage of the method is that the range of possible
values for R, L, C, and F is very large, and the procedures for validating them in the field
are demanding. This means that the accuracy of the estimate is generally very low. This
paper briefly describes a method (documented in more detail in Scholes, Kendall, and
Justice (1995) and Scholes, Ward, and Justice (1995) that greatly reduces the uncertainties
by applying the following strategies:
1. The area burned is measured using a combination of low- and high-resolution satellite
   images.
2. The fuel load is modeled in four categories, constrained by climate.
3. The emission factors are related to the fuel mixture.

The method has been applied to Africa south of the equator. It could probably also be
applied to West Africa and other tropical areas that are subject to frequent and extensive
fires, but the predictive equations would have to be recalibrated for areas outside of southern
Africa.