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Agriculture as a Global Polluter

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This Gatekeeper Series is produced by the International Institute for Environment and Development to highlight key topics in the field of sustainable agriculture. Each paper reviews a selected issue of contemporary importance and draws preliminary conclusions of relevance to development activities. References are provided to important sources and background material.

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AGRICULTURE AS A GLOBAL POLLUTER

Jules N. Pretty and Gordon R. Conway

We tend to associate pollution with industrial activity, but agriculture, too, is a polluter. Pesticides, fertilisers and farm wastes can create severe pollution of water and land, on a local and sometimes even regional scale. In recent years it has also become apparent that agriculture is a major source of atmospheric pollution, with consequences that are both long term and global.

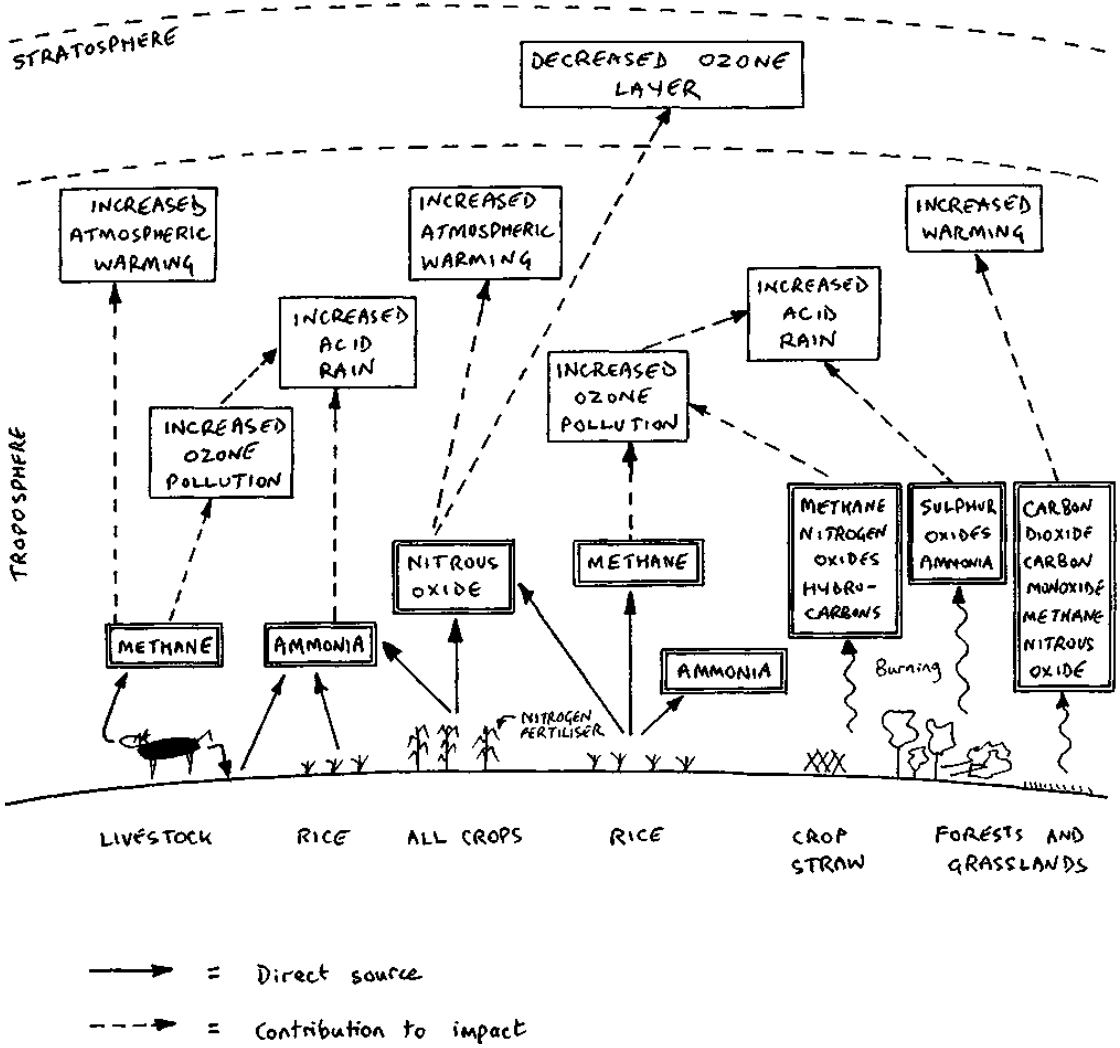
Crop plants and livestock interact, of course, continuously with the atmosphere: plants take in carbon dioxide as part of photosynthesis and produce oxygen, while both animals and plants take in oxygen and respire carbon dioxide. These activities, though, do not result in pollution of the atmosphere, or even in significant contamination. What is potentially harmful is the production of gases and particulates, arising both from the crops and animals themselves together with their immediate environments, and from the practices of contemporary crop and animal husbandry.

The most important of the gases are methane, ammonia and nitrous oxide, to which may be added the smoke, particulates and other gases resulting from the burning of vegetation. All of these gases are produced in some quantity by natural processes, but agriculture has increased the rates of emission, slowly at first but now with dramatic effect as a result of the greater expansion and intensification of agricultural production. For instance, expansion of land area in the tropics under rice paddies has led to a greater production of methane; the intensification of livestock husbandry has greatly increased the emissions of ammonia; growth in fertiliser applications has produced much larger emissions of nitrous oxide; while straw burning and the clearance of forests and grasslands has resulted in a rise in production of carbon and nitrogen oxides, as well as much more smoke and particulates.

The principal atmospheric emissions from agriculture, their causes and immediate contribution to impacts are described in the diagram overleaf.

Methane

Methane is produced by specialised bacteria in environments that are oxygen-free: such conditions occur naturally in wetland ecosystems – swamps and marshes – and in their agricultural equivalent, the rice paddy. They also occur within the guts of cattle, other ruminants and wood-eating insects. The other major sources of methane are the burning of fossil fuels and biomass, the mining of coal and natural gas and the decomposition of organic wastes.



Analysis of polar ice cores indicates an increase in global average methane levels from about 650 parts per billion by volume (ppbv) to the present 1684 ppbv during the past two to three centuries. The current upward trend is about one per cent per year. Future trends, though, are difficult to predict. In the troposphere methane is destroyed by the hydroxyl ion, but this in turn is affected by other gases, notably carbon monoxide, nitrogen oxides and other hydrocarbons. Thus the recent growth in carbon monoxide emissions is predicted to reduce the availability of hydroxyl ions, which are then not available to destroy methane.

Nitrous Oxide

Nitrous oxide is produced by the action of some bacteria in soils and water and by the burning of biomass and fossil fuels. The most important natural source is bacterial action on natural nitrogen compounds in tropical soils, particularly under tropical rainforests, which may account for some 40% of total global emissions. Bacterial action on nitrogen fertilisers is also important. Fertilised soils emit 2–10 times as much nitrous oxide as unfertilised soils and pastures, but experimental results show considerable variation. One factor is the type of fertiliser used - most studies in temperate countries show ammonium and urea compounds to produce the highest emissions, while a study on tropical soils showed nitrate to be producing five times as much as ammonium. Fertilisers, though, are not the only culprits: losses of nitrogen can be high following applications of animal wastes and slurry to land. The amount of nitrogen added as fertiliser, wastes or slurry that end up as N_2O is between 0.01% and 2.1%.

Like methane, N_2O levels are rising: from a pre-industrial level of about 280–290 ppbv to about 303 ppbv today, and are currently increasing at a rate of 0.2–0.3% annually, driven by growing fossil fuel combustion and applications of nitrogen fertiliser. Given present rates of increase for these sources, predictions suggest a concentration of between 350–450 ppbv will be reached by the year 2030. Although reductions in fuel consumption or fertiliser use could limit this trend, the very long atmospheric residence time of N_2O suggests that an atmospheric steady state will only be reached some 150–200 years after emission rates have become constant.

Ammonia

Ammonia is produced when nitrogen in fertilisers or in the excreta of animals is volatilised. In the industrialised countries domestic livestock and fertilisers are responsible for 80–90% of emissions, the rest coming from industrial processes, coal combustion, traffic and human wastes. On a global scale animal wastes are still the largest source, but biomass burning and loss from fertilised rice paddies are also important. The highest losses occur from open slurry lagoons, particularly if they are regularly agitated, and from land that has received animal wastes. Densely packed animal feedlots are important sources because of the continuous physical disturbance of the wastes. Emissions following fertiliser applications are less well understood, but it is known that hot and dry conditions, high wind speed and high soil pH all favour losses. Such conditions also favour losses from animal wastes. The amount of nitrogen lost as ammonia from fertilised paddy fields is usually 5-15%, but sometimes reaches 40–60%.

Estimates of ammonia emissions in Europe suggest a doubling over the last 30 years: in the UK the annual average loss is now 15 kg N/hectare. The highest emissions are in the west of the country, where cattle and sheep populations are most dense, though they are locally important in parts of East Anglia, where there are many pig farms. The emissions vary seasonally, being highest in spring when the spreading of wastes is common. Emissions are increasing in North America with growing cattle populations - the greatest losses occurring from large feedlot operations in the central and western states. In one region of southern California some 160,000 cattle in an area of 12 by 12 km have raised local ammonia concentrations to 20-30 times those of a nearby non-dairy region. There is little information on losses in the developing countries.

Biomass Burning

The final important agricultural pollutants are those produced when vegetation is burnt. Most phosphorus and potassium is returned to the soil, but the remaining carbon, sulphur and nitrogen is emitted to the atmosphere as carbon monoxide, carbon dioxide, nitrogen oxides, nitrous oxide, ammonia, methane, other hydrocarbons and various sulphur products. This is not a new phenomenon. It even pre-dates agriculture: natural fires are caused by lightning and volcanic eruptions, and hunter-gatherers have long known how to create fire and to use it to improve grazing grounds. What has changed is the extent and amount of burning that goes on each year, as more and more land is cleared.

The largest land clearance is for shifting agriculture, for which some 20–100 million hectares of tropical forests and savanna are cleared each year. There has also been a rapidly growing clearance of these lands to make way for permanent agriculture and livestock raising, as well as for settlements and highways. For these purposes some 8–15 million hectares are cleared annually. In the Amazon region probably as much as 90% of the burning is to open the land for livestock raising. The burns usually take place in the dry season, the plumes of smoke from individual fires joining to form very widespread layers of smoke. Satellite images taken during the months of July and August in 1985 revealed more than 12,000 fires and an area of 90,000 km^2 covered in smoke. There were layers of smoke haze at altitudes between 1000 and 4000 metres, usually only 100–300 m thick, but extending over several hundred kilometres. In these plumes and haze layers the concentrations of carbon monoxide, carbon dioxide, nitric oxide and ozone were all significantly elevated over regional background levels.

The burning of farm wastes, such as cereal stubble and straw, also contributes to the problem. In the absence of alternative uses in the industrialised countries, farmers now burn about half of all straw produced. In the developing countries the most significant wastes are those of sugar cane and pineapple crops, which are burnt to reduce the bulk and increase yields, and rice straw which is burnt in some intensive lowland regions in Asia. On a worldwide basis the industrialised countries, particularly in North America, are responsible for most of the burning of agricultural wastes.

In summary, agriculture is a major contributor to the total global production of methane, nitrous oxide, ammonia and the products of biomass burning (Table 1).

Table 1 Contribution of agriculture to total production of globally important gases and smoke

Product	Proportion produced by agriculture	Agricultural source activities
Methane	40-60%	Paddy, Livestock, biomass burning
Nitrous Oxide	10-25%	Fertilisers, biomass burning
Ammonia	80-90%	Livestock wastes, paddy
Other combustion gases	60-65%	Biomass burning
Particulates & smoke	60-65%	Biomass burning

Impact of these Gases

The burning of vegetation and crop wastes often has serious, though local, undesirable effects. Fires may get out of control, affecting nearby settlements or destroying valuable watersheds or other natural habitats. Smoke and particulates may also create a considerable local nuisance, and in industrialised countries frequently cause serious traffic accidents through smoke billowing across roads. More serious, though, are the potential global consequences arising from the emission of these gases, notably their contribution to increased environmental acidification, to a reduction in the ozone layer and to changes in the global climate.

Ammonia in the atmosphere increases the conversion rate of sulphur dioxide to the sulphate ion, and the ammonium sulphate so produced leads to increased soil and water acidity, causing damage to fish, trees and other wildlife. In addition high levels of ammonia can directly affect communities of plants by disturbing mineral uptake, by leaching out elements from leaves or by acting as an excessive nutrient source. These and other factors may have been playing a role in the forest die-back common in many temperate regions.

The impact on ozone is even more complex: in the lower levels of the atmosphere (the troposphere), nitrogen oxides, hydrocarbons and carbon monoxide, together with nitrous oxide and methane, interact with other gases to increase ozone concentrations, but in the upper atmosphere (the stratosphere) nitrous oxide depletes the protective ozone layer. The increases in tropospheric ozone have been shown to harm agricultural crops and reduce yields, and may also play a role in tree death. But in the stratosphere, where some 90% of all ozone resides, production of ozone is beneficial. Ozone here results from the action of ultraviolet light on oxygen, but it is then broken down by a variety of molecules including chlorine, nitric oxide and the hydroxyl ion. One of the major sources of the chlorine is now known to be the chlorofluorocarbons derived from aerosol propellants, foam packaging and insulation, and refrigeration coolants; the hydroxyl ion is derived from methane and water vapour; while the nitric oxide comes mainly from nitrous oxide. Agriculture may thus simultaneously be responsible for increasing tropospheric ozone and decreasing stratospheric ozone.

However there are many uncertainties – a fairly comprehensive model would contain over 30 constituents and 200 reactions, and these would have to be replicated for different altitudes, latitudes and at different times of the year. The best models currently available indicate that growing nitrous oxide abundance will cause a reduction in stratospheric ozone abundance that will have significant consequences for human health. What is clear from direct observations, however, is that a marked decline in the ozone layer is already occurring, particularly recognisable in the spring "ozone hole" over the Antarctic.

The importance of the ozone layer is that it is an effective screen of ultra-violet B light. Many organic molecules, notably DNA and proteins, can absorb and be destroyed by ultraviolet light, resulting in certain types of skin cancer, eye disorders and immunological changes. All of these would be expected to become more common following a decline in the ozone layer.

As serious as the depletion of the ozone layer is the long term effect on the global climate. The atmosphere and the earth are heated by incoming solar radiation, but heat is lost through radiation from the earth's surface to the atmosphere and out to space. The incoming radiation is mainly visible and shortwave, whilst the outgoing is thermal and longwave. Certain gases, including carbon dioxide, ozone, methane, nitrous oxide, chlorofluorocarbons and water vapour, only weakly absorb the short wave radiation but strongly absorb the long wave – in effect they trap the heat being radiated out from the surface of the globe, in a manner akin to that of a greenhouse.

But again the physical and chemical reactions are very complex and as yet poorly understood. There are several important complicating feedback mechanisms: a warmer atmosphere increases the amounts of water vapour which results in further warming; ozone in the troposphere behaves as a greenhouse gas, but in the lower stratosphere increases outgoing longwave radiation and hence reduces surface warming; chlorofluorocarbons are themselves greenhouse gases, but as they deplete stratospheric ozone they produce a further indirect warming effect.

The role of carbon dioxide as a greenhouse gas is well known, but the other greenhouse gases are now known to be equally as important. Present assessments indicate an average global temperature increase by the middle of the next century of about 2.3°C (range 1.4–3.7°C), of which non-carbon dioxide gases will have contributed 1.1°C (range 0.3–1.8°C). Methane has more impact upon climatic warming than nitrous oxide, though the combined effect of both is likely to be in the range of 20-45% of the effect of carbon dioxide alone.

The consequences of such a global temperature increase are likely to be very serious, although they will vary from place to place in ways that are not yet fully predictable. Weather patterns will shift and sea levels will rise, initially from thermal expansion of the oceans, and perhaps eventually as a result of melting of the polar ice caps. With these changes in temperature will also come a growing likelihood of short-term extreme climatic events. These are expected to have a more severe and immediate impact upon the semi-arid tropics compared with the humid tropical and cool temperate regions, even though the latter will actually experience a greater rise in warmth. Crop and forage yields are more sensitive to changes in seasonal rainfall in the semi-arid tropics than in the humid regions – year-to-year variability tends to be greater and in the driest years yields can be considerably lower. During the 1980s persistent droughts in Ethiopia, North Central India, Northeast Brazil, South and Eastern Africa and Australia have led to hardship, famine, out-migration and forest fires. These may well become more frequent and widespread. Buffering these semi-arid tropics against such extreme events during the next century will require concerted action and practical recommendations from farm to national level, many of which will have to centre on both increasing and stabilising crop productivity.

Yet under current conditions such an increase in production will only lead to more agricultural pollution. What is required, then, is practices that will reduce the emissions of methane, ammonia and nitrous oxide. There appears to be little than can be done about methane; but ammonia and nitrous oxide emissions could be reduced by the choice of appropriate fertilisers and mode of application, and ammonia by changes in storage and application to land of livestock wastes. So far, though, little attention has been given to agricultural practices and technologies that are designed to inhibit the production of gaseous pollutants.

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The Sustainable Agriculture and Rural Livelihoods Programme

The Sustainable Agriculture and Rural Livelihoods Programme of IIED promotes and supports the development of socially and environmentally aware agriculture through policy research, training and capacity strengthening, networking and information dissemination, and advisory services.

The Programme emphasises close collaboration and consultation with a wide range of institutions in the South. Collaborative research projects are aimed at identifying the constraints and potentials of the livelihood strategies of the Third World poor who are affected by ecological, economic and social change. These initiatives focus on the development and application of participatory approaches to research and development; resource conserving technologies and practices; collective approaches to resource management; the value of wild foods and resources; rural-urban interactions; and policies and institutions that work for sustainable agriculture.

The Programme supports the exchange of field experiences through a range of formal and informal publications, including *PLA Notes* (*Notes on Participatory Learning and Action - formerly RRA Notes*), the *IIED Participatory Methodology Series*, the *Working Paper Series*, and the *Gatekeeper Series*. It receives funding from the Swedish International Development Cooperation Agency, the British Department for International Development, the Danish Ministry of Foreign Affairs, the Swiss Agency for Development and Cooperation, and other diverse sources.

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