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Edited by R E Hester and R M Harrison

Sustainability in Agriculture

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EDITORS: R.E. HESTER AND R.M. HARRISON

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Preface

The World Trade Organisation (WTO) Ministerial Meeting which was held in Cancún, Mexico, in September 2003, was marked by mass demonstrations and protests against globalisation and the impacts of unfair trade on developing country agriculture. These public demonstrations received much attention in the world's newspapers and broadcast media. An estimated 10,000 activists marched in Cancún and a similar number of Mexican police were involved in securing the barricades separating activists from the WTO delegates. The self-immolation of Mr Lee Kyung Hae at the security barricade was widely reported – he was wearing a sign that declared 'the WTO kills farmers'.

The issues of 'free trade' and 'fair trade' are at the heart of the – often heated, sometimes violent – debate on world trade in agriculture. Massive subsidies, restrictive barriers, international collaboration and competition, and the livelihoods of millions of farmers around the world are involved. Concerns about sustainability in agriculture must inevitably take these issues into account, as well as changes in agricultural productivity and the impacts of novel developments such as genetically modified crops.

This volume aims to bring together many of the key issues which impact on agricultural sustainability in an endeavour to throw light on the subject and thereby promote informed and rational discussion of topics which so often generate powerful emotions and heated argument. A distinguished group of experts have contributed to the book from many different points of view and special interests. We believe this overall balanced assessment will contribute positively to the continuing debate.

The first article is by Jules Pretty who is professor in the Centre for Environment and Society at the University of Essex. Writing on recent progress and emergent challenges in agricultural practice, his review touches on food production and environmental costs, with a focus on pesticide use. This is followed in Chapter 2 by an overview of the ecological risks of transgenic plants by Paul Thompson, professor in the field of agriculture, food and community ethics at Michigan State University. Risk assessment and risk management in the context of the products of agricultural biotechnology and their ecological impacts are central themes of this article. The potential for health and socio-economic hazards implicit in the production of drugs and industrial chemicals from GM crops imposes a need for strict biological containment. These and other related concerns associated with the growth of transgenic crops are discussed in this chapter.

Nick Birch and Ron Wheatley, both members of the Entomology Group in the Scottish Crop Research Institute, take forward the discussion of transgenic plants in the next chapter on non-target impacts of GM pest-resistant crops. Their review of relevant scientific risk assessment studies focuses on the above- and below-ground interactions of *Bt* crops with their agro-ecosystems. Risks and benefits to non-target organisms, effects on important ecological functions and economic impacts are examined.

Chapter 4 presents a survey of land use change and sustainable development written by Dan Osborn from the Centre for Ecology and Hydrology at Lancaster University. This then is followed by a chapter by Ian Dickie of the Royal Society for the Protection of Birds and Anna Shiel of the National Trust which is focused on the UK environmental-economic consequences of decoupled European Union (EU) Common Agricultural Policy (CAP) payments. The June 2003 reform of the CAP introduced a phased single-farm payment for EU farmers, decoupled from production, to replace the old subsidy system and new requirements for basic agricultural and environmental standards were introduced. The environmental policy implications of this reform are examined with the aid of two specific case studies of its economic consequences.

The wider implications of agricultural subsidies are the subject of the final two chapters. In Chapter 6 James Smith of the University of Edinburgh's Centre of African Studies, has reviewed the impacts of unfair trade on developing country agriculture under the title 'Globalising Vulnerability'. Particular attention is given to a case study of sugar production in southern Africa countries. The book concludes with a chapter written by Colin Butler of the National Centre for Epidemiology and Population Health at the Australian National University. This discusses the moral and physical hazards associated with free trade in food. Although the general prognosis looks poor, a strong case is presented for a greater emphasis on fair trade and the need for greater consideration of moral issues in addition to economic ones in order to improve the lot of farmers and agricultural labourers in the less developed countries.

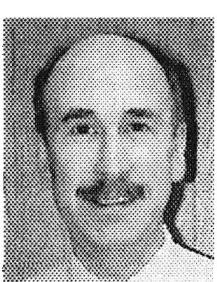
In summary, this volume of *Issues* presents an authoritative and balanced overview of many of the key factors that impact upon sustainability in agriculture. Its timeliness in treating hotly debated matters such as free trade, fair and unfair trade, GM crops, land use change and the economic consequences of recent changes in the CAP, make it essential reading for all those involved in agriculture. It will have particular value for farmers and students of farming, for policy makers, for environmental science students and teachers, and more broadly for all concerned about the future of agriculture worldwide.

Ronald E Hester
Roy M Harrison

Editors

Ronald E. Hester, BSc, DSc(London), PhD(Cornell), FRSC, CChem

Ronald E. Hester is now Emeritus Professor of Chemistry in the University of York. He was for short periods a research fellow in Cambridge and an assistant professor at Cornell before being appointed to a lectureship in chemistry in York in 1965. He was a full professor in York from 1983 to 2001. His more than 300 publications are mainly in the area of vibrational spectroscopy, latterly focusing on time-resolved studies of photoreaction intermediates and on biomolecular systems in solution. He is active in environmental chemistry and is a founder member and former chairman of the Environment Group of the Royal Society of Chemistry and editor of 'Industry and the Environment in Perspective' (RSC, 1983) and 'Understanding Our Environment' (RSC, 1986). As a member of the Council of the UK Science and Engineering Research Council and several of its subcommittees, panels and boards, he has been heavily involved in national science policy and administration. He was, from 1991 to 1993, a member of the UK Department of the Environment Advisory Committee on Hazardous Substances and from 1995 to 2000 was a member of the Publications and Information Board of the Royal Society of Chemistry.



Roy M. Harrison, BSc, PhD, DSc(Birmingham), FRSC, CChem, FRMetS, Hon MFPH, Hon FFOM

Roy M. Harrison is Queen Elizabeth II Birmingham Centenary Professor of Environmental Health in the University of Birmingham. He was previously Lecturer in Environmental Sciences at the University of Lancaster and Reader and Director of the Institute of Aerosol Science at the University of Essex. His more than 300 publications are mainly in the field of environmental chemistry, although his current work includes studies of human health impacts of atmospheric pollutants as well as research into the chemistry of pollution phenomena. He is a past Chairman of the Environment Group of the Royal Society of Chemistry for whom he has edited 'Pollution: Causes, Effects and Control' (RSC, 1983; Fourth Edition, 2001) and 'Understanding our Environment: An Introduction to Environmental Chemistry and Pollution' (RSC, Third Edition, 1999). He has a close interest in scientific and policy aspects of air pollution, having been Chairman of the

Department of Environment Quality of Urban Air Review Group and the DETR Atmospheric Particles Expert Group as well as a member of the Department of Health Committee on the Medical Effects of Air Pollutants. He is currently a member of the DEFRA Air Quality Expert Group, the DEFRA Advisory Committee on Hazardous Substances and the DEFRA Expert Panel on Air Quality Standards.

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Sustainability in Agriculture: Recent Progress and Emergent Challenges

JULES PRETTY

1 Recent Progress on Food Production

There have been startling increases in food production across the world since the beginning of the 1960s. Since then, aggregate world food production has grown by 145%. In Africa, it rose by 140%, in Latin America by almost 200%, and in Asia by a remarkable 280%. The greatest increases have been in China – an extraordinary five-fold increase, mostly occurring in the 1980s and 1990s. In the industrialised regions, production started from a higher base – yet it still doubled in the USA over 40 years, and grew by 68% in western Europe.

Over the same period, world population has grown from three to six billion. Again, though, *per capita* agricultural production has outpaced population growth. For each person today, there is an extra 25% more food compared with people in 1960. These aggregate figures, however, hide important differences between regions. In Asia and Latin America, *per capita* food production increased by 76% and 28%, respectively. Africa, though, has fared badly, with food production per person 10% less today than in 1960. China performs best, with a trebling of food production per person over the same period. These agricultural production gains have lifted millions out of poverty and provided a platform for economic growth in many parts of the world.

However, these advances in aggregate productivity have not brought reductions in incidence of hunger for all. In the early 21st century, there are still some 800 million people hungry and lacking adequate access to food. A third are in East and South-East Asia, another third in South Asia, a quarter in Sub-Saharan Africa, and 5% each in Latin America/Caribbean and in North Africa/Near East. Nonetheless, there has been progress, as incidence of under-nourishment stood at 960 million in 1970, comprising a third of people in developing countries at the time. Since then, average *per capita* consumption of food has increased by 17% to 2,760 kilocalories per day–good as an

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average, but still hiding a great many people surviving on less: 33 countries, mostly in Sub-Saharan Africa, still have *per capita* food consumption under 2,200 kcal/day.[1]

Despite great progress, things will probably get worse for many people before they get better. As total population continues to increase, until at least the mid 21st century, so the absolute demand for food will also increase. Increasing incomes will also mean people will have more purchasing power, and this will increase demand for food. But as diets change, so demand for the types of food will also shift radically. In particular, increasing urbanisation means people are more likely to adopt new diets, particularly consuming more meat and fewer traditional cereals and other foods, what has been called the nutrition transition.[2]

One of the most important changes in the world food system will come from an increase in consumption of livestock products. Meat demand is expected to rise rapidly, and this will change many farming systems. Livestock are important in mixed production systems, using foods and by-products that would not have been consumed by humans. But increasingly farmers are finding it easier to raise animals intensively, and feed them with cheap, though energetically-inefficient, cereals and oils. Currently, *per capita* annual food demand in industrialised countries is 550 kg of cereal and 78 kg of meat. By contrast, in developing countries it is only 260 kg of cereal and 30 kg of meat. These food consumption disparities between people in industrialised and developing countries are expected to persist.[3]

2 What is Agricultural Sustainability?

What do we understand by agricultural sustainability? Many different terms have come to be used to imply greater sustainability in some agricultural systems over prevailing ones (both pre-industrial and industrialised). These include sustainable, ecoagriculture, permaculture, organic, ecological, low-input, biodynamic, environmentally-sensitive, community-based, wise-use, farm-fresh and extensive. There is continuing and intense debate about whether agricultural systems using some of these terms qualify as sustainable.

Systems high in sustainability are making the best use of nature's goods and services whilst not damaging these assets.[4–11] The key principles are to:

i. integrate natural processes such as nutrient cycling, nitrogen fixation, soil regeneration and natural enemies of pests into food production processes;
ii. minimise the use of non-renewable inputs that damage the environment or harm the health of farmers and consumers;
iii. make productive use of the knowledge and skills of farmers, so improving their self-reliance and substituting human capital for costly inputs;
iv. make productive use of people's capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management.

The idea of agricultural sustainability does not mean ruling out any technologies or practices on ideological grounds. If a technology works to improve productivity for farmers, and does not harm the environment, then it is likely to be beneficial on sustainability grounds. Agricultural systems emphasising these principles are also multi-functional within landscapes and economies. They jointly produce food and other goods for farm families and markets, but also contribute to a range of valued public goods, such as clean water, wildlife, carbon sequestration in soils, flood protection, groundwater recharge and landscape amenity value.

As a more sustainable agriculture seeks to make the best use of nature's goods and services, so technologies and practices must be locally adapted and fitted into place. These are most likely to emerge from new configurations of social capital, comprising relations of trust embodied in new social organisations, new horizontal and vertical partnerships between institutions, and human capital comprising leadership, ingenuity, management skills and capacity to innovate. Agricultural systems with high levels of social and human assets are more able to innovate in the face of uncertainty.[12–13]

A common, though erroneous, assumption has been that agricultural sustainability approaches imply a net reduction in input use, and so are essentially extensive (they require more land to produce the same amount of food). All recent empirical evidence shows that successful agricultural sustainability initiatives and projects arise from changes in the factors of agricultural production (*e.g.* from the use of fertilisers to nitrogen-fixing legumes; from the use of pesticides to emphasis on natural enemies). However, these have also required reconfigurations on human capital (knowledge, management skills, labour) and social capital (capacity to work together).[14]

A better concept than extensive, therefore, is to suggest that sustainability implies intensification of resources – making better use of existing resources (*e.g.* land, water, biodiversity) and technologies. For many, the term intensification has come to imply something bad – leading, for example, in industrialised countries, to agricultural systems that impose significant environmental costs.[15–17] The critical question centres on the 'type of intensification'. Intensification using natural, social and human capital assets, combined with the use of best available technologies and inputs (best genotypes and best ecological management) that minimise or eliminate harm to the environment, can be termed 'sustainable intensification'.

3 The Environmental Challenge

Most commentators agree that food production will have to increase in the coming years, and that this will have to come from existing farmland. But solving the persistent hunger problem is not simply a matter of developing new agricultural technologies and practices. Most hungry consumers are poor, and so simply do not have the money to buy the food they need. Equally, poor producers cannot afford expensive technologies. They will have to find new types of solutions based on locally-available and/or cheap technologies combined with making the best of natural, social and human resources.

Increased food supply is a necessary though only partial condition for eliminating hunger and food poverty. What is important is who produces the food, has access to the technology and the knowledge to produce it, and has the purchasing power to acquire it. The conventional wisdom is that, in order to increase food supply, efforts should be redoubled to modernise agriculture. But the success of industrialised agriculture in recent decades has masked significant negative externalities, with environmental and health problems increasingly well-documented and costed, including Ecuador, China, Germany, the Philippines, the UK and the USA.[16–23] These environmental costs change our conclusions about which agricultural systems are the most efficient, and indicate that alternatives that reduce externalities should be sought.

There are surprisingly few data on the environmental and health costs imposed by agriculture on other sectors and interests. Agriculture can negatively affect the environment through overuse of natural resources as inputs or through their use as a sink for pollution. Such effects are called negative externalities because they are usually non-market effects and therefore their costs are not part of market prices. Negative externalities are one of the classic causes of market failure whereby the polluter does not pay the full costs of their actions, and therefore these costs are called external costs.[24]

Externalities in the agricultural sector have at least four features: i) their costs are often neglected; ii) they often occur with a time lag; iii) they often damage groups whose interests are not well represented in political or decision-making processes; and iv) the identity of the source of the externality is not always known. For example, farmers generally have few incentives to prevent pesticides escaping to water bodies, the atmosphere and to nearby nature as they transfer the full cost of cleaning up the environmental consequences to society at large. In the same way, pesticide manufacturers do not pay the full cost of all their products, as they do not suffer from any adverse side effects that may occur.

Partly as a result of lack of information, there is little agreement on the economic costs of externalities in agriculture. Some authors suggest that the current system of economic calculations grossly underestimates the current and future value of natural capital.[25–26] Such valuation of ecosystem services remains controversial because of methodological and measurement problems[22, 27–29] and because of its role in influencing public opinions and policy decisions. The great success of industrialised agriculture in recent decades has masked significant negative externalities, many of which arise from pesticide overuse and misuse.

There are also growing concerns that such systems may not reduce food poverty. Poor farmers, at least whilst they remain poor, need low-cost and readily available technologies and practices to increase local food production. At the same time, land and water degradation is increasingly posing a threat to food security and the livelihoods of rural people who occupy degradation-prone lands. Some of the most significant environmental and health problems centre on the use of pesticides in agricultural systems.[30]

4 How Much Pesticide is Used?

In the past 50 years, the use of pesticides in agriculture has increased dramatically, and now amounts to some 2.56 billion kg per year. The highest growth rates for the world market, some 12% per year, occurred in the 1960s. These later fell back to 2% during the 1980s, and reached only 0.6% per year during the 1990s. In the early 21st century, the annual value of the global market was US $25 billion, down from a high of more than $30 billion in the late 1990s. Some $3 billion of sales are in developing countries.[31] Herbicides account for 49% of sales, insecticides 25%, fungicides 22%, and others about 3% (Table 1).

Table 1 *World and US use of pesticide active ingredients (average for 1998–99)*[48,49]

Pesticide Use	*World pesticide use*		*US pesticide use*	
	(Million kg of active ingredient)	*%*	*(Million kg of active ingredient)*	*%*
Herbicides	948	37	246	44
Insecticides	643	25	52	9
Fungicides	251	10	37	7
Other[a,b]	721	28	219	40
Total	2563	100	554	100

Notes

[a] Other includes nematicides, fumigants, rodenticides, molluscicides, aquatic and fish/bird pesticides, and other chemicals used as pesticides (*e.g.* sulfur, petroleum products)

[b] Other in the US includes 150 million kg of chemicals used as pesticides (sulfur, petroleum products)

A third of the world market by value is in the USA, which represents 22% of active ingredient use. In the US, though, large amounts of pesticide are used in the home/garden (17% by value) and in industrial, commercial and government settings (13% by value). By active ingredient, US agriculture used 324 million kg per year (which is 75% of all reported pesticide use, as this does not include sulfur and petroleum products). Use in agriculture has increased from 166 million kg in the 1960s, peaked at 376 million kg in 1981, and since fallen back. However, expenditure has grown. Farmers spent some $8 billion on pesticides in the USA in 1998–99, about 4% of total farm expenditures.

Industrialised countries accounted for 70% of the total market in the late 1990s, but sales are now growing in developing countries (Figure 1). Japan is the most intensive user per area of cultivated land. The global use of all pesticide products is highly concentrated on a few major crops, with some 85% by sales applied to fruit and vegetables (25%), rice (11%), maize (11%), wheat and barley (11%), cotton (10%), and soybean (8%).[30]

There is also considerable variation from country to country in the kinds of pesticide used. Herbicides dominate the North America and European domestic markets, but insecticides are more commonly used elsewhere in the world. In the USA in the late 1990s, 14 of the top 25 pesticides used were herbicides (by kg active ingredient (a.i.)), with the most commonly used products being atrazine (33–36 million kg), glyphosate (30–33 million kg), metam sodium (a fumigant, 27–29 million kg), acetochlor (14–16 million kg), methyl bromide (13–15 million kg), 2,4-D (13–15 million kg), malathion (13–15 million kg), metolachlor (12–14 million kg), and trifluran (8–10 million kg). Glyphosate and 2,4-D were the most common products used in domestic and industrial settings (EPA, 2001). In Asia, 40% of pesticides are used on rice, and in India and Pakistan some 60% are used on cotton. India and China are the largest pesticide consumers in Asia. Pesticide consumption in Africa is low on a per hectare basis.

5 The Benefits of Integrated Pest Management (IPM)

Recent IPM programmes, particularly in developing countries, are beginning to show how pesticide use can be reduced and pest management practices can be modified