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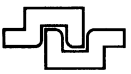

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Climate Change and World Food Security

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Foreword

In the last half decade since sustainable development became a serious objective, what have we achieved? Are livelihoods more secure? Are nations wealthier and more resilient? Is environmental quality being restored or maintained? These are essential questions of development. Their answers are many, varied between communities and regions, even between individuals.

Two years ago, in the aftermath of the Earth Summit and ratification of the Framework Convention on Climate Change, but before the first Conference of Parties, I participated in a panel at the inaugural Oxford Environment Conference on Climate Change and World Food Security. The panel vigorously reviewed issues of resilient development and food security.

This book is a product of the Oxford Environment Conference. It takes the essential questions of sustainability as a starting point to focus on present food security and its future prospects in the face of climate change. Why is this book important? First, I believe our goals to end hunger are under threat. We know what to do in many respects, but fail to generate the finances and political will to change the structures that thrive on poverty. Second, I believe concern about the environment has become dangerously separated from the fundamental issues of human deprivation. Third, I believe climate change is a serious threat and I am dismayed at the way nations dither over how to control greenhouse gas emissions and mechanisms to meet the challenge of adverse climate impacts. By joining the two perspectives – the present crisis of hunger and the future threat of degrading resources – *Climate Change and World Food Security* addresses both the development and environment agendas.

Who should read this book? It will be a valuable resource for professionals working in the fields of development, climate change and food security. It should also be required reading for students of these fields. More importantly, I hope it is used to support local, national and international action to apply its message and to work together in designing and building a sustainable future for our descendants. The vision for a food-secure world is captured in these papers. What must we do to achieve it?

Lord Judd
Marston, Oxfordshire

Preface

This volume of papers addresses the threat of climate change to world food security, by providing an authoritative review of climate change and surprise, contrasting trends in world food security, case studies of food and the environment, and papers on adaptive responses. Most of the papers had their inception at a North Atlantic Treaty Organisation (NATO) Advanced Research Workshop and the Oxford Environment Conference on *Climate Change and World Food Security* at the University of Oxford in July 1993, organised by Robert S. Chen, Thomas E. Downing, Robert W. Kates and Martin L. Parry.

The workshop had three objectives, each with three components. We sought to bring together three communities concerned with hunger and environmental change. *Food policy and hunger* researchers, primarily drawn from the social sciences, focus on a five to ten year time scale of the recent past and the horizon of development planning. They seek to reduce vulnerability, improve monitoring of famine and food security, and provide efficient interventions in times of crisis and as social support systems. *Agricultural system* modellers, from atmospheric, agricultural and economic sciences, seek to understand food production systems, from the plant level to world agricultural potential and trade. They provide models that integrate resources and economies with specific policy objectives. A third group focuses on *climate impact assessment*, from scenarios of future global climate change to estimates of biophysical sensitivity and economic, social and political implications. We sought to enhance our collective understanding between these three communities and to shape a common research agenda that includes food security as an essential focus, in addition to the more customary indicators of agricultural production, commodity prices and world trade.

The group of some forty invited experts from ten countries were asked to deliberate on three themes. We reviewed projections of the *incidence and distribution of hunger* over the next few decades and its dependence on economic growth and its distribution, resource constraints, and concerted action to prevent hunger or mitigate its effects. The workshop then examined the *threat of climate change*, alternative models of world agricultural potential that have simulated the impacts of climate change and the threats to food security from multiple environmental, social, economic and political change. Finally, we sought to identify practicable *adaptive strategies* that would both mitigate the effects of climate change and reduce vulnerability and food insecurity, as a contribution to the protocol on adaptation for the Framework Convention on Climate Change.

For each theme, we sought to identify *what's new*, *what's uncertain*, and *what should we do*? Over the past five years the literature on hunger and food policy and on drought and global environmental change has burgeoned. Yet, few studies integrate the social and economic dimensions of hunger and its roots in environmental change, and even fewer span the past and present to assess potential changes in the future. Given the wealth of studies and results of new research, the second question should be easily answered: how much confidence do we have in projections of future hunger and its sensitivity to climate change? Finally, the workshop sought to identify a research agenda that would support informed policies to reduce hunger, mitigate climate change and adapt to its adverse consequences.

In the intervening months since the workshop, the commissioned background papers were published in 1994 in special issues of *Food Policy* (edited by Thomas E. Downing and Martin L. Parry, Volume 19, Number 2) and *Global Environmental Change* (edited by R.S. Chen and R.W. Kates, Volume 4, Number 1). The two journal issues present papers reviewed and substantially edited in light of the workshop deliberations. This book, *Climate Change and World Food Security*, contains ten new papers and fourteen papers published in the two journals. Almost all of the papers that were previously published have been extensively revised and updated. To our knowledge, this book is the first authoritative collection of research on the prospects for climate change and food security.

The organisers of the workshop are grateful to the growing research communities who work on food security, climate change and environment; those whom we have drawn upon for reviews, advice and collegial support. This volume would not have appeared without funding for the workshop – from NATO, the Consortium for International Earth Science Information Network (CIESIN), UK Overseas Development Administration, U.S. National Oceanic and Atmospheric Administration (NOAA), and U.S. Department of Agriculture (USDA). Preparation of the manuscript was facilitated with additional funding from Nuclear Electric, Plc. Over the past year, the editor is particularly grateful to: Megan Gawith who undertook many of the editorial tasks and layout; Philippa Logan for copy-editing most of the papers; John Orr for cartography; and to Richard Macrory, Director of the Environmental Change Unit. The support of the above groups is gratefully acknowledged, while the findings reported here are those of the authors and may not necessarily reflect the views of the funding agencies.

July 1995 Robert S. Chen, Thomas E. Downing, Robert W. Kates and Martin L. Parry

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Introduction: Climate Change and World Food Security

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1 Introduction

What is the future of hunger? Is climate change an unprecedented threat to world food security? What can be done to reduce vulnerability and promote sustainable, resilient development? The assemblage of papers in *Climate Change and World Food Security* (Downing, 1995) seeks to place the Earth and its vulnerable populations between two worlds. The *present*, in which up to a billion people are threatened by chronic undernutrition, micronutrient deficiencies and disease, is subject to drought and climatic variations. The *future*, subject to multiple environmental threats as the world warms by 1.5°C to 4.5°C by the middle or end of the next century, could see rapid improvement in food security.

The papers are organised into five parts:

2 Trends in agriculture and food security

The goals for a food-secure world encompass: the end of famine; chronic and seasonal undernutrition rates of less than 1 per cent (100 million people); virtually no deficiencies in micronutrients (e.g. iodine and vitamin A); and control of diseases such as malaria, diarrhoea and anaemia that affect nutritional status. These goals, suggested by Chen and Kates (1994, 1995, this volume), are in line with the agenda endorsed by the International Conference on Nutrition and the Bellagio Declaration (FAO and WHO, 1992). This *normative* scenario of a food-secure future is contrasted with trend projections and the 'common wisdom'. Indeed, nutritional status is

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improving in many parts of the world, often quite dramatically (ACC/SCN, 1992, 1993). Yet, in 1990: 15-35 million people were at risk of famine, 786 million were vulnerable to chronic undernutrition; and hundreds of millions suffered from micronutrient deficiencies and diseases. Policies to achieve a food-secure world in the next few decades include the suite of sustainable agricultural development, implementation of a social norm of food as a human right, and effective safety nets for famine prevention, emergency assistance, income support, and groups with special needs.

Crosson and Anderson (1994, 1995, this volume) consider the sustainability of the global agricultural system. Rising demand for food and fibre over the next forty years requires substantial increases in supply. What are the environmental implications in less developed countries? Unacceptable environmental effects are likely, unless knowledge (including technology) can substitute for natural resources. The required new knowledge necessitates investment in its development; past growth in knowledge did not 'just happen'. The key policy issue to achieve sustainability is increasing knowledge on economic terms to farmers. Achieving this level of investment presents political, economic and intellectual challenges as resources are allocated to people, institutions and technology.

3 Risk and global impacts of climate change on agricultural systems

Schneider (1995, this volume) reviews the current estimates of climate change: the canonical range of global temperature increases of 1.5 to 4.5°C with a doubling of greenhouse gas concentrations (measured in carbon-dioxide equivalents). This could occur by the end of the next century, in the absence of any efforts to reduce the emission of greenhouse gases (Houghton *et al.* 1990, 1992, 1995). Regional projections are highly uncertain, but suggest that the largest changes in temperature will be in more poleward latitudes and delayed warming in the Southern Hemisphere due to the thermal capacity of the oceans. Potential changes in precipitation, the key factor affecting agriculture for many vulnerable populations, is more difficult to estimate. The IPCC is now working on the second full assessment, including projections of climate change, potential impacts, and effective response strategies, to be reported in late 1995.

Estimating climate change and its impacts, however, is still an uncertain science. Average changes predicted in most assessments appear to be gradual, leading to global and continental changes that

the world can cope with, albeit at some cost. On the other hand, history is replete with surprise. Schneider provides examples from the past and proposes a surprise-rich assessment paradigm. Interactions and surprises that affect food security encompass changes in demand, natural ecosystems, climate and water, crops, health, diseases and food distribution. At the regional level, each of these components includes potential surprises. Science must anticipate surprise; policy must increase its resilience and adaptability to surprise.

The effects of climate change on world agriculture are charted in two papers, reflecting comparable methodologies of global economic modelling. Fischer, Frohberg, Parry and Rosenzweig (1994, 1995, this volume) present the results of the most ambitious assessment of global climate change and international agriculture to date. Scientists in over twenty countries participated in developing climate scenarios, modelling site effects for major crops, scaling the site simulations to regional productivity changes, and modelling the world food trade system. More than 50 scenarios have now been tested. Clearly, world food production can be maintained against a broad spectrum of changes in productivity (eg. climate change) and demand (eg, population and economic growth). What is less clear, however, is the ultimate effect on regional production and food security. Developing countries appear to be less able to cope with climate change than developed countries. As a result, estimates of the population at-risk of food poverty (an economic indicator in the model) rise by 5 to 50 per cent, depending on the climatic scenario. Yet, key uncertainties dominate the pioneering analysis and span the site to global levels: carbon dioxide fertilisation; regional area suitable for agriculture (including irrigation supplies); economic comparative advantage and trade policies.

Reilly, Hohmann and Kane (1994, 1995, this volume) provide a similar analysis at the global level, using a different world trade model. Impacts differ significantly among scenarios and among countries. The total effects on welfare range from an increase of $7 billion to a decrease of $38 billion for three climate scenarios with CO_2 direct effects and adaptive responses. In contrast, the most pessimistic scenario results in a loss of welfare of $250 billion. The balance of economic winners and losers is determined by the direct impact of climate change on yield, the global effect on commodity prices and national exports vs. imports. Adaptive responses must be fashioned in light of the high degree of uncertainty in national impacts and their propagation through international trade.

The future may well be one of surprise. Our understanding of climate and its interactions with oceans and the biosphere is still elementary; history is replete with lessons of unforeseen ecological change. While trends in food security are promising, the sudden disruption of armed conflict throughout the world is a salutary caution against over-optimism.

3 Vulnerability and multiple threats to sustainable agriculture

Given the (normative) vision of a food-secure world in the middle of the next century, presented by Chen and Kates, how great are the threats of population growth, environmental degradation, and climate change? What are the major impacts on agriculture and food security?

To begin with, what is vulnerability? Downing, Watts and Bohle (1995, this volume; see also Bohle *et al.*, 1994) argue that understanding the characteristics and causal structure of vulnerability to hunger and food insecurity is a precondition for grasping the potential consequences of global climate change. The conjuncture of social vulnerability, derived from human ecology, expanded entitlements and political economy, may be affected in unpredictable, or at least surprising, ways as climate change is refracted through markets, new ecological stresses, and multilateral agreements. Two pathways of resilient development, vulnerability and climate change are charted for Zimbabwe.

Crawshaw and Shaw (1995, this volume) draw upon the extensive experience of the World Food Programme to discuss regional variations and causes of vulnerability, the population at risk, and ability to cope with chronic and transitory food insecurity. Data prepared for the International Conference on Nutrition (ACC/SCN 1992) suggest that chronic undernutrition is declining, albeit slowly and less in Africa than elsewhere. The anti-hunger strategies of the poor include accumulation and diversification strategies. Traditional coping strategies may have become less effective because of social and economic transitions and because many societies have been under pressure for so long that they have exhausted their assets. The international community has not been as adaptable to the changing vulnerability of the poor – new approaches are needed to identify viable options and target assistance.

Multiple threats – environmental degradation, economic change, population growth and climate change – to regional food production are evaluated by Norse (1994, 1995, this

volume). The greatest threats are sub-regional, often linked to poverty. Sub-Saharan Africa is the most threatened, due to a fragile environment, poor economic growth, rapid population growth, and prospects for adverse climate change. The greatest challenges will be in the next two to three decades, when climatic variations (possibly related to climate change) pose significant threats.

For some analysts, the dominant issue in global environmental change is the potential for unprecedented forced migration, or environmental refugees. MacGregor (1994, 1995, this volume) reviews the ongoing debate over 'environmental refugees' and 'forced migrants'. Conceptual insights and empirical studies place migrants' decisions to flee in a complex of systemic failure, of which environment is only one aspect. The economic and ecological transformations in regions that receive forced migrants are diverse, challenging host countries and international responses. Much can be achieved if constraints on the displaced populations own efforts to secure their livelihoods are removed. However, humanitarian assistance for the victims of environmental change is likely to be limited. The human right to food for the most vulnerable must be supported within their communities – legal status as refugees is not likely to be forthcoming and may not be the most suitable intervention.

Rothman and Coppock (1995, this volume) explore the questions: what are the essential components of a sustainable existence? And, how can practical scenarios of the future be developed and used? They contrast forecasting (those who blindly follow current trends) and backcasting (boldly forging new worlds and identifying plausible pathways that connect the present and the new world). A holistic perspective is required, as are regional perspectives. Unfortunately, the 2050 Project, a collaborative programme of the World Resources Institute, Sante Fe Institute and the Brookings Institute which is the basis of this innovative approach, has been scaled down.

In a wealthier, more crowded world, agriculture will have to grow at nearly 2 per cent per year to feed the world's population, allowing for changes in diet with higher incomes, but also with shifts in preferences toward more efficient nutrition. This is clearly possible, as postulated in the scenarios presented by Chen and Kates (1995, this volume), Crosson and Anderson (1995, this volume) and Fischer *et al* (1995, this volume). The environmental and economic costs of the increased agricultural demand are only acceptable if knowledge – human capital, institutional

innovation and technology – keeps pace. Knowledge, rather than population growth or economic change, is seen as the key determinant of the balance between resource needs and sustainable use (Norse, 1995, this volume).

4 Local impacts and responses to global change

Food security is necessarily a local phenomenon: vulnerable individuals and households, communities under pressure, nations with large populations at risk. Regional studies in this section draw upon a wealth of local experience to chart present and future food security.

Wang and Zhao (1995, this volume) outline scenarios of climate change for China. The next 50 years could witness increases in temperature of 1.5 deg C or so and up to 5 per cent increase in precipitation, notwithstanding large regional variations. Against the prospects of climate change, agricultural development for the past 40 years shows low yields and slow development through the 1960s, a decade of medium yields and great fluctuations, and since 1980 rapid increases in yields. Potential impacts of climate change on agriculture include changes in cropping intensity as more intensive agriculture become feasible further north. At least regarding rainfed agriculture, China could benefit from climate change.

Two papers on Bangladesh summarise the depth of information and analysis available for one of the world's most vulnerable places. Karim (1995, this volume) reviews the vulnerability of the poor in Bangladesh, against a background of agroecological resources, food production systems, and drought impacts. Prospects for climate change imply quite significant increases in drought hazard – a doubling or more of land susceptible to very severe drought. With an expanding population and increased incomes, food security will depend on: rapidly revitalising agricultural production; promoting non-conventional food crops; enhancing rural agro-processing activities; and medium-term measures to restructure cropping patterns. These are feasible options, but action needs to undertaken now to cope with present and future environmental vulnerability.

A multi-sectoral vulnerability analysis is reported by Huq, Ahmed and Koudstaal (1995, this volume), drawing upon the databases described above by Karim. Regional vulnerability profiles, based on primary physical effects, impacts on natural ecosystems, socio-economic

stresses and response strategies, were compared for three scenarios of climate change, three development situations, and three conditions of international water resources. Climate change and sea level rise will affect the whole of Bangladesh. The country is highly vulnerable under present conditions, although with some regional variations. The combination of high (less resilient) development and international conflict for water from India and Nepal, could lead to critical climate change and major vulnerabilities in production and food security. The vulnerability assessment methodology enables integration and relative ranking of effects. Further assessments need to focus on social groups and effective adaptive strategies.

In fragile zones, notably mountain/hill regions and dry tropical areas, food security is dynamic, sensitive to population growth and climate change. Jodha (1995, this volume) recommends a dual-purpose approach to enhance present food security and strengthen community capacity to withstand future food shortages. These fragile zones are marked by the conjuncture of environmental, economic and political threats the limit their opportunities: marginal environments sensitive to extreme events, failure of agricultural technology, lower carrying capacities, recurrent food deficits, dependence on aid, and lack of attention by policy makers. Food security in these zones is thus extremely sensitive to perturbations, of which climate change could be significant. Policies must reverse the negative processes, change their focus and context, and recognise the essence of food security.

Four papers provide comparable perspectives on southern Africa. Schulze, Kiker and Kunz (1995, this volume) outline the scientific foundations of food production in South Africa. Crop-model simulations provide 'food for thought', not off-the-shelf answers to climate change impacts and food security in southern Africa. A modest warming, of +2°C would not seriously affect national maize production, if the CO_2 'fertilisation' effect is realised in the humid zones and if prècipitation is not decreased. Both of these are uncertain – solid methodologies for impact assessment are being developed but hindered by the fundamental uncertainties of atmospheric, oceanic and plant sciences.

Recent drought in southern Africa provides an analogue for insight into the effects of climate change (Magadza, 1994, 1995, this volume). The region is particularly sensitive in its water resources, wetland habitats, biodiversity, fisheries, agriculture and hydroelectricity. The

cascade of effects related to climate change (including climatic extremes) could well affect food security, if not the basis of agriculture in much of the region. Long-term strategies for resource development and drought mitigation could alleviate many of the adverse impacts, but require concerted action now.

In Senegal, rice production is sensitive to water resources in the ecological-political economy (Bass *et al.*, 1995, this volume). Irrigated development of the Senegal River Basin exacerbates existing problems of landscape degradation, rural poverty and rural-to-urban migration. Adapting to climate change and alleviating poverty must understand technological or innovation bias in coping with resource fluctuations and development aims.

The effects of climate change on pastoral systems has been less well studied, and is hampered by the lack of regional climate scenarios (particularly for precipitation), models of grassland dynamics, and the complexity of pastoral resource management. Homewood (1995, this volume) sketches some fundamental features of pastoral production systems in sub-Saharan Africa and the special circumstances that make them vulnerable to climate change. Lessons learned from past interventions to raise productivity in Africa should inform future adaptive strategies in response to climate change. Despite contrasting policies and investment, food security among the Maasai of Tanzania and Kenya has not improved much since the 1930s. Adapting to adverse climate change requires buffering the production system by: maintaining access to grazing and water, retaining mobility, ensuring restocking, and fostering markets with realistic terms of trade. Efforts to increase food security, through increased production, secure individual land tenure and economic growth, can have the paradoxical effect of increasing vulnerability, particularly so for marginal pastoralists.

Variations in agricultural policy and climatic conditions have altered maize production and food security in Mexico, as reviewed by Appendini and Liverman (1994, 1995, this volume). The present food system is in transition, from goals of self-sufficiency in production to more open markets in agricultural trade, land and water. At the same time, food production has always been constrained by low rainfall and drought, and climate change may well decrease precipitation and yields. Dramatic events since the paper was written have highlighted Mexico's vulnerability. In the Spring of 1995, reservoir levels were 20 to 30 per cent of average in northern Mexico, thousands of hectares were withdrawn from agriculture. At the

same time, economic policies under the North American Free Trade Agreement increased the cost of inputs, withdrew subsidies on maize and other crops, and reduced credit to peasant and small farmers. The conjuncture of an economic crisis and prolonged drought, could cause dramatic increases in food poverty and deprivation. At least for economies in transition, current adaptive strategies may not be adequate to cope with future risks.

In Asia, Africa and Latin America, national and local economies are sensitive to the present range of climatic fluctuations. Climate change could seriously reduce production of the principal food staples and the availability of water resources for irrigation. However, the real effect of climate change on food security depends on the interaction of macroeconomic policy, demographic trends and social changes. For example, land tenure in Mexico dominates access to land, water and credit, and as a consequence risk of drought and food insecurity. Economic integration in both Mexico and southern Africa provides new opportunities, but uncertain prospects for vulnerable populations.

5 Strategies to limit climate change and improve food security

The dominant argument of the papers in this part centres on lessons learned in coping with present environmental changes. However, the first paper looks at the reverse question: how much would efforts to reduce greenhouse gases affect food production and food security? Rosenberg and Scott (1994, 1995, this volume). Mitigation efforts could compete with efforts to promote food security through: higher energy costs; displacement of irrigation by hydropower; direct controls on farm emissions of methane and nitrous oxide; and competition for land for afforestation and biomass sequestration. The effects of geoengineering are less clear. Perhaps the greatest trade-off is with CO_2 – the direct fertilisation effect would be lost. The authors propose that GHG controls can be designed to minimise effects on agriculture, or in fact to increase efficiency They argue that the total costs of climate change are likely to outweigh the adverse effects of mitigation on food security.

Whereas most studies of food availability focus on food production, Bender (1994, 1995, this volume) presents an end-use analysis. Four sources of potential change in global food requirements are: changes in calorie requirements resulting from improved nutritional status and change in physical activity; efficiency changes in storage, handling, transport and

consumption of food; changes in consumption of animal products; and changes in dietary structures due to increased concerns about health impacts. In the long run, there is significant scope for altering the relationship between income and demand, a critical equation in most projections of supply, demand and trade. Investment in increasing agricultural supply must be compared against other interventions in the food system that alter demand. Dietary quality need not be lost while environmental sustainability and food security can be enhanced.

Rural communities face uncertain futures, stemming from economic change, policy instability, climatic shocks, and health risks, among others. Eele (1995, this volume) reviews community vulnerability and adaptability, drawing upon African case studies. In order to survive, rural communities seek to maintain both consumption and their livelihood. *A priori*, adaptation to climate change must build upon and support existing coping strategies.

The interactions of agriculture, health and environment in food security need to be matched by a vision of research that generates new knowledge and technology to meet the challenge for sustainable, resilient, food-secure worlds. This is the challenge posed by Ruttan, Bell and Clark (1995, this volume). The 18 centres (as of 1992) in the Consultative Group on International Agricultural Research (CGIAR) have suffered from budget constraints and the difficulties of organisational maturity. The prospects for meeting future food demand are further hampered by a lack of a farm-oriented approach, weakness of the private sector in many countries, and poor performance in national research centres. Health research could learn from the experience of international agriculture: a solid national foundation and an international focus on knowledge and technology aimed at the most prevalent and debilitating diseases. Much can be done in developing countries, and even poor countries can make significant advances. Global environmental research still requires pre-natal care, in contrast to the adolescence of health systems and the challenges of maturity in international agriculture. The START initiative–a System for Analysis, Research and Training–seeks to implement a cohesive research focus at the regional level, amongst the many layers of international oversight. Ultimately, the research challenge is to 'bridge the island empires' of each discipline and sectoral focus to address global change and vulnerable regions and populations.