

- *Global environmental change – Food provision – Food systems – Interdisciplinary research*

John Ingram (Wallingford) and **Mike Brklacich** (Ottawa)

Global Environmental Change and Food Systems – GECAFS: A New Interdisciplinary Research Project

*Globaler ökologischer Wandel und Nahrungssysteme –
GECAFS: ein neues interdisziplinäres Forschungsprojekt*

GECAFS (Global Environmental Change and Food Systems – www.gecafs.org) is a Joint Project of the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP) and the World Climate Research Programme (WCRP). It is a new, international research programme involving a wide range of social, physical and biological scientists, investigating the vulnerability of human food systems to, and interactions with, global environmental change. The project has been developed to address the growing need for integrated analyses of (i) vulnerability and impacts of GEC on food systems; (ii) adaptation options; and (iii) consequences of possible adaptation strategies on both socioeconomic and environmental conditions. The paper considers some of the background issues and describes the three GECAFS Science Themes. An example of GECAFS research in the Indo-Gangetic Plain is described.

1. Introduction: Food Provision and the Environment

Food is fundamental to human well-being. Improved methods are needed to grow, harvest, store, process and distribute food as societal demand for agricultural and fisheries products increases; in many parts of the world economic and social development is often mediated by food constraints at local and regional levels.

Links between food systems and the environment are well-documented. Environmental factors such as climate, soils and water availability have long been recognised as major determinants of the ability to produce food in a given location, and a wide range of farming and fishing strategies have

been developed in response to the differing environmental conditions around the world. The production, processing and distribution of food, however, have considerable impacts on the environment by, for instance, altering biodiversity, emitting greenhouse gases and degrading soils and other natural resources by over-exploitation and pollution. This close two-way relationship with the environment exerts considerable influence on production and – ultimately – on the availability of, and accessibility to, food.

Until recently, the effects that food systems have on environment were perceived at relatively local spatial scales. For example, soil erosion caused by intensive crop production resulted in the siltation of nearby water courses, and contamination of

ground and surface water supplies by agricultural chemicals did not reach beyond local water sources. However, human activities – in considerable part due to satisfying the need for food – are now recognised to be changing the environment over large regions, and even at global level. Overall these macro-scale changes can be divided into two broad categories: One involves fundamental changes to major earth systems and functions which operate at the global level, such as climate and the cycling of nitrogen. The other involves incidences of environmental change at the local level which are so widespread as to be considered global phenomena; degradation of fresh water resources and soil erosion have, through their collective extent, transformed from local concerns and are now issues that must be considered and addressed over large regions. Collectively these changes are termed ‘Global Environmental Change’ (GEC). GEC will bring additional complications to the already difficult task of providing sufficient food of the right quantity and quality to many sections of the society. Improving food provision in the face of GEC, while at the same time minimising further environmental change, is a crucial issue for both development and society at large.

2. Food Provision and Food Systems

Recent years have seen a greatly increased understanding of how GEC will affect food productivity at field level, and research results pave the way for broader analyses of GEC impacts on food production on a regional basis. However, there is a need to think beyond productivity and production – of ultimate interest is food provision, a concept of greater relevance to society well-being and hence policy-making.

A wide range of sciences are needed to address the components of the ‘Food Provision Equation’ (Fig. 1): Estimates of food production are founded in agroecology, agriculture and fisheries sciences, while issues related to distribution are largely researched by social and policy-related sciences. The broader notion of access requires consideration of a further set of disciplines including economics, sociology and nutritional sciences.

Akin to the need for adopting the broader concept of food provision (rather than just food production), research planning and policy formulation needs to be set within the context of

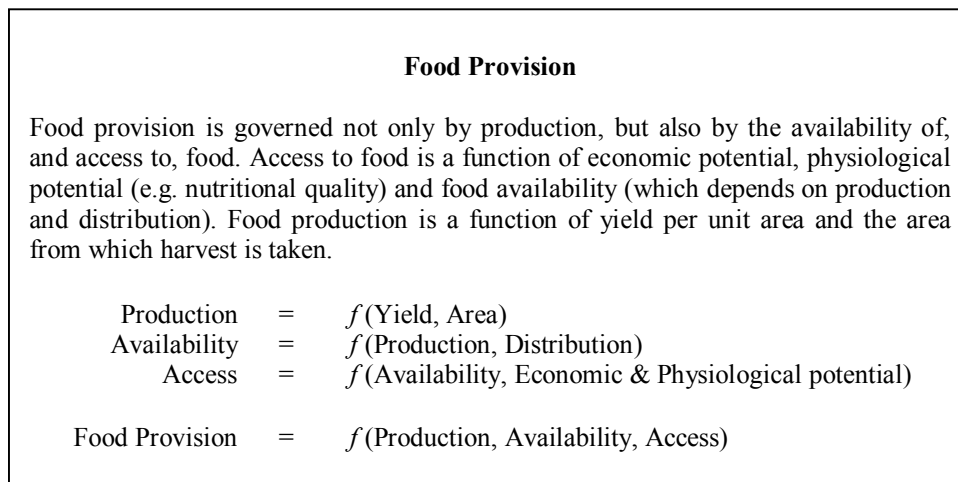


Fig. 1 Food Provision and its determining factors / Nahrungsvorsorgung und ihre Bestimmungsfaktoren

food systems, rather than just food supply. Developing research in the context of food systems helps to identify and integrate the links between a number of factors ‘from plough to plate’ (Atkins and Bowler 2001), including consideration of production, harvesting, storage, processing, distribution and consumption. The approach thereby allows a more thorough understanding to be developed of the ‘impacts’ and ‘feedbacks’ links between food provision and environment. It will also help to identify where technical and policy interventions might be most effective to (i) cope with short-term impacts of GEC; and (ii) help adapt for environmental conditions in the longer term. Coping and adaptation strategies for food provision will however need to differ depending on the degree to which people and communities are vulnerable to the impacts of GEC. Not all individuals and sections of society are equally vulnerable to GEC; their capacity to cope with existing variability in biophysical and socioeconomic systems, and their ability to perceive GEC and adapt food systems accordingly vary considerably. This is because these factors are controlled by the flexibility with which the supply, availability and access to food (and related, essential resources) is mediated by socioeconomic institutions such as land tenure, access to credit, exploitation rights of renewable resources, etc.

Adaptation strategies will need to encompass both biophysical and policy options. Management decisions must however be underpinned by a sound understanding of both the socioeconomic and environmental consequences that different possible strategies will bring.

3. GECAFS: A New Research Approach

The interactions between global environmental change and food provision involve many complex issues spanning natural, social and climate sciences. The International Geosphere-Bio-

sphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP) and the World Climate Research Programme (WCRP) already encompass broad research agendas in these three major areas. However, in order to advance our understanding of the links between GEC and food provision (and thereby help to develop and promote effective interventions) IGBP, IHDP and WCRP have launched the Global Environmental Change and Food Systems (GECAFS) Joint Project as a new, interdisciplinary approach. Furthermore, the research agenda is broader than impact studies alone (important though these continue to be) as it explicitly includes research on how food provision systems could be adapted to the additional impacts of GEC, and the consequences of different adaptation strategies for socioeconomic conditions and the environment. By including both ‘impacts’ and ‘feedbacks’ in the context of food provision a niche for new research is clearly defined.

GECAFS has been conceived to address issues of interest to development, and to society at large, as well as to science. An innovative three-way dialogue between policy-makers, donors and scientists is being established to develop specific research agendas which are useful to aid policy formulation, scientifically exciting and fundable. Many research groups are active in the general area of food ‘security’ but their activities generally focus on *current* impediments to food production. Building on ongoing studies but emphasising GEC issues, and linking closely to the needs of policy formulation, the structured approach will deliver an efficient research mechanism to address the rapidly emerging ‘GEC-Food’ agenda. Of ultimate interest is the link between GEC and societal well-being (rather than with food systems *per se*). This however has to be addressed through the researchable issues needed to understand the relationships between GEC and food systems and it is this that requires the innovative, interdisciplinary approach.

4. GECAFS Goal and Science Agenda

The GECAFS goal is to determine strategies to cope with the impacts of Global Environmental Change on food provision systems and to analyse the environmental and socioeconomic consequences of adaptation.

Research is being developed as three inter-related Science Themes (see *Fig. 2*):

Theme 1: Vulnerability and Impacts: Effects of GEC on Food Provision

Theme 2: Adaptations: GEC and Options for Enhancing Food Provision

Theme 3: Feedbacks: Environmental and Socioeconomic Consequences of Adapting Food Systems to GEC

4.1 Theme 1: 'Vulnerability and Impacts'

Theme 1 research is set within the context of the question 'Given changing demands for food, how will GEC additionally affect food provision and vulnerability in different regions and among different social groups?' This question recognises that many factors already affect food provision and vulnerability, and that these are posing different stresses. It however raises the issue that GEC may well bring further complications – hence the word 'additionally' – and further recognises that vulnerability to GEC varies for different food provision systems, and hence will have differing impacts among different social groups.

Food provision is controlled by a range of biophysical and socioeconomic factors working interactively at a range of temporal and spatial levels. These factors ultimately determine the vulner-

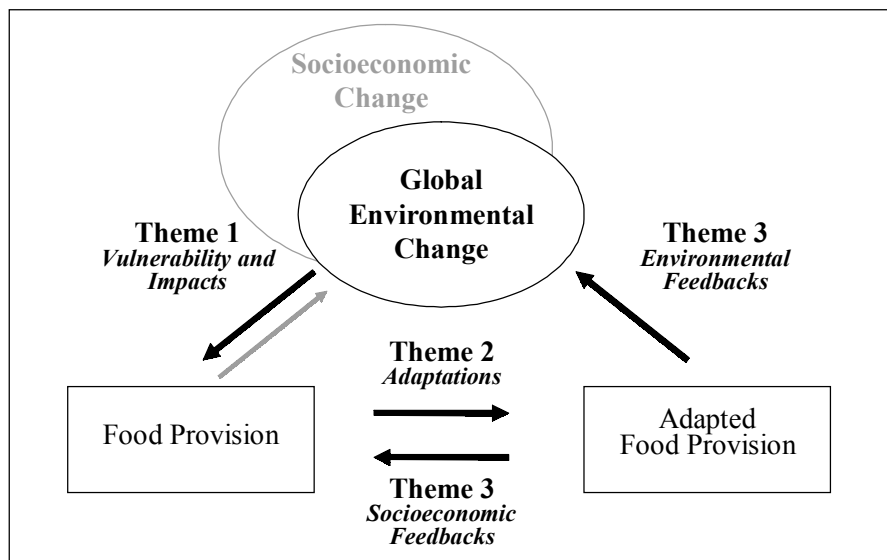


Fig. 2 A diagrammatic representation of the three GECAFS Science Themes with respect to GEC and food provision systems. The contextual issues of changing socioeconomic conditions and the consequences of current food provision systems on GEC are depicted in grey, while the main features of GECAFS are shown in black. / *Graphische Darstellung der drei GECAFS Forschungsthemen mit Bezug zu globalem ökologischem Wandel und Nahrungsvorsorgungssystemen. Die Aspekte des sozioökonomischen Wandels und die Folgen der gegenwärtigen Nahrungsvorsorgungssysteme für den GEC sind in grau abgebildet, während die wesentlichen Themenfelder von GECAFS schwarz dargestellt sind.*

ability of food systems to both biophysical and socioeconomic change (see *Fig. 3*). Biophysical factors include climate, weather and site-related natural resources (e.g. soils, topography, water availability, previous vegetation and site management, distribution of exploited fish populations, coral reefs); socioeconomic factors include current agricultural, aquaculture and fisheries management (e.g. germplasm selection, timing of operations, nutrient and pest management), population density and demand for food products (for local consumption and trade), availability (markets, distribution, storage) and access (e.g. socio-political controls, exploitation rights, equity, wealth). Research will therefore address constraints and opportunities for meeting future demands for food from several perspectives including aggregate regional supply and demand, and broad-scale socioeconomic conditions which either threaten or promote food accessibility. Theme 1 will identify where GEC will be particularly important and why, and also examine the crucial is-

sue of vulnerabilities and impacts of GEC on regional food production potential.

4.2 Theme 2: 'Adaptations'

Theme 2 deals with the basic question 'How might different societies and different categories of producers adapt their food systems to cope with GEC against the background of changing demand?' This question recognises that within given societies not all people and groups will be equally able to adapt to changing demands for food, and that adaptation strategies to cope with the additional complication of GEC will vary; different groups will have different limitations to adaptation.

Theme 2 aims to understand how communities and institutions might anticipate, resist or adapt to, and recover from the impacts of GEC. GEC may cause food provision problems in the short term, when adaptations mechanisms are too slow, and

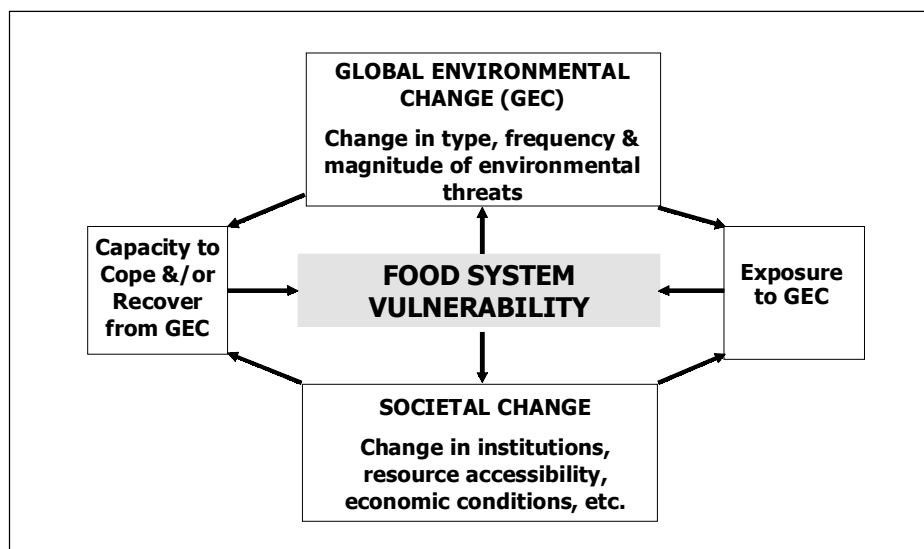


Fig. 3 Human vulnerability vis à vis global environmental and societal changes (derived from *Bohle 2001* and *McMichael and Githeko 2001*) / *Verwundbarkeit menschlicher Gesellschaften im Kontext globalen ökologischen Wandels und gesellschaftlicher Veränderungen* (nach *Bohle 2001* und *McMichael und Githeko 2001*)

in the long term, where adaptation mechanisms are simply not effective. Research needs to concentrate on how environmental and socio-economic forces combine at local to regional levels either to enhance or reduce vulnerability; on existing strategies for coping with food shortages; and on the extent to which global environmental and socio-economic forces might alter human vulnerability within selected regions. To make these assessments will require the identification of the most vulnerable groups, the key institutions in society that make or break coping and adaptation efforts, and management efforts which will be needed to counteract the negative aspects of GEC. The nature of critical thresholds for adaptation, and when and where these will be exceeded will be a critical part of the research agenda. In addition, it will determine the speed of coping and adaptation that different groups in society possess, and how this relates to GEC.

4.3 Theme 3: 'Feedbacks'

The third theme considers 'What would be the environmental and socioeconomic consequences of alternative adaptation strategies?' The question recognises that different adaptation strategies will have different consequences for both socioeconomic systems and environment, and that both types of consequence are equally important and need to be considered simultaneously. Theme 3 will allow regional-level analyses of 'tradeoffs' between socioeconomic and environmental issues for a range of management and policy options. These analyses will be conducted within the scenarios agreed upon in the project planning phase.

Research will need to develop tools to identify, and quantify as far as possible, the feedbacks to environmental issues such as atmospheric composition and other climate change drivers, consequences for biodiversity and land and aquatic degradation, and also to socioeconomic issues such as livelihoods, institutional flexibility and

policy reform. The rapidly growing concern for potential environmental degradation due to changes in genetic variability and biotechnology will be included.

By complementing work in Themes 1 and 2, this 'feedbacks' component will identify GECAFS as a comprehensive GEC research programme.

The GECAFS Science Themes provide an innovative framework within which new areas of science can be developed and harnessed to address societal concerns. Examples include:

- methods for the analysis of environmental and socioeconomic tradeoffs in food systems;
- analyses of changing human wealth and food preferences and interactions with biophysical models of GEC to produce new insights of regions where food provision may be sensitive to GEC;
- methods to allow the appropriate level of aggregation of small-scale food production systems and disaggregation of global-scale scenarios and datasets to address regional and sub-regional issues;
- new analyses and insights into the institutional factors which can reduce societal vulnerability to GEC;
- developing combined socioeconomic-biophysical indices of vulnerability.

GECAFS studies will need to be set within clearly defined sets – or 'scenarios' – of future biophysical and socioeconomic conditions. These will be specifically designed to assist analysis of possible policy and biophysical interventions using the interdisciplinary science at the Project's core and will set the context for the individual research projects. They will help to 'tease out' the meaning of 'socioeconomic change' in the context of

GEC. The development of these comprehensive scenarios is in itself a major research exercise. This has been initiated by defining three broad categories of attributes as a minimum set of required contributing data: the food system; socioeconomic and demographic factors; and environmental and ecological data. The further development of 'aggregated indicators' to assess vulnerability will be a significant new science output.

5. Research Design and Implementation

GECAFS aims to help strengthen policy formulation for reducing vulnerability to global change at national to sub-continental scales; and to provide tools and analyses to undertake assessments of trade-offs between food provision and environment in the context of global change. To be effective research will be developed that meets the needs of national and regional policy-makers, the principal 'clients' for GECAFS research. GECAFS will therefore engage with policy makers early in the research planning process to develop research that directly addresses their needs and maintain close links throughout the implementation and reporting phases. In collaboration with research partners and collaborators, donors and end-users, GECAFS will (i) identify interdisciplinary research topics of mutual interest to science, development and policy formulation; (ii) help in developing databases and future scenarios to explore tradeoffs; (iii) help in the dissemination of results and obtaining feedback from end-users; and (iv) assist in capacity building as part of its research approach.

GECAFS research will thus be implemented in two major ways: (i) *Individual GECAFS projects* at sub-continental-level, 'tailor-made' to address particular interests of policy makers, donors and science community; and (ii) *Integrative GECAFS studies* at multi-region to global level, which integrate individual studies. Individual studies will undertake research addressing all three science themes.

6. GEC and the Food System of the Indo-Gangetic Plain: An Example GECAFS Research Project

One of the initial regional GECAFS research projects concerns the food system of the Indo-Gangetic Plain (IGP). This is largely dependent on rice and wheat grown in rotation and there is growing concern that the productivity of the system is declining, especially the rice component: An assessment of 11 long-term rice-wheat experiments (ranging from 7 to 25 years in duration) from the region indicates a marked yield decline of up to 500 kg/ha/yr in rice in nine of the experiments (Duxbury et al. 2000). Continuation of these trends will have serious implications for food provision, local livelihoods and the regional economy. As a given season's weather is a major determinant of yield (due to both the direct effects on crop growth and indirect effects related to management), there is concern that changes in climate, especially related to changes in climate variability, will exacerbate the observed trend. Moreover, other analyses (e.g. Grace et al. 2001) show that the highly-intensive production approach currently practiced in large parts of the region is a major source of greenhouse gases, while the current irrigation practice is having serious negative effects on local water tables and water quality.

As the IGP food system is both threatened by global change and contributes to further global change 'forcing', research is needed to help develop policy and agronomic strategies to (i) sustain production, especially in the face of potential increased climate variability and degradation of land and water resources; and (ii) promote production systems which enhance environmental and socioeconomic conditions. Due however to the marked socioeconomic and biophysical differences across the region, a single approach is not appropriate. A consultation process with local and regional policy-makers has determined information needs in relation to GEC for regional policy formulation and given rise to a number of possible research issues.

The eastern region of the IGP is a food deficit region characterised by low productivity, low inputs of fertiliser and water, risk of flooding, poor infrastructure and an out-migration of labour. Interdisciplinary research will be developed to address questions such as:

Theme 1: How will climate variability affect vulnerability to flooding within the region?

Theme 2: What are the market opportunities and management options for diversifying crops (e.g. aquaculture) to make more effective use of flood and groundwater?

Theme 3: How will these strategies effect labour migration, the interregional movement of food grains and water quality and river flow?

In contrast, the western region is a food surplus region characterised by higher investment, high productivity, major use of fertilisers and groundwater for irrigation, and an in-migration of labour. Interdisciplinary research will be developed to address questions such as:

Theme 1: How will climate variability affect change in water demand in high production regions of the IGP?

Theme 2: How can changes in water management (e.g. through policy instruments such as water pricing, and/or agronomic aspects such as alternative cropping, soil levelling) reduce vulnerability to climate variability?

Theme 3: What will be the consequences of changed water management on the local and regional socio-economic situation; and on greenhouse gas emissions, water tables and land degradation?

A more detailed research planning exercise for the IGP is now being initiated with national policy-makers and research groups; with international collaborators including the CGIAR, FAO and WMO; and with IGBP, IHDP and WCRP scientists. GECAFS will

add value to the individual efforts of all its research partners by building on their complementary skills and contributions; it will not 'replace' their existing efforts, but draw upon them, and set them in a broader canvas of societal concern.

7. References

Atkins, P.J. and I.R. Bowler 2001: Food in society. – London
Bohle, H.-G. 2001b: Vulnerability and criticality: Perspectives from social geography. – IHDP – Update 2: 1-5

Duxbury, J.M., I.P. Abrol, R.K. Gupta and K.F. Bronson 2000: Analysis of long-term soil fertility experiments with rice-wheat rotations in South Asia. – In: *Abrol, I.P., K.F. Bronson, J.M. Duxbury and R.K. Gupta* (eds.): Long-term soil fertility experiments in rice-wheat cropping systems. Rice-Wheat Consortium for the Indo-Gangetic Plains. – New Delhi: vii-xxii

Grace, P.R., M.C. Jain and L.W. Harrington 2001: Global environmental impacts from conservation agriculture. – In: Proceedings of the International Workshop on 'Conservation Agriculture for Food Security and Environment Protection in Rice-Wheat Cropping Systems', Lahore, Pakistan, 6-9 February 2001

McMichael, A. and A. Githeko 2001: Human health. – In: *McCarthy, J., O. Canziani, N. Leary, D. Dokken and K. White* (eds.): 2001 Climate change: Impacts, adaptation and vulnerability: Third assessment report. – Cambridge: 451-485

Summary: Global Environmental Change and Food Systems – GECAFS: A New, Interdisciplinary Research Project

Global environmental change is happening. Human activities, including those related to food, are now recognised to be partly responsible for changing the world's climate and giving rise to other, globally- and locally-important environmental changes. These include alterations in supplies of freshwater, in the cycling of nitrogen, in biodiversity and in soils. There is growing concern that the ability to provide food – particularly to more vulnerable sections of society – will be further complicated by global environmental

change (GEC). There is also concern that meeting the rising societal demand for food will lead to further environmental degradation, which, in many cases, will result in further uncertainties for food provision systems. Policies need to be formulated that enable societies to adapt to the added complication GEC will bring to food provision, while promoting socio-economic development and limiting further environmental degradation. Such policy formulation needs to be built upon an improved understanding of the links between GEC and food provision. The interdisciplinary project 'Global Environmental Change and Food Systems' (GECAFS) is designed to meet this need.

Zusammenfassung: Globaler ökologischer Wandel und Nahrungssysteme – GECAFS: ein neues interdisziplinäres Forschungsprojekt

Der globale ökologische Wandel ist nicht aufzuhalten, und mittlerweile ist allgemein anerkannt, dass Aktivitäten der Menschen – darunter auch jene, die sich auf die Nahrungsversorgung beziehen – zum Teil für den globalen Klimawandel verantwortlich sind und zudem andere Umweltveränderungen von globaler oder lokaler Bedeutung hervorrufen. Zu diesen gehören Veränderungen der Süßwasserressourcen, des Stickstoffkreislaufes, der Biodiversität und der Böden. Daraus erwächst die zunehmende Besorgnis, dass der globale ökologische Wandel (GEC) die Nahrungsversorgung weiter erschwert – insbesondere die der verwundbareren Gruppen der Gesellschaft. Außerdem besteht die Sorge, dass der zunehmende Bedarf an Nahrungsmitteln zu weiterer Umweltschädigung führt, die sich dann ihrerseits in vielen Fällen in verstärkter Unsicherheit bei der Versorgung mit Nahrungsmitteln auswirkt. Strategien und Maßnahmen sind erforderlich, die Gesellschaften ermöglichen, auf diese Situation der durch den globalen ökologischen Wandel erschwerten Nahrungsversorgung zu reagieren und dabei sowohl die sozioökonomische Entwicklung zu fördern als auch die zunehmende Umweltschädigung zu begrenzen. Die Formulierung derartiger Ansätze muss sich auf ein verbessertes Verständnis des Zusammenhangs zwischen globalem ökologischem Wandel (GEC) und der Nahrungsmittelversorgung stützen. Das interdisziplinäre Projekt 'Global Environmental Change and Food Systems' (GECAFS) ist so angelegt, dass diese Erfordernis erfüllt wird.

Résumé: Changement environnemental global et systèmes alimentaires – GECAFS: un nouveau projet de recherche interdisciplinaire

Le changement global environnemental est en cours. Les activités humaines, y compris celles relatives à l'alimentaire, sont maintenant reconnues comme en partie responsables du changement climatique mondial, ainsi que d'autres changements environnementaux, tant locaux que globaux. Ceux-ci comprennent les modifications subies par les systèmes d'approvisionnements en eau douce, le cycle de l'azote, la biodiversité et les sols. Le changement environnemental global (CEG) va accroître les difficultés à fournir l'approvisionnement alimentaire – et ce en particulier pour les secteurs les plus vulnérables de la société – ceci est une source d'inquiétude grandissante. Un autre sujet de préoccupation est le fait que des effets environnementaux négatifs sont créés pour répondre à la demande croissante de la société en produits alimentaires. Un cadre législatif est nécessaire et doit être créé pour permettre aux sociétés de s'adapter à la complexité croissante qu'engendrera le CEG pour l'agriculture; et ceci tout en favorisant le développement socio-économique et en limitant de nouvelles détériorations environnementales. La formulation de ce cadre législatif doit être établie sur une meilleure compréhension des liens qui existent entre le CEG et la production alimentaire. Le projet interdisciplinaire « Global Environmental Change and Food Systems » (GECAFS) est conçu pour satisfaire ce besoin.

John Ingram, GECAFS International Project Office, NERC Centre for Ecology and Hydrology, Wallingford OX10 8BB, England, jsii@ceh.ac.uk

Dr. Mike Brklacich, GECHS (Global Environmental Change and Human Security Project) International Project Office, Department of Geography and Environmental Studies, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario K1S 5B6, Canada, michael_brklacich@carleton.ca

Manuskripteingang: 21.8.2002

Annahme zum Druck: 21.11.2002