

**Societal Adaptation to Abrupt Climate
Change and Monsoon Variability:
Implications for Sustainable Livelihoods of
Rural Communities**

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SUMMARY

Throughout the known human history during the Holocene monsoon rains had experienced abrupt change and randomly recurring droughts and floods during the past 11,000 years. Abrupt climate and monsoon oscillations, compared to gradual changes, had come as surprises that are likely to become more frequent because of the anthropogenic forcing. Although some human societies have adapted to rapid climate changes in the past, but there are also examples of civilization-collapse under the persistent influence of climate change. Whereas historical adaptations to climate change are widely recognized, adaptations by the contemporary society living in regions with fluctuating climate are not. For example, over thousands of years, local people evolved a diversity of vegetation management regimes combined with traditional water management systems as an adaptation to monsoon variability that continue to support livelihoods globally, particularly in tropical Asia, South America and Africa. This is an exploration of literature on monsoon climate variability and consequent adaptations as well as implications of such adaptive systems for sustainable livelihoods. Learning from the adaptive strategies employed by contemporary rural societies in regions that experience rapid climate oscillations might be helpful in designing the appropriate policies and programmes for adaptation to climate change, conservation of biodiversity in agroecosystems, as well as reduction of vulnerability and poverty and enhancement of sustainable livelihoods.

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Section A

Societal Adaptation to Abrupt Climate Change and Monsoon Variability: Implications for Sustainable Livelihoods of Rural Communities

Review of Literature

1. INTRODUCTION

Scientific evidence on climate variability, such as droughts and floods, suggests that such oscillations have occurred in the past and may occur in future, potentially with large impacts on society, economy and ecosystems. There is evidence to show that gradual and smooth climate changes in the Earth's history were interspersed with abrupt climate changes such as rapid cooling, warming, wetting and drying¹⁻³, due to the forcing of Earth system across thresholds⁴. Thus, even though future man-made global warming may come gradually, it may be interspersed with large droughts and floods⁵.

These societally disruptive climate oscillations have impacted the human society in many ways, including possibly the rise and fall of great human civilizations during the last 11,700 years (the time-span known as the Holocene epoch). For example, in the past sudden global cooling has resulted in severe failure of agriculture and it may again bring down global food production in future⁶. Further, livelihoods may diminish due to reduced productivity of green revolution in developing countries under the influence of recurring droughts and floods⁷.

Societal vulnerability to the risks associated with climate change may exacerbate ongoing social and economic challenges, particularly for poor rural people and societies dependent on natural resources that are sensitive to climate change. Risks of global warming and environmental changes are already clearly visible in agriculture⁸⁻¹⁰, forestry¹¹, fisheries^{12,13,14}, water resources^{15,16} tropical soils¹⁷, a variety of plants and animals¹⁸⁻²⁰ and other components that constitute the livelihood of rural people in developing countries. Adaptation to climate change is thus inevitable^{21,22}. Indeed, there is a small but certain probability that climate change will impose catastrophic impacts on future society unless adequate steps are taken to reduce greenhouse gas emissions²³. Adaptation strategies are inevitable as climate extremes are expected to be more profound in the future.

The basic premise of any action on climate change, therefore, should now be to promote adaptive capacity in the context of concurrent provisioning for sustainable livelihoods and sustainable development.

Even the gradual climate change will significantly affect the economic, social, and environmental dimensions of sustainable development, as well as key issues like poverty and equity²⁴. There is a felt need for combining disaster reduction, natural resource management and climate change adaptation in a new approach to the reduction of vulnerability and poverty and enhancement of resilience²⁵.

Therefore, learning the societal adaptation to climate change may provide strategies to maintain resilience of the social and economic systems needed for sustainable development. In this article we review the literature to provide a fundamental scientific understanding of abrupt climate oscillations and their impact on society. We also explore how human society affects environmental change and how in turn becomes vulnerable to these changes. In particular, we explore the knowledge gap on how likely ecosystem goods and services are to abrupt climatic oscillations (*environmental sensitivity*) and the ability of rural communities to adapt (*social resilience*) to those changes. We, thus, identify the priority research areas on contemporary societal adaptations to climate change.

2. EXISTING KNOWLEDGE ON ABRUPT CLIMATE CHANGE

Earth climate has experienced large-scale oscillations between glacial and interglacial conditions over the past million years. The last glacial period was punctuated by a series of large and abrupt climate changes. The last glacial period was punctuated by a series of large and abrupt climate changes. These palaeoclimate proxy records suggest frequent episodes of abrupt climate change believed to be the result of nonlinear response of the climate system to internal or

external forcing. At the orbital (10^4 – 10^5 years) and millennial time scales, abrupt climate change appears as sudden, rapid warming events, each followed by periods of slow cooling. The sequence often forms a distinctive saw-tooth shaped time series, epitomized by the deep-sea records of the last million years and the Dansgaard–Oeschger (D/O) oscillations of the last glacial²⁶. Two lines of hypotheses exist to explain the large and abrupt climate changes that punctuated glacial time. Climate may have changed abruptly either due to reorganizations of the ocean's thermohaline circulation or due to changes in tropical atmosphere-ocean dynamics²⁷. Precise cause of abrupt climate changes in the past is yet to be known. However, there remains no doubt that Earth's climate system has changed abruptly several times in the past.

While the causes of abrupt climate changes in the past were natural, it is plausible that anthropogenic forcing of climate system—which, contrary to popular perception, actually began during the early Holocene starting with the human settlement, domestication and early agriculture²⁸—may increase the likelihood of large, abrupt changes (such as drought due to oceanic influence²⁹) and connected impacts^{30, 31}. Although climate models can predict gradual climate change, some uncertainty will always be associated with projections of the abrupt climate events. Because of these uncertainties, it would be wise for policy-makers to learn from research on societal adaptations to abrupt climate change for designing actions and strategies to enhance the adaptability and resilience of social, economic and ecological systems.

Abrupt climate change had influenced the human evolution and advancement³², as is evident in the links between climate and society throughout the documented human history. Agrarian society and the landscape have developed as a result of the interactions between the social efforts and the ecological capacity of a region, which in turn was influenced by climate³³. Although, our understanding on the

science of past climate variability and the projected behaviour in future has progressed (see, for example, refs. 1-6, 36-39) and we also have studies on historical cultural responses to climate oscillations (see refs. 19-27), we do not have robust studies that throw light on the societal adaptations to abrupt climate change by contemporary human society living in marginal environments. Geographically speaking, such studies are particularly lacking in India.

3. KNOWLEDGE GAPS IN SOCIETAL ADAPTATION RESEARCH

Abrupt climate change impacts the natural and social systems abruptly. It is comparatively easy for the society, economy and ecosystems to adapt to gradual and anticipated changes, but adaptation to abrupt climate oscillations remains the most challenging. Above all, rapidity and surprises of the abrupt climate change makes human society more vulnerable. And, poorer the economy, more vulnerable it is to abrupt climate change for obvious reasons.

While ecological adaptations to harsh climate (thermal extremes, scarcity of water and food, and scanty shelter) have been studied³⁴ there are no studies in India on societal adaptation to abrupt climate change. Because of the coupling of climate and society it is expected that human society will have to adapt to climate oscillations^{35, 36}. These adaptations can often be seen in migration to localities where climate is suitable and more productive to support human occupation^{37, 38}. A recent study by Bowler *et al.*³⁹ in Australia, the world's driest inhabited continent, is a case in point. It demonstrates that a most striking climatic change of the last 60 kyr in Australia occurred near 40 kyr ago, that forced early lake-shore *Homo sapiens* to adapt to increasing aridity and deteriorating climate. Other responses to societally disruptive climate change (such as prolonged drought and floods) have been suggested to be the population dislocations, abandonment of villages and urban centres, and even state collapse⁴⁰⁻⁴³.

However, societies may not necessarily collapse. Rajasthan is an example where people have been living under the harsh arid climatic conditions. Another example is the adjustment of planting and sowing time based on the knowledge of climate fluctuations. For instance, Aymara- and Quechua-speaking farmers of the Peruvian and Bolivian Andes in drought-prone regions of Andean South America have traditionally made observations of changes in the brightness of stars in the Pleiades around the time of the southern winter solstice (i.e. December 22) in order to forecast interannual variations in summer rainfall and in autumn harvests. As an adaptation response they moderate the effect of forecasted reduced rainfall by adjusting the planting dates of potatoes⁴⁴. Hence, there are and could be many other societal adaptations that are not documented yet. These human adaptations, with their geographic diversity are critical for human survival, particularly when large uncertainty in predictions of abrupt climate change needs to be taken into consideration⁴⁵ by policy-makers. There is an urgent need to fill this knowledge gap.

As noted earlier, although historical lessons are useful, contemporary analyses of adaptation to climate change in multiple geographical regions are equally important. Understanding the social-ecological resilience and dynamic interaction between nature and society driven by the climate fluctuations requires case studies situated in particular places and cultures⁴⁶ to help identify participatory options for building resilience of the coupled social-ecological systems^{47,48}.

As examined earlier, it is important to know how do present-day village communities maintain resilience and adapt to abrupt climate variability. Also useful is to know how these adaptations can be enhanced in the face of the challenges posed by abrupt climate change. In order to explore options for adaptations to abrupt climate change several issues need to be explored with rural people. These include:

- Review of the literature, and its communication to all stakeholders, on societal adaptations to climate change to gain basic scientific understanding of abrupt climate oscillations and their impact on society.
- Documentation of the occurrence of the recent abrupt climate events such as droughts and floods to understand the occurrence and dynamics of abrupt climate changes in climatically-challenged geographical regions, such as Rajasthan, that has experienced several abrupt climate oscillations.
- Learning the institutional adaptation strategies employed by the village communities to withstand the risks associated with abrupt climate change. The application of this learning is to generate original knowledge useful to design institutions to cope with abrupt climate change.
- Learn the spontaneous as well as planned physical adaptation strategies employed by villagers in the event of abrupt climate change. The relevance of such studies could be to create original knowledge needed to design policy and specific actions for societal adaptation to abrupt climate change.

4. LEARNING TOOLS

What tools and techniques need to be employed for the studies intended to learn to societal adaptation to abrupt climate change? Participatory learning methods such as in-depth interviews, group discussions, participant observation and learning workshops with village communities could be more useful than exploration of purely physical phenomenon. These are widely used method in

social sciences. Furthermore, local oral histories and published material can be used to obtain insights on societal adaptations to abrupt climate change.

Such tools and methods have obvious rationale. In anticipation of potentially recurrent abrupt climate extremes human may play “a game with the environment endeavouring to learn, manipulate, or change the rules in order to realize goals, satisfy needs, or maintain a degree of freedom of choice and action”⁴⁹. Such interactions give rise to local adaptive practices that are sustained because of societal mechanisms such as local institutions, leadership, regulatory rules and norms, and adaptations for the creation, transmission, and application of knowledge⁵⁰. Thus, contemporary interactions of people and their environment may provide insights to design adaptation policies.

Moreover, adaptations are crafted by men and women both. They can be spontaneous or planned; mechanistic or value-based or a combination thereof. Adaptation can also be as ‘hardware’ (physical) such as water-harvesting structures, or software (i.e. institutions, norms etc.) such as village councils for collective irrigation management or groups of seasonal migration in fluctuating monsoons. The respondents of the adaptation studies, therefore, should include both women and men to solicit knowledge of a full range of stakeholders. This is necessary as values, norms, ethics, symbols, and precedents are part of an adaptation-network and cannot be ignored.

5. PRIORITY REGIONS FOR ADAPTATION STUDIES

Why some areas, such as Rajasthan, warrant priority in adaptation research? Rajasthan is ideal geographical region for the study of societal adaptation to abrupt climate change. Antiquity of human occupation of the arid regions of Thar goes back to Late Pleistocene or even earlier as indicated by archaeological studies⁵¹.

During the mid-Holocene, region around the Indian Ocean witnessed the rise of three great civilizations of the world (i.e. Mesopotamian, Egyptian and Indus Valley)⁵². Indus-Saraswati Civilization (also called Indus-Harappa civilization or Indus Valley civilization) is the earliest known urban civilization in South Asia that flourished and fell in the region that includes parts of present-day Rajasthan.

Although the controversy remains, but there is now increasing evidence in favour of climate change as driver for societal disruption and collapse of Indus-Saraswati Civilization. Some studies have implicated the climate change as the reason for the collapse of Indus Valley civilization^{53, 54}. This conclusion was not supported by other studies (such as Enzel *et al.*); rather they suggested that chronology indicates that there is no relation between the proposed drought that caused the desiccation of the lakes and the collapse of the Indus valley civilization, as the lakes in the region dried out >1500 years earlier. Northwestern India during the period of Indus-Saraswati Civilization experienced semiarid climatic conditions that are similar to those of present. However, studies by Staubwasser *et al.*⁵⁵ based on the planktonic oxygen isotope ratios off the Indus delta reveal climate changes with a multi-centennial pacing during the last 6 ka, with the most prominent change recorded at 4.2 ka BP. Contrasting isotopic trends across the northern Arabian Sea surface at that time indicate a reduction in Indus river discharge and suggest that later cycles also reflect variations in total annual rainfall over south Asia. The 4.2 ka event is coherent with the termination of urban Harappan civilization in the Indus valley. Thus, drought may have initiated southeastward habitat tracking within the Harappan cultural domain. The late Holocene drought cycles following the 4.2 ka BP event vary between 200 and 800 years and are coherent with the evolution of cosmogenic ¹⁴C production rates. This suggests that solar variability is one fundamental cause behind Holocene rainfall changes over south Asia.

Multiple evidence⁵⁶ suggests that Rajasthan has witnessed several abrupt changes in climate and monsoon. These include drying and disappearance of river Saraswati and its feeding waterways⁵⁷ perhaps during the period of 4950 to 4400 years before present⁵⁸, onset of aridity, and fluctuations in monsoon throughout the Holocene⁵⁹⁻⁶² affecting the life and property of the people. A recent discovery of fossilized elephant bones in the Quaternary gypsum deposits at Bhadawasi, Nagaur district, Rajasthan further indicates the changing environmental conditions and the abrupt climate changes where a forested and fertile land along the mighty river system (possibly the Vedic Saraswati) changed to the present day Thar desert⁶³.

In more recent times Rajasthan has experienced severe and frequent spells of droughts than any other region in India. During the period 1871-1990 there have been 30 drought years in western and 23 in eastern Rajasthan⁶⁴. During the last 5 years Rajasthan has experienced a persistent drought due to monsoon failure. For these reasons, Rajasthan also has specific resource management problem⁶⁵. In addition, availability of high-resolution Holocene monsoon records further make Rajasthan a suitable geographical region for studies on societal adaptation to climate change.

6. WHY AN EMPHASIS ON CLIMATE AND WOMEN

Global climate change in general and abrupt climate change in particular may threaten the social, economic, and ecological systems. Missing from the climate-change debate, however, is the differential impact of climate change on women, and how implementation of the United Nations Framework Convention on Climate Change and the Kyoto Protocol could specifically benefit and help adapt economically disadvantaged women in developing countries. The argument favouring implementation of the Kyoto Protocol would be strengthened if it

included recognition of gender economics and societal adaptation to climate change⁶⁶.

Any fruitful discussion on the climate change must consider: the additional work burden of women⁶⁷ and female children⁶⁸; the differences, according to gender, in access to resources and consumption patterns⁶⁹; and the comparative vulnerability of women to climate change⁷⁰. Men and women have differential knowledge of local resources⁷¹ and climate issues^{72, 73}. Women can also play a crucial role in climate change mitigation and adaptation through adaptive management of local resources⁷⁴. In doing so, they can save the flora and fauna from overexploitation⁷⁵ and the consequent catastrophic shifts in ecosystems⁷⁶.

Enhancing the capability in order to reduce risk and vulnerability to climate change in India is urgently required⁷⁷. Women should be active and equal partners in the decision-making process on the Clean Development Mechanism, as well as in capacity building, technology transfer, vulnerability and resilience studies, and projects concerning climate-change mitigation and adaptation^{78, 79}.

In shaping a sustainable society, creative strength of 50% of the world's population constituted by women cannot be ignored. Scientific and policy efforts on climate-change adaptation, mitigation and sustainable development should, therefore, be required to give full attention to the profound influence that gender economics has in any collective attempt to build a sustainable society.

7. CONCLUSIONS

Adaptation research is now a crucial aspect combining climate change, vulnerability and sustainable livelihoods⁸⁰. Human dimensions to climate change are vital to learn^{81, 82} since society either must continuously adapt to inevitable climate change⁸³ or perish. Because the purpose of present is to guide the future,

we must therefore learn climate adaptation employed by people living in climatically fluctuating environments today.

There is an urgent need “to plan and design adaptation strategies, to implement them, and to monitor and evaluate their performance”⁸⁴. By learning the adaptations employed by the societies that live in the areas where climate variability is common, such as Rajasthan, we can enhance our understanding to increase the adaptability of social, economic and ecological systems. This will provide us policy options to reduce vulnerability and enhance the adaptation strategies. “The scientific evidence on global warming is now beyond doubt” as Donald Kennedy asserts, but we still have “the policy drought on climate change”⁸⁵. There has been a concerted effort on the part of Conference of Parties in the Delhi meet (CoP 8) in the year 2002 for more emphasis on adaptation to climate change, rather than the dominant focus of the Kyoto Protocol for mitigation of green house gas emissions⁸⁶. Learning the adaptations employed by the village communities of areas such as Rajasthan can provide insights to design useful policies and public actions.

Climate change presents a serious risk to poverty eradication and sustainable livelihoods. The adverse impact of climate change is more severely felt by poor people who are more vulnerable than rich. Appropriate policy responses can strengthen adaptation and help build the resilience of communities and households to climate change⁸⁷. Steps to promote the mainstreaming of adaptation into sustainable development may potentially deliver better results when combined with adaptive management of natural resources.

Such studies may provide insights on the adaptations that are valuable for the poor communities lacking modern infrastructures and therefore more vulnerable to social and economic impact of abrupt climate change. Understanding social and

economic vulnerability as well as local adaptive processes are a necessity because human behaviour, institutional capacity and culture are more important than study of just the biophysical impacts⁸⁸. Such adaptations are useful when abrupt climate change particularly implies changes in the occurrence or intensity of extreme weather events as the society can cope with appropriate adjustments⁸⁹. Societal adaptation therefore should be taken as a priority research area⁹⁰. Such studies with insights from rural people may provide guidance on the extent to which adaptation can reduce impacts of abrupt climate change, and the type of adaptation policies required and the best way to develop and apply such policies.

SECTION B

Societal Adaptation to Abrupt Climate Change and Monsoon Variability: Implications for Sustainable Livelihoods of Rural Communities

Annotated Bibliography

Abler, D., J. Shortle, A. Rose and G. Oladosu (2000). "Characterizing regional economic impacts and responses to climate change." Global and Planetary Change 25(1-2): 67-81.

While much progress has been made in recent years in modeling the impacts of greenhouse gases on global climate and impacts of global climate change on regional climates, much less progress has been made in modeling economic impacts and responses to climate change, particularly at a regional level. This lack of progress is due, in large part, to the fact that there is no generally accepted framework for characterizing the regional economic impacts of, and responses to, climate change. The objective of this paper is to make a start at such a framework. Authors divide economic impacts at a regional level into four broad categories: direct impacts on production of market goods and services; direct impacts on production of nonmarket goods and services; indirect impacts on other economic sectors within the region; and indirect impacts operating through other regions and countries. They go on to consider two modeling frameworks for responses to climate change: static, in which regional capital stocks, technologies, and public and private institutions are exogenous; and dynamic, in which these variables are endogenous. Dynamic responses in capital stocks, technologies, and institutions are likely to be the most important adaptations to climate change and its effects on ecosystems, but also the least well understood at the present time.

Abbott, M. B., M. W. Binford, M. Brenner, and K. R. Kelts. (1997). "A 3500¹⁴C yr High-Resolution Record of Water-Level Changes in Lake Titicaca, Bolivia/Peru." Quaternary Research 47: 169-180.

Sediment cores collected from the southern basin of Lake Titicaca (Bolivia/Peru) on a transect from 4.6 m above overflow level to 15.1 m below overflow level are used to identify a new century-scale chronology of Holocene lake-level variations. The results indicate that lithologic and geochemical analyses on a transect of cores can be used to identify and date century-scale lake-level changes. Detailed sedimentary analyses of subfacies and radiocarbon dating were conducted on four representative cores. A chronology based on 60 accelerator mass spectrometer radiocarbon measurements constrains the timing of water-level fluctuations. Two methods were used to estimate the ¹⁴C reservoir age. Both indicate that it has remained nearly constant at ~250¹⁴C yr during the late Holocene. Core studies based on lithology and geochemistry establish the timing and magnitude of five periods of low lake level, implying negative moisture balance for the northern Andean altiplano over the last 3500 cal yr. Between 3500 and 3350 cal yr B.P., a transition from massive, inorganic-clay facies to laminated organic-matter-rich silts in each of the four cores signals a water-level rise after a prolonged mid-Holocene dry phase. Evidence of other significant low lake levels

occurs 2900–2800, 2400–2200, 2000–1700, and 900–500 cal yr B.P. Several of the low lake levels coincided with cultural changes in the region, including the collapse of the Tiwanaku civilization.

Adger, W. N. (1999). "Social Vulnerability to Climate Change and Extremes in Coastal Vietnam." World Development **27**(2): 249-269.

A framework for analyzing social vulnerability is outlined, an aspect largely underemphasized in assessments of the impacts of climate change and climate extremes. Vulnerability is defined in this paper as the exposure of individuals or collective groups to livelihood stress as a result of the impacts of such environmental change. It is constituted by individual and collective aspects which can be disaggregated, but are linked through the political economy of markets and institutions. Research in coastal northern Vietnam shows that baseline social vulnerability is enhanced by some institutional and economic factors associated with Vietnam's economic transition from central planning, namely the breakdown of collective action on protection from extreme events and an increasingly skewed income. Offsetting these trends are other institutional changes associated with the dynamic nature of the economic restructuring and evolution of the market transition in Vietnam, which decrease vulnerability.

Adger, W. N. (2001). "Scales of governance and environmental justice for adaptation and mitigation of climate change". Journal of International Development **13**(7): 921-931.

This paper examines the issue of scale of governance relevant for adaptation to the impacts of global climate change. The UN Framework Convention on Climate Change is the primary mechanism for coordinating international action on the threat of global climate change. The Convention process perceives adaptation as a further rationale for international transfers, in this case to compensate for and prepare for potential or realized impacts. This approach can be justified by recourse to the idea that enhancing sustainable development will enhance adaptive capacity and that planned activities are a key part of overall adaptation. But many adaptations to climate change will be spontaneous actions to perceived and actual risks in the environment. Thus institutional and economic parameters determine the underlying vulnerability and adaptive capacity of societies. It has been, therefore argued, that an understanding of adaptation processes allows interventions and planned adaptations at the most appropriate scales. Author illustrates these arguments with reference to adaptation in agriculture and outlines the insights from interdisciplinary development studies that can inform the climate change debates.

Adger, W. N. (2003). "Social capital, collective action, and adaptation to climate change." *Economic Geography* **79**(4): 387-404.

Future changes in climate pose significant challenges for society, not the least of which is how best to adapt to observed and potential future impacts of these changes to which the world is already committed. Adaptation is a dynamic social process: the ability of societies to adapt is determined, in part, by the ability to act collectively. This article reviews emerging perspectives on collective action and social capital and argues that insights from these areas inform the nature of adaptive capacity and normative prescriptions of policies of adaptation. Specifically, social capital is increasingly understood within economics to have public and private elements, both of which are based on trust, reputation, and reciprocal action. The public-good aspects of particular forms of social capital are pertinent elements of adaptive capacity in interacting with natural capital and in relation to the performance of institutions that cope with the risks of changes in climate. Case studies are presented of present-day collective action for coping with extremes in weather in coastal areas in Southeast Asia and of community-based coastal management in the Caribbean. These cases demonstrate the importance of social capital framing both the public and private institutions of resource management that build resilience in the face of the risks of changes in climate. These cases illustrate, by analogy, the nature of adaptation processes and collective action in adapting to future changes in climate.

Adger, W. N., Arnell, N. W. and Tompkins, E. L. (2005). "Successful adaptation to climate change across scales." *Global Environmental Change Part A* **15**(2): 77-86.

Climate change impacts and responses are presently observed in physical and ecological systems. Adaptation to these impacts is increasingly being observed in both physical and ecological systems as well as in human adjustments to resource availability and risk at different spatial and societal scales. We review the nature of adaptation and the implications of different spatial scales for these processes. We outline a set of normative evaluative criteria for judging the success of adaptations at different scales. We argue that elements of effectiveness, efficiency, equity and legitimacy are important in judging success in terms of the sustainability of development pathways into an uncertain future. We further argue that each of these elements of decision-making is implicit within presently formulated scenarios of socio-economic futures of both emission trajectories and adaptation, though with different weighting. The process by which adaptations are to be judged at different scales will involve new and challenging institutional processes.

Adger, W. N., S. Huq, K. Brown, D. Conway, M. Hulme. (2003). "Adaptation to climate change in the developing world". Progress in Development Studies 3(3): 179-195.

Authors explore the nature of risk and vulnerability in the context of climate change and review the evidence on present-day adaptation in developing countries and on coordinated international action on future adaptation. It is argued that all societies are fundamentally adaptive and there are many situations in the past where societies have adapted to changes in climate and to similar risks. However, some sectors are more sensitive and some groups in society more vulnerable to the risks posed by climate change than others. All societies need to enhance their adaptive capacity to face both present and future climate change outside their experienced coping range. The challenges of climate change for development are in the present. Observed climate change, present-day climate variability and future expectations of change are changing the course of development strategies and development agencies and governments are now planning for this adaptation challenge. The primary challenge, therefore, posed at both the scale of local natural resource management and at the scale of international agreements and actions, is to promote adaptive capacity in the context of competing sustainable development objectives.

Aggarwal, P. K., P. K. Joshi, J. S. I. Ingram, and R. K. Gupta. (2004). "Adapting food systems of the Indo-Gangetic plains to global environmental change: key information needs to improve policy formulation." Environmental Science & Policy 7(2):487-498.

The Indo-Gangetic plain (IGP; including regions of Pakistan, India, Nepal, and Bangladesh) is generally characterised by fertile soils, favourable climate and an abundant supply of water. Nevertheless, the challenge of increasing food production in the IGP in line with demand grows ever greater; any perturbation in agriculture will considerably affect the food systems of the region and increase the vulnerability of the resource-poor population. Increasing regional production is already complicated by increasing competition for land resources by non-agricultural sectors and by the deterioration of agri-environments and water resources. Global environmental change (GEC), especially changes in climate mean values and variability, will further complicate the agricultural situation and will therefore, have serious implications for food systems of the region. Strategies to reduce the vulnerability of the region's food systems to GEC need to be based on a combination of technical and policy options, and developed in recognition of the concurrent changes in socioeconomic stresses. Adaptation options need to be assessed with regard to their socioeconomic and environmental efficacy, but a

greater understanding of the interactions of food systems with GEC is needed to be able to do this with confidence. This paper discusses information needs relating to resource management and policy support to guide the development of research planning for increasing the robustness of IGP food systems to GEC. Further information is needed to develop a range of adaptation strategies including augmenting production and its sustainability, increasing income from agricultural enterprises, diversification from rice–wheat systems, improving land use and natural resource management, and instigating more flexible policies and institutions.

Ahmed, A. U., M. Alam, and A. A. Rahman. 1999. "Adaptation to climate change in Bangladesh: future outlook". In S. Huq, Z. Karim, M. Asaduzzaman, and F. Mahtab, eds. *Vulnerability and adaptation to climate change for Bangladesh*. Kluwer Academic Publishers, Dordrecht, Netherlands, Pages 125-143.

The paper examines the possibilities, opportunities and challenges of adaptation to climate change for the people of Bangladesh. Issues discussed are: vulnerability to climate change; response to climate change (types of adaptation; anticipatory adaptation measures; possible actors and their respective domains; opportunities for Bangladesh: an assessment; challenges of managing adaptation); and the way ahead.

Aldenderfer, M. (1999). "The Pleistocene/Holocene transition in Peru and its effects upon human use of the landscape." *Quaternary International* **53-54**: 11-19.

This paper reviews the state of our knowledge regarding the effects of the Pleistocene/Holocene transition on the kinds and range of human adaptations in what is now Peru. Following a discussion of geological, paleoclimatic, and archaeological data, the paper focuses upon four aspects of environmental change with specific regard to how these would have affected human adaptations: environmental changes on the Pacific littoral, the extinction of Pleistocene faunal and floral species and their replacement with modern faunas, the adaptive radiation of these modern flora and fauna, especially into the Andean highlands, and characteristics of newly available high elevation environments that would have affected the process by which foraging peoples moved into them. Although Pleistocene fauna have been discovered in Peru, none of these finds have been made in the context of indisputable human activity, and therefore, the effect of their extinction on early foraging peoples is unknown. The earliest acceptable archaeological sites in Peru date around 11-12,000 years ago, and are found on the coastal lowlands. The highlands were not occupied until after 11,000 years ago. While high elevation environments were attractive after 11,000 years ago, they

were only slowly occupied by humans due to the constraints of the combined effects of hypoxia and cold.

Alexandrov, V., J. Eitzinger, V. Cajic, and M. Oberforster (2002). "Potential impact of climate change on selected agricultural crops in north-eastern Austria." Global Change Biology **8**(4): 372-389.

The vulnerability and adaptation of major agricultural crops to various soils in northeastern Austria under a changing climate were investigated. The CERES crop model for winter wheat and the CROPGRO model for soyabean were validated for the agrometeorological conditions in the selected region. The simulated winter wheat and soyabean yields in most cases agreed with the measured data. Several incremental and transient global circulation model (GCM) climate change scenarios were created and used in the study. In these scenarios, annual temperatures in the selected region are expected to rise between 0.9 and 4.8 deg C from the 2020s to the 2080s. The results show that warming will decrease the crop-growing duration of the selected crops. For winter wheat, a gradual increase in air temperature resulted in a yield decrease. Incremental warming, especially in combination with an increase in precipitation, leads to higher soyabean yield. A drier climate will reduce soyabean yield, especially on soils with low water storage capacity. All transient GCM climate change scenarios for the 21st century, including the adjustment for only air temperature, precipitation and solar radiation, projected reductions of winter wheat yield. However, when the direct effect of increased levels of CO₂ concentration was assumed, all GCM climate change scenarios projected an increase in winter wheat yield in the region. The increase in simulated soyabean yield for the 21st century was primarily because of the positive impact of warming and especially of the beneficial influence of the direct CO₂ effect. Changes in climate variability were found to affect winter wheat and soyabean yield in various ways. Results from the adaptation assessments suggest that changes in sowing date, winter wheat and soyabean cultivar selection could significantly affect crop production in the 21st century.

Allen, M. S. (2004). "Bet-hedging strategies, agricultural change, and unpredictable environments: Historical development of dryland agriculture in Kona, Hawaii." Journal of Anthropological Archaeology **23**(2): 196-224.

It is argued that current models of agricultural change are overly focused on productive increases. Risk management strategies, practices that can be critical to the long-term survival of a given agronomic system, warrant a more prominent role. Neo-Darwinian theory, and the bet-hedging model in particular, offers a way to evaluate both kinds of agronomic change within a single theoretical paradigm,

as well as a means of assessing the long-term outcomes of variant agronomic strategies. The bet-hedging model is used herein to assess agricultural change in an unpredictable Hawaiian environment, the Kona District of central West Hawaii. A fine-grained record of agronomic change from one of the region's more productive areas is compared with patterns from the region at large. The analysis shows that variance minimizing (or risk management) strategies were initiated by 1450 AD, if not earlier, and occurred in even the most productive localities. Innovations in gardening architecture, novel cultivation practices and changes in the scale of agronomic integration, are argued to have been effective in reducing the impact of environmental variance. Later in time (after 1650 AD) there was a shift in emphasis to productive maximizing strategies, with implications for the region's economic and socio-political stability.

Alley, R. B., J. Marotzke, W. D. Nordhaus, J. T. Overpeck, D. M. Peteet, R. A. Pielke, R. T., Pierrehumbert, P. B. Rhines, T. F. Stocker, L. D. Talley, J. M. Wallace. (2003). "Abrupt climate change." *Science* **299**: 2005-2010.

Large, abrupt, and widespread climate changes with major impacts have occurred repeatedly in the past, when the Earth system was forced across thresholds. Although abrupt climate changes can occur for many reasons, it is conceivable that human forcing of climate change is increasing the probability of large, abrupt events. Were such an event to recur, the economic and ecological impacts could be large and potentially serious. Unpredictability exhibited near climate thresholds in simple models shows that some uncertainty will always be associated with projections. In light of these uncertainties, policy-makers should consider expanding research into abrupt climate change, improving monitoring systems, and taking actions designed to enhance the adaptability and resilience of ecosystems and economies.

Alley, R. B. and Ágústsdóttir, A. M.. (2005). "The 8k event: cause and consequences of a major Holocene abrupt climate change." *Quaternary Science Reviews* **24**(10-11): 1123-1149.

A prominent, abrupt climate event about 8200 years ago brought generally cold and dry conditions to broad northern-hemisphere regions especially in wintertime, in response to a very large outburst flood that freshened the North Atlantic. Changes were much larger than typical climate variability before and after the event, with anomalies up to many degrees contributing to major displacement of vegetative patterns. This "8k" event provides a clear case of cause and effect in the paleoclimatic realm, and so offers an excellent opportunity for model testing. The response to North Atlantic freshening has the same general anomaly pattern as observed for older events associated with abrupt climate changes following North

Atlantic freshening, and so greatly strengthens the case that those older events also reflect North Atlantic changes. The North Atlantic involvement in the 8k event helps in estimating limits on climate anomalies that might result in the future if warming-caused ice-melt and hydrologic-cycle intensification at high latitudes lead to major changes in North Atlantic circulation. Few model experiments have directly addressed the 8k event, and most studies of proxy records across this event lack the time resolution to fully characterize the anomalies, so much work remains to be done.

Alvard, M. S. (2003). "The adaptive nature of culture." Evolutionary Anthropology **12**(3): 136-149.

Some have argued that the major contribution of anthropology to science is the concept of culture. Until very recently, however, evolutionary anthropologists have largely ignored culture as a topic of study. This is perhaps because of the strange bedfellows they would have to maintain. Historically, anthropologists who claimed the focus of cultural anthropology tended to be anti-science, anti-biology, or both. Paradoxically, a segment of current mainstream cultural anthropology has more or less abandoned culture as a topic. It is particularly ironic that in spite of a growing awareness among evolutionary anthropologists that culture is critical for understanding the human condition, the topic of culture has fallen out of favor among many "cultural" anthropologists.

An, C. B., Z. D. Feng L. Y. Tang. (2004) Environmental change and cultural response between 8000 and 4000 cal. yr BP in the western Loess Plateau, northwest China. Journal of Quaternary Science **19**(6): 529-535.

Two ancient swamps in the western Loess Plateau, northwest China record the climate history between 8000 and 4000 cal. yr BP. Grain size, CaCO₃, organic matter, mollusc fauna and pollen assemblages show that climate was wet between 8300 and 7400 cal. yr BP, distinctly humid and warm between 7400 and 6700 cal. yr BP, semi-humid from 6700 to 6300 cal. yr BP, and semi-arid between 6300 and 4000 cal. yr BP. The temporal and spatial distribution of archaeological sites shows that the prosperity of the neolithic cultures in the western part of the Chinese Loess Plateau did not appear until the climate changed to semi-arid, implying that the semi-arid climate was more favourable than wet and humid climate to neolithic peoples, whose subsistence was based on cereals adapted to environments.

Antle, J. M. (1995). "Climate change and agriculture in developing countries." American Journal of Agricultural Economics **77**(3): 741-746.

The paper begins with a discussion of what researchers currently believe the impacts of climate change could be on developing country agriculture, principally tropical agriculture. It goes on to address the issue of predicting the long term trend in productivity by building on the knowledge of the economic factors determining agricultural innovation and adaptation. An economic approach to modelling managed ecosystems is outlined.

Antle, J. M., S. M. Capalbo, E. T. Elliott, and K. H. Paustian. (2004). "Adaptation, spatial heterogeneity, and the vulnerability of agricultural systems to climate change and CO₂ fertilization: an integrated assessment approach." Climatic Change **64**(3): 289-315.

In this paper authors develop economic measures of vulnerability to climate change with and without adaptation in agricultural production systems. Authors implement these measures using coupled, site-specific ecosystem and economic simulation models. This modeling approach has two key features needed to study the response of agricultural production systems to climate change: it represents adaptation as an endogenous, non-marginal economic response to climate change; and it provides the capability to represent the spatial variability in bio-physical and economic conditions that interact with adaptive responses. Authors apply this approach to the dryland grain production systems of the Northern Plains region of the United States. The results support the hypothesis that the most adverse impacts on net returns distributions tend to occur in the areas with the poorest resource endowments and when mitigating effects of CO₂ fertilization and adaptation are absent. It is found that relative and absolute measures of vulnerability depend on complex interactions between climate change, CO₂ level, adaptation, and economic conditions such as relative output prices. The relationship between relative vulnerability and resource endowments varies with assumptions about climate change, adaptation, and economic conditions. Vulnerability measured with respect to an absolute threshold is inversely related to resource endowments in all cases investigated.

Apuuli, B., J. Wright, C. Elias, and I. Burton (2000). "Reconciling national and global priorities in adaptation to climate change: with an illustration from Uganda." Environmental Monitoring and Assessment **61**(1): 145-159.

Many developing countries, especially in Africa, contribute only very small amounts to the world total of greenhouse gas emissions. For them, the reduction of such emissions is not a priority, and the more important issue is to find ways to reduce their vulnerability to the projected climate change which is being imposed upon them largely as a result of emissions from developed countries. This priority does not accord with the ultimate objective of the United Nations Framework

Convention on Climate Change, which is to achieve stabilization of greenhouse gas emissions. This paper reports upon studies in Uganda designed to help in the development of a national adaptation strategy, and addresses the need to reconcile such a strategy with the global priority accorded to mitigation and with national economic development priorities. Some features of a national climate change adaptation strategy are identified and questions are raised about the need for an international regime to facilitate and support adaptation.

Arnell, N. W. (1998). "Climate change and water resources in Britain." Climatic Change **39**(1): 83-110.

This paper explores the potential implications of climate change for the use and management of water resources in Britain. It is based on a review of simulations of changes in river flows, groundwater recharge and river water quality. These simulations imply, under feasible climate change scenarios, that annual, winter and summer runoff will decrease in southern Britain, groundwater recharge will be reduced and that water quality - as characterized by nitrate concentrations and dissolved oxygen contents - will deteriorate. In northern Britain, river flows are likely to increase throughout the year, particularly in winter. Climate change may lead to increased demands for water, over and above that increase which is forecast for non-climatic reasons, primarily due to increased use for garden watering. These increased pressures on the water resource base will impact not only upon the reliability of water supplies, but also upon navigation, aquatic ecosystems, recreation and power generation, and will have implications for water quality management. Flood risk is likely to increase, implying a reduction in standards of flood protection. The paper discusses adaptation options.

Arnell, N. W. (2003). "Relative effects of multi-decadal climatic variability and changes in the mean and variability of climate due to global warming: future streamflows in Britain." Journal of Hydrology **270**(3/4): 195-213.

Climate change impact assessments conventionally assess just the implications of a change in mean climate due to global warming. This paper compares such effects of such changes with those due to natural multi-decadal variability, and also explores the effects of changing the year-to-year variability in climate as well as the mean. It estimates changes in mean monthly flows and a measure of low flow (the flow exceeded 95% of the time) in six catchments in Britain, using the UKCIP98 climate change scenarios and a calibrated hydrological model. Human-induced climate change has a different seasonal effect on flows than natural multi-decadal variability (an increase in winter and decrease in summer), and by the 2050s the climate change signal is apparent in winter and, in lowland Britain, in summer. Superimposing natural multi-decadal variability onto

the human-induced climate change increases substantially the range in possible future streamflows (in some instances counteracting the climate change signal), with important implications for the development of adaptation strategies. Increased year-to-year variability in climate leads to slight increases in mean monthly flows (relative to changes due just to changes in mean climate), and slightly greater decreases in low flows. The greatest effect on low flows occurs in upland catchments.

Arnell, N. W., M. J. L. Livermore, S. Kovats, P. E. Levy, R. Nicholls, M. L. Parry, and S. R. Gaffin. (2004). "Climate and socio-economic scenarios for global-scale climate change impacts assessments: characterising the SRES storylines." Global Environmental Change **14**(1): 3-20.

This paper describes the way in which the socioeconomic projections in the SRES scenarios were applied in a global-scale assessment of the impacts of climate change on food security, water stresses, coastal flood risk and wetland loss, exposure to malaria risk and terrestrial ecosystems. There are two key issues: (i) downscaling from the world-region level of the original scenarios to the scale of analysis (0.5 deg x 0.5 deg), and (ii) elaborating the SRES narrative storylines to quantify other indicators affecting the impact of climate change. National estimates of population and GDP were derived by assuming that each country changed at the regional rate, and population was downscaled to the 0.5 deg x 0.5 deg scale assuming that everywhere in a country changed at the same rate. SRES scenarios for future cropland extent were applied to current baseline data, assuming everywhere within a region changed at the same rate. The narrative storylines were used to construct scenarios of future adaptation to the coastal flood risk and malaria risk. The paper compares the SRES scenarios with other global-scale scenarios, and identifies sources of uncertainty. It concludes by recommending three refinements to the use of the SRES scenarios in global and regional-scale impact assessment: (i) improved disaggregation to finer spatial resolutions, using both "downscaled narrative storylines" and new technical procedures, (ii) explicit consideration of uncertainty in the population, GDP and land cover characterisations of each storyline, and (iii) use of a wider range of future socioeconomic scenarios than provided by SRES if the aim of an impact assessment is to estimate the range of possible future impacts.

Asquith, N. M., M. T. Vargas Ríos, Smith, J. (2002). "Can forest-protection carbon projects improve rural livelihoods? Analysis of the Noel Kempff Mercado Climate Action Project, Bolivia." Mitigation and Adaptation Strategies for Global Change **7**(4): 323-337.

Authors studied the Noel Kempff Mercado Climate Action Project (NKMCAP), Bolivia, to assess whether forest protection carbon (C) projects can significantly benefit local people. Authors hypothesized that forest protection can only securely deliver C if significant stakeholders are meaningfully and transparently involved, traditional or customary rights are recognized and their loss compensated for, and there are direct linkages between conservation and development objective. Our research focused on 53 members of the communities of Florida, Porvenir and Piso Firme and 36 secondary stakeholders. In each of the villages half-day meetings were held with community leaders, complemented by semi-structured one-hour interviews with 5, 10, and 7 families, representing 20%, 10% and 8% of each community. The long-term impact of the NKMCAP on the local communities may well be positive. However, in the short run, certain sections of the local communities are financially poorer. Forest protection projects clearly have the potential to sequester C, protect biodiversity and simultaneously contribute to sustainable rural development, but if they really are to improve rural livelihoods, they must be designed and implemented carefully and participatively.

Attri, S. D. and L. S. Rathore (2003). "Simulation of impact of projected climate change on wheat in India." International Journal of Climatology **23**(6): 693-705.

The problem of global climate change due to natural processes and anthropogenic sources and its impacts on world food security in general and its regional impacts in particular have come to forefront of the scientific community in recent years. Though the uncertainty of projected climate change at the regional level is higher, it is still necessary to assess its impacts on crop productivity for formulating response strategies. Climate change scenarios projected by the middle of the current century, based on the latest studies, were created and the impacts of concurrent changes of temperature and CO₂ on the growth, development and yields of wheat in northwest India were quantified using a state-of-the-art dynamic simulation model. Yield enhancements of the order of 29-37% and 16-28% under rainfed and irrigated conditions respectively in different genotypes were observed under a modified climate. Any further increase beyond 3 deg C cancelled the beneficial impact of enhanced CO₂. Adaptation measures to mitigate the potential impact of climate change included possible changes in sowing dates and genotype selection. Enhancement of sowing by 10 days in late-sown cultivars and delaying of sowing by 10 days in normally sown cultivars resulted in higher yields under a modified climate, whereas a reduction in yield was observed in the reverse strategies.

Aura, J. E., V. Villaverde, M. G. Morales, C. G. Sainz, J. S. Zilhao, G. Lawrence (1998). "The pleistocene-holocene transition in the Iberian Peninsula: continuity and change in human adaptations." Quaternary International **49-50**: 87-103.

Data obtained from recent excavations (as well as from selected older excavations) are used to outline the principal environmental, technological and economic aspects of the Pleistocene-Holocene transition in three distinct regions of the Iberian Peninsula: Portugal, Cantabrian and Mediterranean Spain. The period covered extends from the terminal Paleolithic Magdalenian period to the initial Neolithic. Despite proximity to SW France and many similarities with that classic prehistoric culture area in terms of artistic/symbolic expression and technology, the Iberian regions show significant differences, especially in terms of subsistence strategies and their development during the Tardiglacial. While there are striking similarities among the three regions with respect to overall patterns of changes in technology, art and subsistence, there are interesting differences of detail, probably linked to environmental differences among these distinctive coastal zones. Changes in artistic activity are also examined, including the disappearance of cave art and the development of geometric motifs in mobile art in Cantabria, as well as a reinterpretation of Levantine art.

Baker, A., C. Starger, T. R. McClanahan, P. W. Glynn. (2004). "Coral reefs: corals' adaptive response to climate change." *Nature* **430**(7001): 741.

The long-term response of coral reefs to climate change depends on the ability of reef-building coral symbioses to adapt or acclimatize to warmer temperatures, but there has been no direct evidence that such a response can occur. Here authors show that corals containing unusual algal symbionts that are thermally tolerant and commonly associated with high-temperature environments are much more abundant on reefs that have been severely affected by recent climate change. This adaptive shift in symbiont communities indicates that these devastated reefs could be more resistant to future thermal stress, resulting in significantly longer extinction times for surviving corals than had been previously assumed. Corals being an economically useful group of species human may have to adjust their collection strategies in a changing climate.

Barker, T. (2003). "Representing global climate change, adaptation and mitigation." *Global Environmental Change* **13**(1): 1-6.

The diagrammatic representation of climate change, adaptation and mitigation is important in conceptualizing the problem, identifying important feedbacks, and communicating between disciplines. The Synthesis Report of the IPCC's Third Assessment Report, 2001, uses a "cause and effect" approach developed in the integrated assessment literature. This viewpoint reviews this approach and suggests an alternative, based on stocks and flows. The alternative gives a much richer representation of the problem so that it includes the enhanced greenhouse effect, ancillary benefits of mitigation, the distinction between climate-

change and other stresses on natural systems, and a more refined distinction between adaptation and mitigation.

Barnett, J. (2001). "Adapting to climate change in Pacific Island Countries: the problem of uncertainty." *World Development (Oxford)* **29**(6): 977-993.

This paper investigates the problem of scientific uncertainty and the way it impedes planning for climate change and accelerated sea-level rise (CC & ASLR) in Pacific Island Countries (PICs). The paper begins by discussing the problems that CC & ASLR pose for PICs, and it explores the limitations of the dominant approach to vulnerability and adaptation. Next, the paper considers the way scientific uncertainty poses problems to policies aimed at adaptation to CC & ASLR. It argues that the prevailing approach, which requires anticipation of impacts, is unsuccessful, and proposes a complementary strategy aimed to enhance the resilience of whole island social-ecological systems. Recent developments in the theory and practice of resilience are discussed and then applied to formulate goals for adaptation policy in PICs.

Beg, N., J. C. Morlot, O. Davidson, Y. Afrane-Okesse, L. Tyani, F. Denton, Y. Sokona, J. P. Thomas, E. L. La Rovere, and J. K. Parikh. (2002). "Linkages between climate change and sustainable development." *Climate Policy* **2**(2-3): 129-144.

Climate change does not yet feature prominently within the environmental or economic policy agendas of developing countries. Yet evidence shows that some of the most adverse effects of climate change will be in developing countries, where populations are most vulnerable and least likely to easily adapt to climate change, and that climate change will affect the potential for development in these countries. Some synergies already exist between climate change policies and the sustainable development agenda in developing countries, such as energy efficiency, renewable energy, transport and sustainable land-use policies. Despite limited attention from policy-makers to date, climate change policies could have significant ancillary benefits for the local environment. The reverse is also true as local and national policies to address congestion, air quality, access to energy services and energy diversity may also limit GHG emissions. Nevertheless there could be significant trade-offs associated with deeper levels of mitigation in some countries, for example where developing countries are dependent on indigenous coal and may be required to switch to cleaner yet more expensive fuels to limit emissions. The distributional impacts of such policies are an important determinant of their feasibility and need to be considered up-front. It follows that future agreements on mitigation and adaptation under the convention will need to recognise the diverse situations of developing countries with respect to their level

of economic development, their vulnerability to climate change and their ability to adapt or mitigate. Recognition of how climate change is likely to influence other development priorities may be a first step toward building cost-effective strategies and integrated, institutional capacity in developing countries to respond to climate change. Opportunities may also exist in developing countries to use regional economic organisations to assist in the design of integrated responses and to exploit synergies between climate change and other policies such as those designed to combat desertification and preserve biodiversity.

Bergkamp, G., B. Orlando, and I. Burton. (2003). Change: adaptation of water resources management to climate change. IUCN-The World Conservation Union, Gland, Switzerland.

This book contains five chapters providing an outline of a new water management approach that can be taken to adapt to the changes in the world's water regimes expected to occur over the coming decades due to climatic change. The new management style includes all stakeholders, relies on the capacities of people, encourages joint learning, and invests in managing conflicts.

Berkes, F. and D. Jolly. (2002). "Adapting to climate change: social-ecological resilience in a Canadian Western Arctic community." Conservation Ecology 5(2):18. [online] URL: <http://www.consecol.org/vol5/iss2/art18>.

Human adaptation remains an insufficiently studied part of the subject of climate change. This paper examines the questions of adaptation and change in terms of social-ecological resilience using lessons from a place-specific case study. The Inuvialuit people of the small community of Sachs Harbour in Canada's western Arctic have been tracking climate change throughout the 1990s. Authors analyze the adaptive capacity of this community to deal with climate change. Short-term responses to changes in land-based activities, which are identified as coping mechanisms, are one component of this adaptive capacity. The second component is related to cultural and ecological adaptations of the Inuvialuit for life in a highly variable and uncertain environment; these represent long-term adaptive strategies. These two types of strategies are, in fact, on a continuum in space and time. This study suggests new ways in which theory and practice can be combined by showing how societies may adapt to climate change at multiple scales. Switching species and adjusting the "where, when, and how" of hunting are examples of shorter-term responses. On the other hand, adaptations such as flexibility in seasonal hunting patterns, traditional knowledge that allows the community to diversity hunting activities, networks for sharing food and other resources, and intercommunity trade are longer-term, culturally ingrained mechanisms. Individuals, households, and the community as a whole also provide

feedback on their responses to change. Newly developing co-management institutions create additional linkages for feedback across different levels, enhancing the capacity for learning and self-organization of the local inhabitants and making it possible for them to transmit community concerns to regional, national, and international levels.

Berkhout, F., Hertin, J. and Gann, D. M. (2004) "Learning to adapt: Organisational adaptation to climate change impacts". Tyndall Centre Working Paper 47. Tyndall Centre for Climate Research, U.K., pp. 21.

The starting point of this paper is that the analysis of adaptation should be based on realistic models of adaptive behaviour at the micro-level of organisations. Based on empirical research into adaptation by nine UK companies in two sectors – water services and house-building - the paper sets out a framework for analysing adaptation to the direct and indirect impacts of climate change in business organisations. It argues that adaptation to climate change has many similarities with other organisational processes of change, and that the existing body of knowledge on organisational learning and innovation management can fruitfully be used in this analysis. The paper argues that many business organisations face a number of obstacles in learning how to adapt, so affecting the patterns of adaptation that are likely to emerge. In particular, it shows that organisations face difficulties in recognising signals related to climate change impacts, in evaluating the costs and benefits of alternative adaptation options, and in receiving feedback about the success or failure of these measures. Public policy measures may be needed to help private sector organisations overcome some of these obstacles. The paper identifies a number of different adaptation strategies that organisations may adopt.

Bharara, L. P. and K. Seeland (1994). "Indigenous knowledge and drought in the arid zone of Rajasthan: weather prediction as a means to cope with a hazardous climate." Internationales Asienforum **25**(1/2): 53-71.

The paper identifies traditional social indicators of drought prediction in an arid region of Rajasthan, India and compares their accuracy with that of rainfall data as a contribution to the discussion of the relevance of indigenous knowledge to the development process in a predominantly rural society. The study was carried out in three different ecological areas: pastoral nomadic, mostly rainfed and rainfed with irrigation. The comparison showed minor differences in the way a year was perceived on the basis of folk memory and actual rainfall but the holistic approach, taking account of a number of indicators, gave a more accurate picture of the real situation than mere figures on precipitation.

Bharara, L. P. (1980). "Socio-economic consequences of drought in an arid tract - case study." In, H. S. Mann, ed. Arid Zone Research and Development. Scientific Publishers, Jodhpur, India, pp. 439-445.

The study, conducted in Shergarh Tehsil, western Rajasthan, analyses the nature and extent of the drought-affected area, social changes including social and economic values, disturbances in the agrarian sector, and changes in livestock numbers. Analysis of rainfall data for 78 years (1899-1976) revealed that there were 43 mild drought years when 50 percent of the crops reached maturity, 19 drought years (25 percent crop maturity), and 8 disastrous years (zero crop maturity). Social changes during drought years included a breakdown in the caste system and increased cooperation among people forced to migrate to find a livelihood. Analysis of land use changes revealed a positive correlation between the intensity of drought and the extent of the area damaged. Mean annual yield of kharif crops decreased from 90-100 percent in a drought year and 30-66 percent in a moderately deficit year. Livestock losses ranged from 17 percent for goats to 50 percent for cattle during drought years.

Bhandari, M. M. (1974). "Famine foods in the Rajasthan Desert." Economic Botany **28**(1): 73-81.

Information is given on the plants used as emergency food by the people of the Rajasthan Desert during periods of famine. **ADDITIONAL ABSTRACT:** The utilization of little known foods in times of acute crisis is urged. In view of the sharp decline in the purchasing power of all classes of people in Rajasthan, there have hardly been any buyers of grain since the price of bajra shot up to Rps 110 per quintal. Although this is traditionally a fodder producing area, more than 200,000 head of cattle have been removed elsewhere in search of grazing and water. Several indigenous crop species are described which could be grown and utilized to prevent a great deal of suffering. More research is called for to introduce new species of crops likely to succeed in drought conditions.

Bharara, L. P. (1980). "Social aspects of drought perception in arid zone of Rajasthan." Annals of Arid Zone **19**(1/2): 154-167.

Desert rural folk in Rajasthan, India perceive drought as a multi-dimensional phenomenon varying from meteorological to bio-physical to socio-religious in nature. Among various notions concerning the causes of drought, 77% of the responses were meteorological, exhibiting climatic changes; 49% bio-physical, bringing devastation of natural vegetation; and 33% socio-religious, with supernatural beliefs. Associated with these notions, folk reported drought-induced problems: distress sale of land, livestock, personal assets; set-back to occupational caste's economy; and loss of crop-livestock production. Biophysical problems

revealed indiscriminate cutting of vegetation for fuel, construction, field bunding; traditional practices of overgrazing and frequent lopping of trees by livestock raisers; shifting soils affecting cultivated fields, pastures, barren lands and village ponds/wells. Social disorder revealed migration, occupational diversification, social loss and shifting settlements. Farmer's classification of past droughts revealed that droughts before 1970 were more severe. Changes in climatic and vegetational characteristics, animal behaviour and social behavioural activities are widely believed to be means of drought prediction.

Binford, M. W., A. L. Kolata, M. Brenner, J. W. Janusek, M. T. Seddon, M. Abbott, and J. H. Curtis. (1997). "Climate variation and the rise and fall of an Andean Civilization". Quaternary Research **47**: 235-248.

Paleolimnological and archaeological records that span 3500 years from Lake Titicaca and the surrounding Bolivian-Peruvian altiplano demonstrate that the emergence of agriculture (ca. 1500 B.C.) and the collapse of the Tiwanaku civilization (ca. A.D. 1100) coincided with periods of abrupt, profound climate change. The timing and magnitude of climate changes are inferred from stratigraphic evidence of lake-level variation recorded in ¹⁴C-dated lake-sediment cores. Paleo-lake levels provide estimates of drainage basin water balance. Archaeological evidence establishes spatial and temporal patterns of agricultural field use and abandonment. Prior to 1500 B.C., aridity in the altiplano precluded intensive agriculture. During a wetter period from 1500 B.C. to A.D. 1100, the Tiwanaku civilization and its immediate predecessors developed specialized agricultural methods that stimulated population growth and sustained large human settlements. A prolonged drier period (ca. A.D. 1100-1400) caused declining agricultural production, field abandonment, and cultural collapse.

Bloom, P. R., M. Pohl, C. Buttleman, F. Wiseman, A. Covich, C. Miksicek, J. Ball, J. Stein. (1983). "Prehistoric Maya wetland agriculture and the alluvial soils near San Antonio Rio Hondo, Belize." Nature **301**: 417-419.

The prehistoric Lowland Maya supported an elaborate civilization, which reached peak population densities in the tropical forests of Guatemala, Belize and southern Mexico during the Classic period between AD 300 and 900. It has been proposed that the Maya turned to labour-intensive construction of raised planting platforms in wetlands for year-round cultivation. Excavations at San Antonio Rio Hondo, northern Belize¹, provided the first archaeological data for this hypothesis. In our analysis of data from the San Antonio site, authors conclude that the only indisputable evidence that prehistoric wetland cultivation occurred comes from a time before peak population of the Classic period, and that the technique required less labour than previously envisioned. Exploitation of swampy

terrain initially involved dry-season cropping without extensive ditching and later ditching, probably for soil drainage.

Bloomfield, J. and F. Tubiell (2001). "The potential impacts of global warming on U.S. agriculture: critical findings for agricultural areas from the first National Assessment of the potential consequences of climate variability and change." World Farmers' Times **16**(6): 22-23.

This paper presents an overview of the findings of a national assessment of the potential impacts of global warming on US agriculture. The assessment suggests that future climate change, higher concentrations of atmospheric CO₂, and appropriate farmer adaptation, could result in higher crop yields for the USA as a whole. Nonetheless, projections at the regional level are mixed, with winners and losers. Ways in which farmers can adapt to global warming are outlined.

Bokil, M. (2000). "Drought in Rajasthan: in search of a perspective." Economic and Political Weekly **35**(48): 4171-4175.

This paper develops a systematic perspective on drought in Rajasthan, India, to guide both policy and practice. Drought conditions in the state (where 60% is arid, and the remaining is semi-arid) are discussed. Reference is made to Amartya Sen's *Poverty and Famine* which looks at the phenomena of famines from the entitlement approach. This approach concentrates on the ability of people to command food through the legal means available to society, including the use of production possibilities, trade opportunities, entitlements vis-a-vis the state, and other methods of acquiring food. Broad strategies of drought mitigation through the entitlement approach are outlined, including the provision of gainful employment for landless labourers. It is argued that drought in arid and semi-arid regions is not a calamity, but a regular climatic feature. Instead of restoring to calamity relief, governments should consider drought mitigation as the principal strategy of agricultural and rural development.

IPCC. (1996). Climate change 1995--Impacts, adaptations and mitigation of climate change: Scientific-technical analyses: Contribution of working group II to the second assessment report of the intergovernmental panel on climate change: Cambridge University Press, Cambridge.

This is the most authoritative review of literature on adaptations up to 1995.

Bou-Zeid, E. and M. El-Fadel (2002). "Climate change and water resources in Lebanon and the Middle East." Journal of Water Resources Planning and Management **128**(5): 343-355.

While the extent of human-induced global warming is inconclusive, the vulnerability of natural systems to rapid changes in climate patterns is regarded as one of the most challenging issues in recent years. Water resources are a main component of natural systems that might be affected by climate change. This paper characterizes water resources in several Middle Eastern countries and evaluates regional climate predictions for various scenarios using general circulation models. The country of Lebanon is selected as a case study for an in-depth investigation with potential impacts on the water budget and soil moisture as indicators. Adaptation measures are assessed, with a focus on no-regret actions in the context of local socioeconomic and environmental frameworks.

Bowes, M. D. and R. A. Sedjo (1993). "Impacts and responses to climate change in forests of the MINK region." *Climatic Change* 24(1/2): 63-82.

Adaptability of forests in the US midwest (Missouri, Iowa, Nebraska, Kansas) to a changing climate is assessed. Forests of Missouri are simulated with a forest-gap model, a stochastic model of annual growth and mortality of trees within mixed-species forest plots. Development of representative forest plots under an analog climate like that of the 1930s is compared to development under baseline climate conditions. With no management response, average forest biomass in the region declines by 11% within ten years, primarily due to moisture-stress induced mortality. Longer term declines in forest productivity of the order of 30% are simulated. A variety of possible management responses through planting or harvesting practices are evaluated. None of these adaptations appear to be practical, although salvage harvest of stressed trees would offset economic losses associated with early mortality. Anticipated trends in the broader forest products sector suggests that opportunities for further adaptation to offset decline in primary productivity of this region's forest are quite limited. However, a shift to wood powered electrical generation in the region might justify a level of management that would allow some adaptation to the analog climate change.

Bowler, J. M., H. Johnston, J. M. Olley, J. R. Prescott, R. G. Roberts, W. Shawcross, and N. A. Spooner. (2003). "New ages for human occupation and climatic change at Lake Mungo, Australia." *Nature* 421: 837-840.

Australia's oldest human remains, found at Lake Mungo, include the world's oldest ritual ochre burial (Mungo III) and the first recorded cremation (Mungo I). Until now, the importance of these finds has been constrained by limited chronologies and palaeoenvironmental information. Mungo III, the source of the world's oldest human mitochondrial DNA, has been variously estimated at 30 thousand years (kyr) old, 42-45 kyr old and 62 +/- 6 kyr old, while radiocarbon estimates placed the Mungo I cremation near 20-26 kyr ago. Here authors report a new series of 25

optical ages showing that both burials occurred at 40 +/- 2 kyr ago and that humans were present at Lake Mungo by 50-46 kyr ago, synchronously with, or soon after, initial occupation of northern and western Australia. Stratigraphic evidence indicates fluctuations between lake-full and drier conditions from 50 to 40 kyr ago, simultaneously with increased dust deposition, human arrival and continent-wide extinction of the megafauna. This was followed by sustained aridity between 40 and 30 kyr ago. This new chronology corrects previous estimates for human burials at this important site and provides a new picture of *Homo sapiens* adapting to deteriorating climate in the world's driest inhabited continent.

Brager, G. S. and R. J. de Dear (1998). "Thermal adaptation in the built environment: a literature review." *Energy and Buildings* **27**(1): 83-96.

This a literature reviews environment and adaptations in cities.

Brewer, T. L. (2003). "The trade regime and the climate regime: institutional evolution and adaptation." *Climate Policy* **3**(4): 329-341.

This article addresses concerns that the multilateral trade regime centered in the WTO and the emerging climate regime may conflict in ways that could be damaging to either or both. The article discusses the institutional and diplomatic context of these concerns, and it identifies the kinds of issues that are in question. The analysis suggests that there are opportunities for win-win outcomes in the interactions of the two regimes, for instance in the possibility of reducing fossil fuel subsidies. However, there are also problematic areas where they intersect. A core issue--and as yet an unresolved one--is whether and how emission credit trading and other activities envisioned by the Kyoto Protocol would be subject to WTO rules. The resolution of this issue will affect many other issues as well. Additional specific issues about the interactions of particular provisions in WTO agreements and the Kyoto Protocol are analyzed in a subsequent companion article in *Climate Policy*.

Brooks, N., Adger, W. N. and Kelly, P. M. (2005). "The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation." *Global Environmental Change Part A* **15**(2): 151-163.

Authors present a set of indicators of vulnerability and capacity to adapt to climate variability, and by extension climate change, derived using a novel empirical analysis of data aggregated at the national level on a decadal timescale. The analysis is based on a conceptual framework in which risk is viewed in terms of outcome, and is a function of physically defined climate hazards and socially constructed vulnerability. Climate outcomes are represented by mortality from

climate-related disasters, using the emergency events database data set, statistical relationships between mortality and a shortlist of potential proxies for vulnerability are used to identify key vulnerability indicators. Authors find that 11 key indicators exhibit a strong relationship with decadal aggregated mortality associated with climate-related disasters. Validation of indicators, relationships between vulnerability and adaptive capacity, and the sensitivity of subsequent vulnerability assessments to different sets of weightings are explored using expert judgement data, collected through a focus group exercise. The data are used to provide a robust assessment of vulnerability to climate-related mortality at the national level, and represent an entry point to more detailed explorations of vulnerability and adaptive capacity. They indicate that the most vulnerable nations are those situated in sub-Saharan Africa and those that have recently experienced conflict. Adaptive capacity—one element of vulnerability—is associated predominantly with governance, civil and political rights, and literacy.

Brown, N. (1994). "Climate change and human history. Some indications from Europe, AD400–1400." Environmental Pollution **83**(1-2): 37-43.

The influence of climate change on history is discussed in such a way as to take account of recent research while seeking to herald, rather than foreclose, the much more focussed and definitive debates that will become possible by the turn of the century. By then, much more elaborated time series of global climatic change over the last several millennia should be available. The period chosen for examination is the 1000 years or so following the collapse of Roman Europe. During this time, civilization seems to wane, wax and wane again, very much in phase with the climate deteriorating, improving and then deteriorating once more. What this overview high-lights is the great vulnerability to climatic perturbation of societies that are marginally poised for other reasons. In several major respects, the whole of world society will be marginal in the 21st century.

Bruce, J. P. (1999). "Disaster loss mitigation as an adaptation to climate variability and change. Mitigation and Adaptation Strategies for Global Change **4**(3-4): 295-306.

Extremes of climate and weather, storms, floods and droughts, require vigorous adaptation measures in a generally stable climate or in one that is rapidly changing. These adaptation measures, to reduce loss of life, human suffering and economic losses come under the heading "disaster loss mitigation". Since 1990 the United Nations' International Decade for Natural Disaster Reduction has provided for international cooperation and information dissemination. Nevertheless, worldwide economic disaster losses in the 1990s have continued to show a rapid

increase - and the increase for climate related disasters has been three to four times greater than those for geological disasters.

Is some of this increased loss due to anthropogenic climate change? There is some evidence of increases in frequency of heavy rainfalls in a number of regions and of severe winter storms in the northern hemisphere. On the other hand, there is little global trend in frequency or intensity of tropical cyclones whose geographical distribution is more closely related to ENSO events. But is there a possibility that increases in intensity over the past few decades of El Niño and La Niña events are related to increased radiative forcing from greenhouse gases?

Whatever the outcome of emerging research on extreme events in a changing climate, it is evident that climate adaptation through disaster mitigation measures is of increasing importance with growing populations in more vulnerable regions. Measures that must be supported vigorously include improved warning and preparedness systems, safer buildings, risk-averse land use planning, better protected urban infrastructure, and more resilient water supply systems, among others. Both national and international efforts must not be allowed to diminish after the end of the IDNDR in 1999. The task is only begun.

Bryson, R. A., A. M. Swain. (1981). "Holocene variations of monsoon rainfall in Rajasthan." Quaternary Research **16**: 135-145.

Burton, I. (1998). "Adapting to climate change in the context of national economic planning and development". In: Veit, P. (ed.) Africa's valuable assets: a reader in natural resource management, Washington, DC, USA, World Resources Institute.

Issues discussed on this topic are: climate change mitigation and adaptation in the African and global context; the theory of adaptation (adaptation and maladaptation to climate change and variability; what is it that needs adapting to; who and what adapts; how does adaptation occur; when does adaptation take place; what are adaptation measures); relation to national economic development (what is the capacity to adapt; increasing adaptive capacity; the reduction of current losses and vulnerability; and reasons to adapt now); the development of an adaptation response strategy (the identification of adaptation options; evaluation and assessment of adaptation options); and the example of Uganda.

Burton, I., S. Huq, B. Lim, O. Pilifosova, and E. L. Schipper. (2002). "From impacts assessment to adaptation priorities: the shaping of adaptation policy." Climate Policy **2**(2-3): 145-159.

Under the United Nations Framework Convention on Climate Change (UNFCCC), adaptation has recently gained importance, yet adaptation is much less developed than mitigation as a policy response. Adaptation research has been used to help answer to related but distinct questions. (1) To what extent can adaptation reduce impacts of climate change? (2) What adaptation policies are needed, and how can they best be developed, applied and funded? For the first question, the emphasis is on the aggregate value of adaptation so that this may be used to estimate net impacts. An important purpose is to compare net impacts with the costs of mitigation. In the second question, the emphasis is on the design and prioritisation of adaptation policies and measures. While both types of research are conducted in a policy context, they differ in their character, application, and purpose. The impacts/mitigation research is orientated towards the physical and biological science of impacts and adaptation, while research on the ways and means of adaptation is focussed on the social and economic determinants of vulnerability in a development context. The main purpose of this paper is to demonstrate how the national adaptation studies carried under the UNFCCC are broadening the paradigm, from the impacts/mitigation to vulnerability/adaptation. For this to occur, new policy research is needed. While the broad new directions of both research and policy can now be discerned, there remain a number of outstanding issues to be considered.

Burton, I. and E. May (2004). "The adaptation deficit in water resource management." IDS Bulletin **35**(3): 31-37.

Water resource scientists, managers and users are considering how to adapt to the threats posed by climate change. A useful entry point is to assess the practices and policies in place to deal with current stresses arising from increasing demands and from variability in the quantity and quality of supply. The record is not reassuring, with conditions deteriorating in many places. Thus there are two adaptation deficits, the current deficit and the projected deficit. Scientists in the Intergovernmental Panel on Climate Change and negotiators for the UN Framework Convention on Climate Change tend to focus on the longer term, anthropogenic climate change. A broader view of the multiple stresses on water resources shows that there is a need and an opportunity to address simultaneously the current adaptation deficit and to incorporate adaptation to reduce future stresses due to climate change. To this end, it is suggested that the development of a more strict and operational definition of adaptation within the Convention process could provide useful support for progress in current water management.

Burton, I., A. Hammill, J. Soutan (2003) Livelihoods and Climate Change: Combining Disaster Reduction, Natural Resource Management and Climate

Change Adaptation in a New Approach to the Reduction of Vulnerability and Poverty. IISD/IUCN/SEI, Canada, 2003, p. 24.

What does 'adaptation' mean in the context of climate change? How can policy addressing climate change support the livelihoods and adaptive strategies of the most vulnerable? This inter-agency paper lays the conceptual foundations for an approach to climate change which combines insights from the fields of disaster risk reduction, climate change adaptation, natural resources management and poverty reduction. It serves as an introduction to the three-year Task Force programme involving analysis, consultation, and policy work. Adaptation is now in some places an urgent imperative, but should be seen as a positive embracing of opportunity for beneficial change. An approach is called for that reduces climate-related vulnerability through ecosystem management and restoration activities that sustain and diversify local livelihoods. Specifically the paper offers an approach:

- Rooted in the reduction of existing vulnerabilities, producing 'win-win' solutions serving immediate needs and also supporting longer-term processes of capacity building and structural change.
- Following a three-pronged strategy of understanding vulnerability-livelihood interactions; establishing the legal, policy and institutional framework; and developing a climate-change adaptation strategy through participatory processes.

The role of development assistance must be to facilitate adaptation, to help build capacity and to share in the removal of obstacles. This calls for:

- Greater emphasis on micro-level approaches to vulnerability reduction, and further discussion of this type of approach among all stakeholders.
- Closer collaboration between disciplines and sectors – in particular between climate, disasters, resource management and poverty reduction organisations - to scale-up micro-level activities and integrate them into emerging policy frameworks.

Byrd, W. A. (1990). "Planning in India: Lessons from four decades of development experience." Journal of Comparative Economics **14**(4): 713-735.

This paper argues that planning as practiced in India has in many respects failed to achieve national development objectives over the long term. Four different sets of factors can be identified as probably having contributed to this failure: (1) faulty premises and development strategies, (2) problematic and counterproductive implementation mechanisms, (3) the emergence of powerful interest groups that appropriate public resources and blocked needed policy reforms, and (4) the slowness to learn from experience and consequent lack of

flexibility and adaptation. These forces were not mutually independent, and hence their relative importance is difficult to gauge precisely.

Calvin, W. H. (2002). A Brain for All Seasons: Human Evolution and Abrupt Climate Change. University of Chicago Press, Chicago, 349 pp.

Through the course of a travelogue, Calvin argues that repeated episodes of abrupt cooling played a critical role in human evolution and that human-caused global warming may paradoxically trigger another crash in global temperatures.

Carbone, G. J., W. Kiechle, C. Locke, L. O. Mearns, L. McDaniel, and M. W. Downton. (2003). "Response of soybean and sorghum to varying spatial scales of climate change scenarios in the southeastern United States." Climatic Change **60**(1/2): 73-98.

This study examines how uncertainty associated with the spatial scale of climate change scenarios influences estimates of soybean and sorghum yield response in the southeastern United States. Authors investigated response using coarse (300-km, CSIRO) and fine (50-km, RCM) scale climate change scenarios and considering climate changes alone, climate changes with CO₂ fertilization, and climate changes with CO₂ fertilization and adaptation. Relative to yields simulated under a current, control climate scenario, domain-wide soybean yield decreased by 49% with the coarse-scale climate change scenario alone, and by 26% with consideration for CO₂ fertilization. By contrast, the fine-scale climate change scenario generally exhibited higher temperatures and lower precipitation in the summer months resulting in greater yield decreases (69% for climate change alone and 54% with CO₂ fertilization). Changing planting date and shifting cultivars mitigated impacts, but yield still decreased by 8% and 18% respectively for the coarse and fine climate change scenarios. The results were similar for sorghum. Yield decreased by 51%, 42%, and 15% in response to fine-scale climate change alone, CO₂ fertilization, and adaptation cases, respectively - significantly worse than with the coarse-scale (CSIRO) scenarios. Adaptation strategies tempered the impacts of moisture and temperature stress during pod-fill and grain-fill periods and also differed with respect to the scale of the climate change scenario.

Chattopadhyay, R. and E. Duflo. (2004). "Women as policy makers: Evidence from a randomized policy experiment in India." Journal of the Econometric Society **72**(5): 1409-1443.

This paper uses political reservations for women in India to study the impact of women's leadership on policy decisions. Since the mid-1990's, one third of Village Council head positions in India have been randomly reserved for a woman: In these councils only women could be elected to the position of head.

Village Councils are responsible for the provision of many local public goods in rural areas. Using a dataset we collected on 265 Village Councils in West Bengal and Rajasthan, authors compare the type of public goods provided in reserved and unreserved Village Councils. They show that the reservation of a council seat affects the types of public goods provided. Specifically, leaders invest more in infrastructure that is directly relevant to the needs of their own genders.

Chiotti, Q., T. Johnston, B. Smit, and B. Ebel. 1997. "Agricultural response to climatic change: a preliminary investigation of farm-level adaptation in Southern Alberta." In, B. Ilbery, Q. Chiotti, and T. Rickard, eds. Agricultural restructuring and sustainability: a geographical perspective. Cab International, Wallingford, UK, Pages 201-218.

The adaptive strategies adopted by farm households are examined within the context of agricultural restructuring and the environmental stresses arising from recent variations in climate. An outline of the conventional climate change impact assessment approach and the knowledge gaps pertaining to farm-level decision-making and adaptation is given. The agricultural restructuring literature is drawn upon to develop an integrative framework that offers a more critical understand of how land management decisions can be influenced by a complex of external and internal forces. A regional description of agriculture (irrigated) in southern Alberta (Canada) is presented, providing the broader social and environmental context within which farmers operate. The results from an investigation of three farming systems in that region, which was carried out in the spring and summer of 1994, are analysed and presented. For each farming system aspects of climatic variability to which farmers are sensitive are identified, the importance of climate vis-à-vis other societal forces in the agricultural adaptation process is appraised, and land management responses documented. Ways in which the concept of locality can be used to develop a more fully informed appreciation of climate change impacts are discussed in conclusion, and the significance of the findings in terms of sustainable agriculture is explored.

Chiotti, Q. P. and T. Johnston (1995). "Extending the boundaries of climate change research: a discussion on agriculture." Journal of Rural Studies **11**(3): 335-350.

Global environmental change is one of the most significant research and policy issues facing humankind. Although vast financial and human resource are being allocated to climate change research, there are numerous knowledge gaps between understanding climate variations and human responses, particularly in the area of farm adaptation. The paper argues that four issues need to be addressed in order to narrow these gaps: (1) greater attention needs to be directed towards

impact assessment; (2) future researchers should consider critical methodologies and theories clearly articulated in cognate disciplines; (3) there needs to be an improved understanding of how present agriculture adapts to both climatic and societal forces; and (4) there needs to be an improved understanding of the decision-making process. These issues are addressed by drawing upon three areas of research: (i) the climate change and impact assessment literature; (ii) the natural hazards literature; and (iii) the agricultural restructuring literature, drawn primarily from the disciplines of rural geography and rural sociology. From a review of this literature, it is argued that each area provides an incomplete assessment of the relationship between climatic change and agriculture in developed countries. Consequently, it is concluded that an approach which situates farm-level decision making in relation to both broad structural (including biophysical) and internal forces, provides for a greater understanding of the nexus between climate change and farm adaptation.

Cohen, S. J., K. A. Miller, A. F. Hamlet, and W. Avis. (2000). "Climate change and resource management in the Columbia River basin." Water International **25**(2): 253-272.

Scenarios of global climate change were examined to observe what impacts they might have on transboundary water management in the Columbia River basin, USA. Scenario changes in natural streamflow were estimated using a basin hydrology model. These scenarios tended to show earlier seasonal peaks, with possible reductions in total annual flow and lower minimum flows. Impacts and adaptation responses to the natural streamflow scenarios were determined through two exercises: (a) estimations of system reliability using a reservoir model with performance measures and (b) interviews with water managers and other stakeholders in the Canadian portion of the basin. Results from the two exercises were similar, suggesting a tendency towards reduced reliability to meet objectives for power production, fisheries, and agriculture. Reliability to meet flood control objectives would be relatively unchanged in some scenarios but reduced in others. This exercise suggests that despite the high level of development and management in the Columbia, vulnerabilities would still exist, and impacts could still occur in scenarios of natural streamflow changes caused by global climate change. Many of these would be indirect, reflecting the complex relationship between the region and its climate.

Chlachula, J. (2001). "Pleistocene climate change, natural environments and palaeolithic occupation of the Altai area, west-central Siberia." Quaternary International **80-81**: 131-167.

Diversity of the relief and the Pleistocene environments of the mountain areas of SW Siberia played a major role in the history of the palaeolithic peopling of this territory. The geographical and contextual distribution of the cultural records reflects a climatic instability in the Altai area. Palaeoenvironmental proxy data indicate that the natural conditions during the earlier stages were generally more favourable for early human occupation than during the later stages. The cyclic nature of the glacial and interglacial periods led to periodic landscape transformations and generation of specific ecosystems adjusted to particular topographic settings and responding to climatic variations. The initial occupation of the broader Altai region associated with "pebble-tool" industries from alluvial formations likely occurred during some of the Middle Pleistocene interglacials accompanying the northern expansion of the temperate zone and biota. Mixed coniferous and broadleaf forests established in the tectonically active mountain zone with elevations of 1500-2000 m and parklands in the adjacent plains and continental basins provided a wide range of occupation habitats. There is limited evidence for persistence of Early Palaeolithic inhabitation during glacial stages due to inhospitable periglacial conditions. The last interglacial warming, indicated by re-colonization of southern Siberia by coniferous taiga forests, is linked with the appearance of the Mousterian tradition. Changes in the relief configuration influenced the local climate regime and opened new habitats for the Middle Palaeolithic population concentrated in the transitional zones of 500-1000 m elevation in the karstic area of the NW Altai foothills. Occupation of the central and southern Altai during the early last glacial was impeded by harsh, ice-marginal environments and expansion of glaciers in the valleys filled by large proglacial lakes. Progressive warming during the early mid-last glacial interstadial stage (59-35 ka BP) caused wasting of the ice fields accompanied by cataclysmic releases of ice-dammed lakes and large-scale erosional processes. Periodic outbursts of the glacial basins had a dramatic impact on the regional ecosystems, also obliterating the earlier cultural records. Appearance of the transitional early Late Palaeolithic stone industries reflects adaptation to mosaic interstadial habitats, including sub-alpine forest, dark coniferous forest, mixed parklands and open steppe. The identical geographical distribution of the Middle and Late Palaeolithic sites and the time-transgressive lithic technologies suggest a regional cultural continuity in the broader Altai area during the Late Pleistocene. Re-establishment of cold tundra-steppe and tundra-forest habitats correlates with the Late Palaeolithic horizon with developed stone industries dominated by blade-flaking techniques. These techniques possibly survived in more protected locations characterized by warm microclimates in the northern Altai throughout the last glacial maximum (20-18 ka BP). Emergence of the microlithic assemblages with wedge-shape cores is linked with a new cultural adjustment in the final stage of the Palaeolithic development responding to transformations of the former periglacial ecosystems towards the end of the Pleistocene.

Comenetz, J. and C. Caviedes. (2002). "Climate variability, political crises, and historical population displacements in Ethiopia." Global Environmental Change Part B: Environmental Hazards 4(4): 113-127.

This is a case study of the consequences a climatic crisis can have when coinciding with social unrest and political caprice. El Niño events from the 1970s through the 1990s caused extended droughts in Ethiopia. The political and social developments unleashed in Ethiopia by drought and famine did not end in the subsequent years, but were, on the contrary, exacerbated by further El Niño events in 1976–77, 1982–83, and 1991–93. These droughts were followed by famine and political turmoil that resulted in radical changes of government, secession, and a massive program of population redistribution. These events also coincided with droughts in Asia and the rest of Africa, such as those that occurred in the wake of the warm ENSO episodes of 1540, 1567–68, 1618–19, 1633–35, 1747, 1772–73, 1812, 1828, 1888–92, 1916–18, and 1927–28. After the El Niño of 1957–58, the coincidence of warm ENSO episodes and droughts in Ethiopia in 1965, 1972–73, 1982–83, 1986, 1991–93, and 1997–98 became quite evident, indicating that these phenomena were becoming more frequent and intense, probably due to contemporary global warming. The climatic component of the Ethiopian tragedy is obvious when considering the impact that the droughts and famines (associated with the two El Niños: 1972–73 and 1982–83) had in influencing political developments and altering population flows in the country. However, this was not the end of the duress and deprivation. During the prolonged warm ENSO event ensued from 1991 to 1993, even though precipitation was not critically low, the distress caused by more than 12 years of dryness and food scarcity—added to the excesses of the Mengistu regime and the fatigue caused by constant warfare—caused a famine that affected 6.7 million people. Cartographic analysis of Ethiopian census data from 1984 and 1994 shows changes in demographic patterns. The consequences of government-imposed migration policies, whose catalyst was the climate variability caused by repeated El Niño events, were changes in the ethnic composition of certain Ethiopian regions and changes in the geographic pattern of population growth.

Conner, J. R. (1994). "Assessing the socioeconomic impacts of climate change on grazing lands." Climatic Change 28(1/2): 143-157.

This paper begins with an introduction to human/grazing land interaction, including its history and a description of the general problems in analysing and assessing human use of this vast resource. The second section provides a review and synopsis of the current state of modelling the socioeconomic aspects of grazing lands. Aspects of biophysical models which can provide useful information on grazing land ecology and variability in the associated resources and

human habitat are discussed. Models assessing human activity in relation to grazing lands are reviewed and a few examples of linkage of biophysical and socioeconomic models into integrated assessments for policy analysis are discussed. Modelling the socioeconomic impacts of climate change is discussed in the last section. Problems encountered in incorporating changes in technology and adaptation to such changes are delineated and a model (FLIPSIM) designed to incorporate technological change is discussed. Methods for incorporating technological change and natural adaptation after climate change are then explored with emphasis on use of macro models as a means of parametrizing region specific micro models. The degree of reliability and resolution needed for models to be useful to policy analysts are assessed and it is argued that coarser resolution models are more efficient. The paper ends with an illustration of one type of analysis of socioeconomic impacts of climate change on grasslands that can be conducted with the current data and methodology using a series of models and a 'representative firm' approach.

Cooman, A., M. Salamanca, et al. (1999). "Influence of different greenhouse adaptation strategies on the greenhouse climate in the Bogota Plateau." Acta Horticulturae(No. 482): 377-384.

Three plastic greenhouses were built some 20 km North of Bogota, Colombia, each of area 1100 m², and with computerized climate registration systems installed. The 3 greenhouses were: a 'traditional' Colombian greenhouse with fixed open ridge and side walls that can be opened manually; a greenhouse with an automated roof ventilation system and polyethylene (PE) climate screen; and a retractable roof greenhouse with an ILS thermal screen and heating by gas combustion. Roses were planted in half of each of the greenhouses. In the first phase, the climate in the greenhouses was evaluated. The plastic greenhouse with automated roof ventilation created a more stable and uniform climate regime during the day, in comparison with the traditional greenhouse. During the night, this greenhouse was 1 deg C warmer than the traditional greenhouse, and air humidity was higher. When the PE climate screen was used, mean average night temperature increased by 2 deg C, while the highest difference in minimum temperature between the greenhouse and outside was 4.8 deg C. An earlier study showed that the climate screen improved the night temperature of a traditional greenhouses by an average 2 deg C, and that this difference increases as night temperature falls. An advantage of the retractable roof greenhouse is the improved radiation regime inside. During the trial this greenhouse had a relatively low day temperature, while during the night the average temperature was 0.7 deg C lower than the plastic greenhouse with automated roof ventilation. Humidity under the thermal screen was always lower than under the PE screen, which has condensed water on the screen at daybreak.

Corobov, R. (2002). "Estimations of climate change impacts on crop production in the Republic of Moldova." *GeoJournal* 57(3): 195-202.

Statistical methods for assessing crop sensitivity and vulnerability to climate change in Moldova were demonstrated and the following procedures were discussed: (1) projections of likely agroclimatic change; (2) assessments of crop sensitivity to climate change; and (3) assessments of the impact of climate change on crops. In order to predict the future agroclimate, key meteorological variables were transformed statistically to correspond to changes in plants' heat and water supply characteristics. Sensitivity of crop production was examined for corn and winter wheat. By combining the agroclimatic changes with crop response, possible impacts have been estimated and form a basis for possible adaptation strategies. It was shown that regional climate change can result in elevated aridity of Moldova's territory, especially during periods of crop growth. Cultivation of cereal crops in new agroclimatic conditions without adaptation measures will negatively affect yields, especially of winter wheat, whose yield decrease may be 18-39% by 2020s and 22-50% by 2050s. Corn yields may increase by 0-3% and 1-6%, respectively. As an example of adaptation, it is shown that the use of an increased number of late hybrids results in a 25-35% increase in corn yields.

Covington, W. W., R. L. Everett, R. Steele, L. L. Irwin, T. A. Daer, and A. N. D. Auclair. (1994). "Historical and anticipated changes in forest ecosystems of the Inland West of the United States." *Journal of Sustainable Forestry* 2(1/2): 13-63.

Euro-American settlement of the Inland West has altered forest and woodland landscapes, species composition, disturbance regimes, and resource conditions. Public concern over the loss of selected species and unique habitats (e.g., old-growth) has caused neglect the more pervasive problem of declining ecosystem health. Population explosions of trees, exotic weed species, insects, diseases, and humans are stressing natural systems. In particular, fire exclusion, grazing, and timber harvest have created anomalous ecosystem structures, landscape patterns, and disturbance regimes that are not consistent with the evolutionary history of the indigenous biota. Continuation of historical trends of climate change, modified atmospheric chemistry, tree density increases, and catastrophic disturbances seems certain. However, ecosystem management strategies including the initiation of management experiments can facilitate the adaptation of both social and ecological systems to these anticipated changes. A fairly narrow window of opportunity - perhaps 15-30 years - exists for land managers to implement ecological restoration treatments.

Cullen, H. M., P. B. de Menocal, S. Hemming, F. H. Brown, T. Guilderson, F. Sirocko. (2000). "Climate change and the collapse of the Akkadian empire: Evidence from the deep sea." *Geology* **28**(4): 379-382.

The Akkadian empire ruled Mesopotamia from the headwaters of the Tigris-Euphrates Rivers to the Persian Gulf during the late third millennium B.C. Archeological evidence has shown that this highly developed civilization collapsed abruptly near 4170 ± 150 calendar yr B.P., perhaps related to a shift to more arid conditions. Detailed paleoclimate records to test this assertion from Mesopotamia are rare, but changes in regional aridity are preserved in adjacent ocean basins. Authors document Holocene changes in regional aridity using mineralogic and geochemical analyses of a marine sediment core from the Gulf of Oman, which is directly downwind of Mesopotamian dust source areas and archeological sites. These results document a very abrupt increase in eolian dust and Mesopotamian aridity, accelerator mass spectrometer radiocarbon dated to 4025 ± 125 calendar yr B.P., which persisted for ~ 300 yr. Radiogenic (Nd and Sr) isotope analyses confirm that the observed increase in mineral dust was derived from Mesopotamian source areas. Geochemical correlation of volcanic ash shards between the archeological site and marine sediment record establishes a direct temporal link between Mesopotamian aridification and social collapse, implicating a sudden shift to more arid conditions as a key factor contributing to the collapse of the Akkadian empire.

Curtis, J. H., D. A. Hodell, and M. Brenner. (1996). "Climate variability on the Yucatan Peninsula (Mexico) during the past 3500 years, and implications for Maya cultural evolution." *Quaternary Research* **46**: 37-47.

Climate variability on the Yucatan Peninsula during the past 3500 yrs is reconstructed from the measurement of $\delta^{18}\text{O}$ in monospecific ostracods and gastropods in a 6.3-m sediment core from Lake Punta Laguna, Mexico. This late Holocene record is divided into three periods based on changes in mean $\delta^{18}\text{O}$ values. From ~ 3310 to $\sim 1785^{14}\text{C}$ yr B.P. (Period I), low mean $\delta^{18}\text{O}$ values indicate relatively wet conditions (i.e., low evaporation to precipitation ratio, E/P). Mean oxygen isotopic values increased $\sim 1785^{14}\text{C}$ yr B.P., and the interval between ~ 1785 and $\sim 930^{14}\text{C}$ yr B.P. (Period II) was distinctly drier than the periods before or after. The climate during the latter part of Period II was persistently dry, with exceptionally arid events centered at ~ 1171 , 1019 , and 943^{14}C yr B.P. (equivalent to 862, 986, and 1051 A.D.). This interval of frequent drought was recorded at several other localities in Mexico and Central America, and coincided with the collapse of Classic Maya civilization. Following the last arid event, $\delta^{18}\text{O}$ values decreased abruptly at $\sim 930^{14}\text{C}$ yr B.P. (beginning of Period III), signaling a return to wetter conditions that have generally prevailed to the present, with the

exception of a dry episode centered at 559¹⁴C yr B.P. (1391 A.D.). The paleoclimatic record from Punta Laguna provides evidence that multi-decadal and millennial-scale changes in E/P occurred on the Yucatan Peninsula during the late Holocene. These wet/dry episodes may have influenced cultural evolution in Mesoamerica.

Curtis, J.H., M. Brenner, D. A. Hodell, R. A. Balser, G. A. Islebe, H. Hooghiemstra. (1998). "A multi-proxy study of Holocene environmental change in the Maya Lowlands of Peten, Guatemala. Journal of Paleolimnology **19**(2): 139-159.

Authors used multiple variables in a sediment core from Lake Peten-Itza, Peten, Guatemala, to infer Holocene climate change and human influence on the regional environment. Multiple proxies including pollen, stable isotope geochemistry, elemental composition, and magnetic susceptibility in samples from the same core allow differentiation of natural versus anthropogenic environmental changes. Core chronology is based on AMS ¹⁴C measurement of terrestrial wood and charcoal and thus avoids the vagaries of hard-water-lake error. During the earliest Holocene, prior to ~9000 ¹⁴C yr BP, the coring site was not covered by water and all proxies suggest that climatic conditions were relatively dry. Water covered the coring site by ~9000 ¹⁴C yr BP, coinciding with filling of other lakes in Peten and farther north on the Yucatan Peninsula. During the early Holocene (~9000 to ~6800 ¹⁴C yr BP), pollen data suggest moist conditions, but high $\delta^{18}\text{O}$ values are indicative of relatively high E/P. This apparent discrepancy may be due to a greater fractional loss of the lake's water budget to evaporation during the early stages of lake filling. Nonetheless, conditions were moist enough to support semi-deciduous lowland forest. Decrease in $\delta^{18}\text{O}$ values and associated change in ostracod species at ~6800 ¹⁴C yr BP suggest a transition to even moister conditions. Decline in lowland forest taxa beginning ~5780 ¹⁴C yr BP may indicate early human disturbance. By ~2800 ¹⁴C yr BP, Maya impact on the environment is documented by accelerated forest clearance and associated soil erosion. Multiple proxies indicate forest recovery and soil stabilization beginning ~1100 to 1000 ¹⁴C yr BP, following the collapse of Classic Maya civilization.

Dalfes, H. N., G. Kukla, H. Weiss, eds. (1997). Third Millennium BC Climate Change and Old World Collapse: Its Impacts on the Old World Social Systems (Nato Asi Series. Series I, Global Environmental Change, Vol 49). Springer-Verlag Telos, Berlin Heidelberg. 728 pp.

Around 4000 years ago the advanced urban civilizations in Egypt, Mesopotamia and India suddenly collapsed. What happened? Did a prolonged drought cause the breakdown of social order? Recent discoveries from all over the

world strongly support the suspected link of the collapse with climate. The volume presents the findings of more than 40 researchers and provides a review on the relevant information. It appears that a major shift of the precipitation pattern affected many parts of the world at approximately the same time, with disastrous effects on the nomadic populations of Asia, Africa and Eastern Europe. Can a similar climate shift with a serious adverse impact on society happen again? In a world facing global warming, there could be many lessons to be learned from the experiences of ancient societies.

Dang, H. H., A. Michaelowa, D. D. Tuan. (2003). "Synergy of adaptation and mitigation strategies in the context of sustainable development: the case of Vietnam." Climate Policy 3(Supplement 1): S81-S96.

An emerging topic in current climate negotiations is the political momentum for recognising adaptation to climate change as a crucial part of a comprehensive climate policy. However, there are a number of arguments and doubts raised by politicians, negotiators and environmentalists alike with regard to the necessity of implementing adaptation in parallel with mitigation. The first aim of this article is to analyse possible contradictions and synergies between these two strategies and analyse the implications for developing countries and sustainable development targets. Authors then use Vietnam as a case study to demonstrate how to integrate mitigation and adaptation strategies that can provide additional benefits to the social welfare. This empirical analysis provides a basic understanding of how to address thorny questions in a nascent process of designing public climate policy in Vietnam. Lessons drawn from this research should be replicable in other developing countries having similar circumstances.

Dankelman, I. (2002). "Climate change: learning from gender analysis and women's experiences of organising for sustainable development." Gender and Development 10(2): 21-29.

This article argues that climate change not only requires major technological solutions, but also has political and socio-economic aspects with implications for development policy and practice. Questions of globalisation, equity, and the distribution of welfare and power underlie many of its manifestations, and its impacts are not only severe, but also unevenly distributed. There are some clear connections, both positive and negative, between gender and the environment. This paper explores these linkages, which help to illustrate the actual and potential relationships between gender and climate change, and the gender-specific implications of climate change. It also provides examples of women organising for change around sustainable development issues in the build-

up to the World Summit on Sustainable Development (WSSD), and demonstrates how women's participation can translate into more gender-sensitive outcomes.

Davidson, D. J., T. Williamson, J. R. Parkins. (2003). "Understanding climate change risk and vulnerability in northern forest-based communities." Canadian Journal of Forest Research **33**(11): 2252-2261.

Much research attention regarding climate change has been focused on the macrophysical and, to a lesser extent, the macrosocial features of this phenomenon. An important step in mitigation and adaptation will be to examine the ways that climate change risks manifest themselves in particular social localities. Certain social groups may be at greater risk, not solely because of their geographic location in a region of high climate sensitivity but also because of economic, political, and cultural characteristics. Combining the insights of economics and sociology, authors provide an ideal-type model of northern forest-based communities that suggests that these communities may represent a particularized social context in regard to climate change. Although scientific research indicates that northern forest ecosystems are among those regions at greatest risk to the impacts of climate change, the social dimensions of these communities indicate both a limited community capacity and a limited potential to perceive climate change as a salient risk issue that warrants action. Five features of forest-based communities describe this context in further detail: (i) the constraints on adaptability in rural, resource-dependent communities to respond to risk in a proactive manner, (ii) the national and international identification of deforestation as a central causal mechanism in the political arena, (iii) the nature of commercial forestry investment planning and management decision-making, (iv) the potential by members of these communities to underestimate the risk associated with climate change, and (v) the multiplicity of climate change risk factors in forest-based communities.

Davis, M. (2001) Late Victorian Holocausts El Niño Famines and the Making of the Third World. Verso, London, 474 pp.

In this passionate discussion of interactions among climate, economics, and politics, author argues that the widespread catastrophic crop failures of the late 19th-century led not only to tens of millions of deaths but also to the deepened division of humanity into haves and have-nots.

Davis, M. B. and R. G. Shaw (2001). "Range Shifts and Adaptive Responses to Quaternary Climate Change." Science **292**(5517): 673-679.

Tree taxa shifted latitude or elevation range in response to changes in Quaternary climate. Because many modern trees display adaptive differentiation in

relation to latitude or elevation, it is likely that ancient trees were also so differentiated, with environmental sensitivities of populations throughout the range evolving in conjunction with migrations. Rapid climate changes challenge this process by imposing stronger selection and by distancing populations from environments to which they are adapted. The unprecedented rates of climate changes anticipated to occur in the future, coupled with land use changes that impede gene flow, can be expected to disrupt the interplay of adaptation and migration, likely affecting productivity and threatening the persistence of many species.

de Loe, R., R. Kreuzwiser, L. Moraru. (2001). "Adaptation options for the near term: climate change and the Canadian water sector." Global Environmental Change **11**(3): 231-245.

Climate change poses significant challenges for the Canadian water sector. This paper discusses issues relating to the selection of proactive, planned adaptation measures for the near term (next decade). A set of selection criteria is offered, and these are used in three cases to illustrate how stakeholders can identify measures appropriate for the near term. Cases include municipal water supply in the Grand River basin, Ontario; irrigation in southern Alberta; and commercial navigation on the Great Lakes. In all three cases, it is possible to identify adaptations to climate change that also represent appropriate responses to existing conditions; these should be pursued first.

Demarest, A. (2004). Ancient Maya: The Rise and Fall of a Rainforest Civilization. Cambridge University Press, UK, 390 pp.

Buried beneath the jungle vegetation lie sprawling ruined palaces of fine masonry architecture, still magnificent and beautiful despite the ravages of over a millennium. Scattered between the palaces rise great stone temples, some towering over the level of the dense jungle canopy of mahogany, cedar, and ceiba that reaches two hundred feet above the forest floor. On and between the palaces and temples lie scattered slabs of stone exquisitely carved with elaborate scenes and inscriptions. On these eroded and broken monuments, the complex imagery that remains intact struggles against time to reveal its esoteric secrets. The scattered masonry and rubble of what were once the warm family homes of peasants and the elegant palaces of nobles are strewn for miles into the sea of jungle that stretches in all directions.

Such is the popular image, and the physical reality, of the ruined centers of the ancient Maya. From many centuries before Christ to about AD 900, the lowland Maya civilization achieved its apogee in the Petén forest of northern Guatemala and the adjacent portions of Mexico, Belize, and western Honduras, what today

we call the “Maya lowlands”. For over 1,500 years, this region was covered by a network of kingdoms dominated by “holy lords,” sacred kings who were linked by complex ties of kinship, ritual, trade, and military alliance. Their political and religious centers included great acropoli of massed palaces, temples, stone tombs, and ballcourts. These centers of power and pageantry were supported by nearby populations of thousands of farmers who practiced a complex system of rain forest agriculture – a system which only now is beginning to be understood. Maya monuments displayed remarkable achievements in astronomy, mathematics, and calendrics, as well as an elaborate cosmology and a volatile and violent political history. The accomplishments of the ancient Maya still astonish us today and the decline and disappearance

For nearly two centuries we have been fascinated by the mystery and romance of the archaeology of the ancient Maya civilization. Nineteenth-century explorers found the Maya stone palaces, temples, ballcourts, and monuments buried beneath the dense vegetation of the jungle canopy. The romantic popular scenario was completed by the ancient Maya’s enigmatic, only partially deciphered, hieroglyphic-inscribed monuments, and by their royal tombs filled with treasures of art and precious jade. Then we have the evidence, much debated, of a sudden and unexplained collapse for this sophisticated, literate civilization. The mysteries of ancient lowland Maya civilization have inspired the many “lost jungle cities” of fiction and film, which combine Classic Maya features with an incongruous montage of stylistic elements from other cultures.

One such central challenge has been the very presence of this high civilization in a “rain forest” (technically not a true rain forest but a “humid subtropical forest”). In general, jungles have been perceived by the public as the realm of less complex peoples – “tribes” or even “savages.” Theory in the social sciences has differed from this popular perception more in style than in substance, since scholars, too, have been puzzled by the presence of this complex society in a rain forest environment. Historians and archaeologists traditionally had looked to highland basins or to desert river valleys for the heartlands of civilizations. Such environments had the proper settings to apply the alleged “prime movers” for the development of complex society; that is, settings with factors that demanded centralized management, such as irrigation, conflict over limited land or water, control of trade routes, and so on. The rise of civilization in a rain forest was baffling, given the few navigable rivers, no obvious need for irrigation, and no apparent need for centralized forms of agricultural management. The rain forest setting of the Maya continues to challenge our interpretations and an understanding of this environment is central to any accurate view of Maya civilization and its long history.

deMenocal, P. B. (2001). "Cultural Responses to Climate Change During the Late Holocene." *Science* **292**(5517): 667-673.

Modern complex societies exhibit marked resilience to interannual-to- decadal droughts, but cultural responses to multidecadal-to-multicentury droughts can only be addressed by integrating detailed archaeological and paleoclimatic records. Four case studies drawn from New and Old World civilizations document societal responses to prolonged drought, including population dislocations, urban abandonment, and state collapse. Further study of past cultural adaptations to persistent climate change may provide valuable perspective on possible responses of modern societies to future climate change.

Denham, T. P., S. G. Haberle, C. Lentfer, R. Fullagar, J. Field, M. Therin, N. Porch, B. Winsborough, B. (2003). "Origins of agriculture at Kuk swamp in the highlands of New Guinea." *Science* **301**: 189-193.

Multidisciplinary investigations at Kuk Swamp in the Highlands of Papua New Guinea show that agriculture arose independently in New Guinea by at least 6950 to 6440 calibrated years before the present (cal yr B.P.). Plant exploitation and some cultivation occurred on the wetland margin at 10,220 to 9910 cal yr B.P. (phase 1), mounding cultivation began by 6950 to 6440 cal yr B.P. (phase 2), and ditched cultivation began by 4350 to 3980 cal yr B.P. (phase 3). Clearance of lower montane rainforests began in the early Holocene, with modification to grassland at 6950 to 6440 cal yr B.P. Taro (*Colocasia esculenta*) was utilized in the early Holocene, and bananas (*Musa* spp.) were intensively cultivated by at least 6950 to 6440 cal yr B.P.

The oldest archaeological features at Kuk (phase 1) are pits, stakeholes, postholes, and runnels that are restricted to slightly elevated and better-drained levées of a paleochannel. These features are consistent with planting, digging, and tethering of plants and localized drainage in a cultivated plot and are interpreted to represent a single period of shifting cultivation on the wetland edge. The paleochannel is dated to 10,220 to 9910 cal yr B.P., and two dates from a feature on an adjacent surface are slightly earlier and later than this date, respectively. Based on functional associations among these features and their ages, authors interpret them to be contemporaneous. The use of the wetland margin at this time was not specialized and represents the spatial extension of shifting cultivation practices (that is, dryland practices) onto the wetland margin during a drier period.

The phase 2 palaeosurface consists of the preserved circular and subcircular bases of regularly distributed mounds, as well as less organized features. Phase 3 is composed of sequential ditch networks that articulate with major drainage channels, and an earlier curvilinear feature has also been included in this phase.

The earliest ditch networks are rectilinear, similarly aligned, and contain similar fill types. These early ditch networks date to ~4350 to 3980 cal yr B.P. and pre-date R ash (dated to 3980 to 3630 cal yr B.P.). Late ditch networks are older than 3260 to 2800 cal yr B.P. and the deposition of an overlying tephra, Y ash.

Younger ditches form more complex networks that exhibit dendritic, rectilinear, and triangular arrangements. Major drainage channels articulate with both early and late networks; for example, channel 107 pre-dates the deposition of a diagnostic tephra (R ash) and articulates with two ditches of the early subphase and one ditch of the late subphase. The innovation of ditching indicates a further refinement of, and reliance on, wetland cultivation within resource-poor anthropogenic grassland.

Denton, G. H., Alley, R. B., Comer, G. C. and Broecker, W. S. (2005). "The role of seasonality in abrupt climate change." Quaternary Science Reviews **24**(10-11): 1159-1182.

A case is made that seasonality switches dominated by wintertime were instrumental in abrupt climate changes in the North Atlantic region during the last glaciation and into the Holocene. The primary evidence comes from mismatches between mean annual temperatures from Greenland ice cores in comparison with snowline changes in East Greenland, northern Europe, and North America. The most likely explanation is a shutdown (or reduction in strength) of the conveyor. This allows the spread of winter sea ice across the North Atlantic, thus causing the northern region to experience much colder winters. Because they mimic the Greenland temperature rather than the snowline signal, changes in the Atlantic Intertropical Convergence Zone and the Asian monsoon may also share a winter linkage with Greenland. Thus the paleoclimate record is consistent with the notion that a huge continental sector of the Northern Hemisphere, stretching from Greenland to Asia, was close to an extreme winter threshold during much of the last glaciation. Winter climate crossed this threshold repeatedly, with marked changes in seasonality that may well have amplified and propagated a signal of abrupt change throughout the hemisphere and into the tropics.

Denton, F. (2002). "Climate change vulnerability, impacts, and adaptation: why does gender matter?" Gender and Development **10**(2): 10-20.

Gender-related inequalities are pervasive in the developing world. Although women account for almost 80% of the agricultural sector in Africa, they remain vulnerable and poor. 70% of the 1.3 billion people in the developing world living below the threshold of poverty are women. It is important that the consequences of climate change should not lead already marginalized sections of communities into further deprivation. However, key development issues have been at best 'side-

tracked', and at worst 'blatantly omitted', from policy debates on climate change. The threats posed by global warming have failed to impress on policy makers the importance of placing women at the middle of their 'vision' of sustainable development. This article argues that if climate change policy is about ensuring a sustainable future by combining development and environment issues, it must take into account the interests of all stakeholders. The Global Environment Facility and the Clean Development Mechanism of the Kyoto Protocol can play a role in ensuring sustainable development, provided they are implemented in a way that does not disadvantage women and the poor.

Deotare, B. C., M. D. Kajale, S. N. Rajaguru, S. Kusumgar, A. J. T. Jull, J. D. Donahue. (2004). "Palaeoenvironmental history of Bap-Malar and Kanod playas of western Rajasthan, Thar desert." Proceedings of the Indian Academy of Sciences-Earth and Planetary Sciences **113**(3): 403-425.

Two playas in the arid core of the western margin of the Thar desert viz., Bap-Malar and Kanod, have been investigated using palynology, geomorphology, archaeology, AMS-radiocarbon dating, stable isotopes, evaporite mineralogy and geoarchaeology. The principal objective was to obtain a reliable lithostratigraphy of the playa sediments. These are about 7 m thick in the Bap-Malar and > 2.5 to 3 m thick in the Kanod. AMS C-14 dates of > 15 ka BP on pollen from sediment layers indicates that the Bap-Malar playa possibly existed even during the LGM. These playas were full of water during the early Holocene (8 ka BP - 5.5 ka BP) and were ephemeral during the Pleistocene-Holocene transition and early to mid to late Holocene. The playas dried almost 1000 years earlier than those occurring on the eastern margin. Pollen of graminaceae, henopodiaceae/amaranthaceae, cyperaceae etc. and evaporite minerals like gypsum, halite in the profiles indicate that the playas were surrounded by vegetation dominated by grass and that, they remained brackish to saline even during the mid Holocene, lake full stage. Stable dune surfaces, pediments with regoliths, and gravelly channels of ephemeral streams provided a favorable geomorphic niche for nomadic human activity since similar to 7 ka BP. Though local ecological factors have played an important role in the evolution of the playas, the winter rains, connected with northwesterly depressions, most likely played a vital role in maintaining these playas.

Deshingkar, P. (1998). "Climate change adaptation in India: a case study of forest systems in Himachal Pradesh." International Journal of Environment and Pollution **9**(2/3): 186-197.

Climate-induced changes in the forest sector could have far-reaching consequences for rural communities and the economy in Developing Countries. Despite the many uncertainties involved in predicting impacts, it is sensible to

identify adaptation options now. This case study of the mountainous state of Himachal Pradesh used 2 models to study what might happen to forest structure with climatic change - first a model developed at the Climatic Research Unit of the University of East Anglia (UK) which generated climatic scenarios, and second, a vegetation model developed at Lund University to predict what might happen to the 9 major biomes in Himachal Pradesh (which range from xerophytic woodlands in the lower parts to tundra in the high cold mountains). Subsistence and commercial forest land based activities differ according to altitude/biome. The model simulations predict changes in the location and area of different forest types, and changes in species composition. Commonly suggested adaptation strategies to the changes include the establishment of nature reserves, tree migration corridors and afforestation of waste land. For adaptation measures to be realistic, the needs of different stakeholders with an interest in forest products and services must be addressed. It is recommended that existing programmes to resolve conflicts between different stakeholders be strengthened. Diversification of occupation structures has also been identified as an important strategy to reduce the vulnerability of forest-dependent communities. Additional investment may be required in new areas of research, such as tree genetics programmes, in order to facilitate the selection of species that are resistant to climate change.

Dessai, S., Lu, X. and Risbey, J. S. (2005). "On the role of climate scenarios for adaptation planning. Global Environmental Change Part A **15**(2): 87-97.

Climate scenarios have been widely used in impact, vulnerability and adaptation assessments of climate change. However, few studies have actually looked at the role played by climate scenarios in adaptation planning. This paper examines how climate scenarios fit in three broad adaptation frameworks: the IPCC approach, risk approaches, and human development approaches. The use (or not) of climate scenarios in three real projects, corresponding to each adaptation approach, is investigated. It is shown that the role played by climate scenarios is dependant on the adaptation assessment approach, availability of technical and financial capacity to handle scenario information, and the type of adaptation being considered.

D'Silva, E. (2002). "Participation and empowerment through community institutions: lessons from Adilabad District, Andhra Pradesh." Journal of Rural Development **21**(3): 369-394.

This paper aims to understand how issues relating to participation, empowerment, and sustainability play out in rural areas. It is based on experiences among 5 rural communities in Adilabad district, Andhra Pradesh, India, in January 1998. Five points are emphasized: public participation, empowerment and good

governance are significant tools that can give poor people a way to express their opinions in the affairs of the state and the way money is spent by governments; building community assets can have a positive impact on poverty and help reduce migration to cities; small savings can serve as an effective 'entry point' to other development activities; public institutions can better serve the interests of the poor if they are reoriented; and society and governments should retain the focus on poverty to improve rural livelihoods and to reduce growing social conflicts.

Dethier, J. J. (1999). "Governance and poverty." Quarterly Journal of International Agriculture **38**(4): 293-314.

The paper highlights some of the channels through which governance systems affect poverty and inequality. Governments have a central role to play in creating an environment that gives all individuals the freedom to develop one's capabilities, namely to ensure basic personal protection and security; to provide services such as clean water or basic education; and to foster a climate of equity so that it is possible to carry out collective tasks in spite of ethnic, economic and social differences between groups in society. Evidence from qualitative surveys carried out in 23 countries in 1999 shows that governments in many developing and transition countries fail on all three counts. This paper first reviews the main empirical and analytical macrolinkages between governance and development outcomes. Second, it examines the role of participation of beneficiaries and accountability of officials in the provision of public goods that are relevant for the poor. It stresses the role of corruption and of capture of the state by interest groups in perpetuating poverty and inequality. The paper concludes by discussing some conditions that are necessary for effective governance and the need for a basic level of legal protection for the poor.

Devereux, S. and J. Edwards (2004). "Climate change and food security." IDS Bulletin **35**(3): 22-30.

With an estimated 798 million people currently "undernourished", meeting the Millennium Development Goal of halving hunger by 2015 is already looking difficult. This paper examines how climate change will affect this challenge. Climate change models predict that those likely to be most adversely affected are the regions already most vulnerable to food insecurity, notably Africa, which stands to lose substantial agricultural land. An additional threat is the uncertainty climate change brings, including the negative interactions between gradual and abrupt changes. However, adaptive behaviour and new technology have not been factored into many climate models. It is suggested that if appropriate mitigation and adaptation measures are implemented now, hunger could be substantially reduced, regardless of climate change. But adaptation comes at high economic

cost and those who need it most can afford it least. It is concluded that in order to effectively meet the challenge of climate change, political responses will be just as important as technological change.

Dietz, T., E. Ostrom, P. C. Stern. (2003). "The struggle to govern the commons." Science **302**: 1907-1912.

Human institutions—ways of organizing activities—affect the resilience of the environment. Locally evolved institutional arrangements governed by stable communities and buffered from outside forces have sustained resources successfully for centuries, although they often fail when rapid change occurs. Ideal conditions for governance are increasingly rare. Critical problems, such as transboundary pollution, tropical deforestation, and climate change, are at larger scales and involve nonlocal influences. Promising strategies for addressing these problems include dialogue among interested parties, officials, and scientists; complex, redundant, and layered institutions; a mix of institutional types; and designs that facilitate experimentation, learning, and change.

Dillehay, T. D. (2002). "Climate and Human Migrations." Science **298**(5594): 764-765.

About 14,600 years ago, humans first appeared in south central Chile. But the arid regions of the Atacama desert in northern Chile were not populated for another 2000 years, and human occupation of this region subsequently remained intermittent. In his Perspective, Dillehay highlights the report of Núñez et al., whose integrative archaeological and paleoecological study shows that climate was the key factor in these human migrations. The study illustrates the power of an integrative approach to understanding the relation between human societies and climate change.

Dillehay, T. D. and A. L. Kolata. (2004). "Long-term human response to uncertain environmental conditions in the Andes." PNAS **101**: 4325-4330.

Human interaction with the physical environment has increasingly transformed Earth-system processes. Reciprocally, climate anomalies and other processes of environmental change of natural and anthropogenic origin have been affecting, and often disrupting, societies throughout history. Transient impact events, despite their brevity, can have significant long-term impact on society, particularly if they occur in the context of ongoing, protracted environmental change. Major climate events can affect human activities in critical conjunctures that shape particular trajectories of social development. Here authors report variable human responses to major environmental events in the Andes with a particular emphasis on the period from anno Domini 500–1500 on the desert

north coast of Perú. Preindustrial agrarian societies implemented distinct forms of anticipatory response to environmental change and uncertainty. In conditions of environmental uncertainty and vulnerability, human response can lead to multiple possible outcomes. The forcing factors that drive change to a new response strategy can be either internal or external to the old strategy. Further, the type and degree of response is not determined solely by a centralized or hierarchical political structure. Situational responses derive from reading the cultural and physical landscape at different social, spatial, and temporal scales. Responses to environmental uncertainty are constrained and shaped by human actions that must take into account the landscape-structuring effects of previous strategies and environmental impacts. A defining aspect of complex preindustrial societies in the Andes was the ability to accommodate political and economic strategies to different demographic and social organizational scales. Although contemporary society has evident technological and informational advantages over premodern societies in responding to environmental change, the analysis of past social response to uncertain environmental conditions emphasizes the importance of adaptive strategies and policy-making decisions grounded in a full appreciation of such scalar and landscape structuring effects. Authors conclude that innovations in production strategies and agricultural infrastructures in these indigenous societies reflect differential social response to both transient (El Niño–Southern Oscillation events) and protracted (desertification) environmental change.

Dillehay, T. D., J. Rossen, G. Maggard, K. Stackelbeck, P. Netherly. (2003). "Localization and possible social aggregation in the Late Pleistocene and Early Holocene on the north coast of Perú." Quaternary International **109-110**: 3-11.

Early circular living structures made of rough field stone, radiocarbon dated between 10,800 and 8300 BP, and probably affiliated with the Paiján culture on the north coast of Perú are discussed in terms of possible proto-household economies that are localized and socially aggregated in compressed environmental zones along the lower western slopes of the Andes. The technological, settlement, and economic data recovered from several sites in the Zaña and Jequetepeque Valleys are discussed briefly. Their broader implications are presented as well.

Dillehay, T., A. L. Kolata, M. Pino. (2004). "Pre-industrial human and environment interactions in northern Peru during the late Holocene." The Holocene **14**(2): 272-281.

The result of long-term environmental and human interaction is a variety of potential human responses to major natural crises: population aggregation or dispersal, changes in economic strategies and land-use patterns, restructuring of social organization, increase in the incidence of conflict and warfare, and, in some

instances, urban abandonment and cultural collapse. In the context of pre-industrial societies, two social processes with the greatest potential impact on the environment and on changing human-environmental interaction are urbanization and the development of diversified, regional-scale production systems such as intensive agriculture, pastoralism and exploitation of maritime resources. This paper employs archaeological and geological data from the Jequetepeque and Zana valleys on the north coast desert of Peru to study: (1) the specific responses of Moche, Chimu and Inca societies (c. AD 250-1553) to major episodes of drought, El Niño flooding, and desertification; (2) the social processes of urban-rural relations and economic diversification; and (3) how these processes interacted within the dynamic and north coast. This research focuses on changing palaeoenvironmental regimes, agricultural infrastructures and domestic occupations to explore the complex interplay of cultural and natural forces that shaped the variable human responses and the history of urban-rural systems. Understanding the problem of how pre-industrial systems were sustained or failed in the context of interrelated social and environmental crises is an interdisciplinary objective, one that requires the integration of analytical techniques and theoretical frameworks of both the natural and social sciences as delineated in this study.

Dixon, R. K., J. Smith, Guill, S.. (2003). "Life on the edge: vulnerability and adaptation of African ecosystems to global climate change." Mitigation and Adaptation Strategies for Global Change 8(2): 93-113.

Donor countries are providing financial and technical support for global climate change country studies to help African nations meet their reporting needs under the United Nations Framework Convention on Climate Change (UNFCCC). Technical assistance to complete vulnerability and adaptation assessments includes training of analysts, sharing of contemporary tools (e.g. simulation models), data and assessment techniques, information-sharing workshops and an international exchange programme for analysts. This chapter summarizes 14 African country studies (Botswana, Côte d'Ivoire, Egypt, Ethiopia, the Gambia, Kenya, Malawi, Mauritius, Nigeria, South Africa, Tanzania, Uganda, Zambia and Zimbabwe) assessing vulnerabilities to global climate change and identifying adaptation options. The analysis revealed that the participating African countries are vulnerable to global climate change in more than one of the following socio-economic sectors: coastal resources, agriculture, grasslands and livestock, water resources, forests, wildlife, and human health. This vulnerability is exacerbated by widespread poverty, recurrent droughts, inequitable land distribution, environmental degradation, natural resource mismanagement and dependence on rain-fed agriculture. A range of practical adaptation options were identified in key socio-economic sectors of the African nations analysed. However, underdeveloped human and institutional capacity, as well as the absence

of adequate infrastructure, renders many traditional coping strategies (rooted in political and economic stability) ineffective or insufficient. Future African country studies should be more closely coordinated with development of national climate change action plans.

Dodia, R. (1988). "Holocene vegetation and climate change in Kumaun area based on palynological evidences." Current Science **57**(2): 71-73.

Study of a 5.5 m deep lake core from Naukuchia Tal, India, dating from c.7150 BP, shows a gradual decline in vegetation cover possibly caused by human activity. Some pollen in the profile also provides evidence of man's agricultural activity in the area at that time. Magnetic susceptibility studies show the presence of soil-rich components in the lake sediments which suggest that forest soil was eroded due to lack of forest cover.

Dolukhanov, P. M. (1997). "The Pleistocene-Holocene transition in northern Eurasia: Environmental changes and human adaptations." Quaternary International **41-42**: 181-191.

Following the establishment of Late Palaeolithic occupation during the Last Glacial Maximum, climate change and glacial recession led to the disintegration of the Late Palaeolithic cultures between 15,000 and 10,000 B.P. Extinction of mammoth and other megafauna forced humans to exploit other tundra and forest-tundra species, including enhanced utilization of aquatic resources. Northward migrations co-occurred with the warm Bolling and Allerod events, but much of northern Eurasia remained occupied during the Younger Dryas. Late Glacial sites are commonly located on the crests of large parabolic dunes. Following the initiation of the Holocene, Mesolithic groups in the catchments of the Pripet and Neman occupied riverine sites during the summer, and more permanent winter dwelling in upland areas. In contrast, Mesolithic communities adjacent to the Baltic Sea occupied more permanent estuarine and lacustrine sites, marked by greater resources. During the Holocene Climatic Optimum, the increased biomass led to a marked intensification in foraging by all groups, the development of inter-group contacts, and the initiation of agriculture.

Dominguez-Rodrigo, M., J. A. Lopez-Saez, A. Vincens, L. Alcalá, L. Luque, and J. Serrallonga. (2001). "Fossil pollen from the Upper Humbu Formation of Peninj (Tanzania): hominid adaptation to a dry open Plio-Pleistocene savanna environment." Journal Of Human Evolution **40**(2): 151-157.

Downing, T. E. (1992). Climate change and vulnerable places: global food security and country studies in Zimbabwe, Kenya, Senegal and Chile. Research Report -

Environmental Change Unit, University of Oxford, Oxford UK, Environmental Change Unit, University of Oxford, 54 pp.

This research report summarizes the main results of a collaborative effort to delineate vulnerability and risk of climatic change. The project carried out a global assessment of the sensitivity of crop yields and agricultural production, trade and consumption to scenarios of climatic change. The agricultural effects of climatic change were assessed for societies and regions vulnerable to food poverty due to interactions of climate change, resource constraints, population growth and economic development. Vulnerability to hunger is an aggregate measure of the factors that influence exposure to hunger and predisposition to its consequences. A global assessment and five country studies for Chile, Egypt, Kenya, Senegal and Zimbabwe were taken. In Zimbabwe, shifts in agroclimatic potential would affect national food production and land use. The semi-extensive farming zone, already vulnerable in terms of self-sufficiency and food security, would be further marginalized due to increased risk of crop failure. In Kenya, potential food production would increase with a warmer climate. However, the impact of climate changes on vulnerable socioeconomic groups in the semi-arid areas could be devastating. In Senegal, if agriculture expands and intensifies at a moderate rate, food production can keep pace with projected population growth. Senegal's production of food is less than required by rural populations. Climate change would exacerbate prospects for agricultural development. In Chile the balance of irrigation requirements and water resources in northern Chile is already critical and drought episodes endanger production. The study for Egypt is not included in this research report. Some high potential areas could benefit from warming. Semi-arid areas at the margins of cultivation are sensitive to climate change and the balances of changes in temperature and precipitation could dramatically increase or decrease agricultural potential. For the food-poor at risk of adverse climate change, the fundamental question is who has the right to take the risk that the environmental resources of the world's poor will be altered, to the point their livelihoods are threatened. The complex dynamics of food security and global change hinder our understanding of present vulnerability and the future risk of climate change.

Drabenstott, M. (1992). "Agriculture's portfolio for an uncertain future: preparing for global warming." Economic Review (Kansas City) 77(2): 5-20.

In 1991, the US Department of Agriculture commissioned the Council for Agricultural Science and Technology (CAST) to determine how US agriculture can prepare for global warming. This article summarizes the major findings and recommendations of their report "Preparing US agriculture for global climate change". The report considers: the greenhouse effect and global warming; US

agriculture's contribution to the greenhouse effect; agriculture's potential contribution in reducing greenhouse gases; a portfolio strategy for encouraging adaptation; and a portfolio of flexible climate change assets. The report recommends the strengthening and allowance of greater flexibility with regard to use of the USA's ten major assets for adapting to climate change. These assets are: land; water; a reliable supply of energy; physical infrastructure; research capacity; human resources; political institutions; access to the world market; information systems; and genetic diversity. It is argued that such a portfolio of assets, if assured of flexibility of use, offers the best chance for agriculture to adapt successfully to any climate change.

Driver, J. C. (1998). "Human adaptation at the pleistocene/holocene boundary in Western Canada, 11,000 to 9000 BP." Quaternary International **49-50**: 141-150.

Most of western Canada was covered by ice until about 12,000 BP. Environments suitable for human habitation were established by about 11,500 BP. The earliest known human occupations date to about 10,700 BP. Para-glacial processes may have destroyed most early sites. Post-glacial colonization occurred from the south. Only 14 archaeological sites contain radiocarbon dates earlier than 9000 BP. The limited data from these sites suggest initial exploitation of big game in open environments until about 10,000 BP. Sites dating between 10,000 and 9000 BP are known mainly from the southern interior plains, and document a continuation of bison hunting. Adaptive strategies in early boreal forests are still unknown.

Droogers, P. (2004). "Adaptation to climate change to enhance food security and preserve environmental quality: example for southern Sri Lanka." Agricultural Water Management **66**(1): 15-33.

Adaptation strategies to climate change have been explored using a linked field-scale basin-scale modeling framework for Walawe basin, Sri Lanka. An integrated approach was followed concentrating on enhancement of food security and preservation of environmental quality. Climate change projections were extracted from the Hadley Climate Center (HadCM3) coupled global circulation model (GCM). Impact and adaptation strategies were evaluated with a coupled modeling framework based on the soil-water-atmosphere-plant (SWAP) field scale model and the water and salinity basin model (WSBM) basin scale model. Three time periods were considered where the 1961-1990 period was used to adjust climate change projections to local conditions and to provide a reference to compare expected changes in the near future (2010-2039) and distant future (2070-2099). The overall impact of climate change on food security and environmental quality appears to be positive as a result of enhanced crop growth

due to higher CO₂ levels and a small increase in precipitation. However, extremes will be more profound in the future, making adaptation strategies necessary. Results from the modeling framework have been presented in a format accessible to water resources managers and policy makers to enable them to make sound decisions on the required adaptation strategies.

Dull, R. A. (2004) An 8000-year record of vegetation, climate, and human disturbance from the Sierra de Apaneca, El Salvador. Quaternary Research **61**(2): 159-167.

An similar to 8000-cal-yr stratigraphic record of vegetation change from the Sierra de Apaneca, El Salvador, documents a mid-Holocene warm phase, followed by late Holocene cooling. Pollen evidence reveals that during the mid-Holocene (similar to 8000-5500 cal yr B.P.) lowland tropical plant taxa were growing at elevations similar to 200-250 m higher than at present, suggesting conditions about 1.0 degrees C warmer than those prevailing today. Cloud forest genera (*Liquidambar*, *Juglans*, *Alnus*, *Ulmus*) were also more abundant in the mid-Holocene, indicating greater cloud cover during the dry season. A gradual cooling and drying trend began by similar to 5500 cal yr B.P., culminating in the modern forest composition by similar to 3500 cal yr B.P. A rise in pollen from weedy plant taxa associated with agriculture occurred similar to 5000 cal yr B.P., and pollen from *Zea* first appeared in the record at similar to 4440 cal yr B.P. Human impacts on local vegetation remained high throughout the late Holocene, but decreased abruptly following the Tierra Blanca Joven (TBJ) eruption of Volcan Llopango at similar to 1520 cal yr B.P. The past 1500 years are marked by higher lake levels and periodic depositions of exogenous inorganic sediments, perhaps indicating increased climatic variability.

Duncan, M. T. and S. M. Horvath (1988). "Physiological adaptations to thermal stress in tropical Asians." European Journal of Applied Physiology and Occupational Physiology **57**(5): 540-544.

Young sedentary adult males of Malay, Indian, and Chinese origin who had established continuous residence in tropical Malaysia and presumed to be naturally acclimatized to heat, were studied to evaluate their physiological responses to a standard heat stress test. The Malay and Indian races have evolved in hot and humid geographical zones, whereas the Chinese originated from a temperate area. Subjects exercised at 50% VO₂max alternating 18 minutes walking and 2 min rest during a 2-h exposure to an ambient of 34.9 degrees C dry bulb and 32.1 degrees C wet bulb. Heart rates, core and skin temperatures, sweat rates, and oxygen uptakes were measured during the heat exposure. The subjects of Malay origin exhibited the least circulatory stress of the three ethnic groups. The data obtained

on these long-term residents of a hot-wet climate and who were considered acclimatized to this environment were compared to experimental data obtained by other investigators and other ethnic groups.

Dutta, P. K. and R. Radner. (2004). "Self-enforcing climate-change treaties." PNAS **101**: 5174-5179.

In the absence of world government, an effective treaty to control the emissions of greenhouse gases should be self-enforcing. A self-enforcing treaty has the property that, if a country expects other countries to abide by the treaty, it will be in the self-interest of that country to abide by the treaty too. (A difficulty with the Kyoto Protocol is that it does not appear to lay the groundwork for a self-enforcing treaty). The Kyoto Protocol appears not to have been the basis of a self-enforcing treaty, principally because it did not build in any effective sanctions that would be applied if countries failed to meet their targets. A self-enforcing treaty can be modeled as a Nash equilibrium of a suitably defined dynamic game among a large number of sovereign countries of diverse sizes and economic capabilities. Authors study such a game and characterize its equilibria (typically there are many) and the global-Pareto-optimal solutions. They identify one of the equilibria, which we call "business as usual," with the current situation. The multiplicity of equilibria provides an opportunity to move from the inefficient business-as-usual equilibrium to one or more equilibria that are Pareto-superior. Using a calibrated model with 184 countries, authors give numerical illustrations of business-as-usual and global-Pareto-optimal trajectories and estimate the potential welfare gains from a self-enforcing treaty. Some writers have advocated the use of trade sanctions to help enforce a climate-change treaty, which would expand the set of instruments available for reaching an equilibrium. However, use of trade sanctions would merge two "international games" that have hitherto remained rather separate, and achieving an equilibrium in the larger game would require negotiating a new treaty in a larger and more complex context. Another approach would be to create an "International Bank for the Environment." Such a bank could provide a mechanism for some countries to aid other countries in the reduction of emissions and emission factors, with such aid being placed in escrow with the Bank and paid to the recipients in stages on completion of the required actions. Analysis of such a model is needed.

Dvorák, V., J. Hladný, L. Kaspárek, L. (1996). "Climate change hydrology and water resources impacts and adaptation for selected river basins in the Czech Republic." International Journal of Water Resources Development **12**(2): 181-192.

To study potential impacts of climate change on the hydrological system and water resources, four river basins were selected from the Czech Republic. To

simulate potential changes in runoff, three hydrological models were applied using incremental and General Circulation Models scenarios: the BILAN water balance model, the SACRAMENTO (SAC-SMA) conceptual model and the CLIRUN water balance model. After comparison of the results, the BILAN model was selected to serve for subsequent analyses of hydrological systems in the river basins. The methods applied and the results of the assessments were reviewed, and suggestions for general adaptation policy options presented where the preference is for non-structural measures such as water conservation, efficient water demand management and protection of water resources.

Easterling, W. E. (1996). "Adapting North American agriculture to climate change in review." Agricultural and Forest Meteorology **80**(1): 1-53.

The adaptability of North American agriculture to climatic change is assessed through a review of current literature. A baseline of North American agriculture without climate change suggests that farming faces serious challenges in the future (e.g. declining domestic demand, loss of comparative advantage and rising environmental costs). Climatic change adjustments at the farm level and in government policy, including international trade policy, are inventoried from the literature. The adaptive potential of agriculture is demonstrated historically with situations that are analogous to climate change, including the translocation of crops across natural climatic gradients, the rapid introduction of new crops such as soyabeans in the US and rape in Canada, and resource substitutions prompted by changes in prices of production inputs. A wide selection of modelling studies is reviewed which suggests several agronomic and economic adaptation strategies that are available to agriculture. Agronomic strategies include changes in crop cultivars and species, timing of operations, and land management including irrigation. Economic strategies include investment in new technologies, infrastructure and labour, and shifts in international trade. Overall, such agronomic strategies were found to offset either partially or completely the loss of productivity caused by climatic change. Economic adaptations were found to render the agricultural costs of climatic change small by comparison with the overall expansion of agricultural production. New avenues of adaptive research are recommended including the formalization of the incorporation of adaptation strategies into modelling, linkage of adaptation to the terrestrial carbon cycle, anticipation of future technologies, attention to scaling from *in situ* modelling to the landscape scale, expansion of data sets and the measurement and modelling of unpriced costs. The final assessment is that climatic change should not pose an insurmountable obstacle to North American agriculture.

Easterling, W. E., N. Chhetri, X. Z. Niu. (2003). "Improving the realism of modeling agronomic adaptation to climate change: simulating technological substitution." Climatic Change **60**(1/2): 149-173.

The purpose of the paper is to propose and test a new approach to simulating farmers' agronomic adaptation to climate change based on the pattern of adoption of technological innovation/substitution over time widely described as a S-shaped (or logistic) curve, i.e., slow growth at the beginning followed by accelerating and then decelerating growth, ultimately leading to saturation. The approach authors developed is tested using the Erosion Productivity Impact Calculator crop model applied to corn production systems in the southeastern U.S. using a high-resolution climate change scenario. Corn is the most extensively grown crop in the southeastern U.S. The RegCM limited area model nested within the CSIRO general circulation model generated the scenario. Authors compare corn yield outcomes using this new form of adaptation (logistic) with climatically optimized (clairvoyant) adaptation. The results show logistic adaptation to be less effective than clairvoyant adaptation in ameliorating climate change impacts on yields, although the differences between the two sets of yields are statistically significant in one case only. These results are limited by the reliance on a single scenario of climate change. Authors conclude that the logistic technique should be tested widely across climate change scenarios, crop species, and geographic areas before a full evaluation of its effect on outcomes is possible.

Edwards, M. (1999). "NGO performance - What breeds success? New evidence from South Asia." World Development **27**(2): 361-374.

What is the best way for nongovernment organisations (NGOs) to make a lasting impact on poverty? This paper summarizes the findings of recent research into the impact, sustainability and cost-effectiveness of two NGOs in India and two projects implemented by Save the Children Fund-UK in Bangladesh. The factors determining performance are explored through the interaction of organizational decisions with the external context. Although these interactions are complex and dynamic, some clear conclusions emerge. Making a difference to livelihoods and capacities among poor people depends on NGO successes in fostering autonomous grassroots institutions and linking them with markets and political structures at higher levels. These conclusions question the current predilection among donor agencies to fund large-scale NGO service delivery.

El-Fadel, M. and E. Bou-Zeid (2003). "Climate change and water resources in the Middle East: vulnerability, socio-economic impacts and adaptation." In, C. Giupponi and M. Shechter, eds. Climate change in the Mediterranean: socio-

economic perspectives of impacts, vulnerability and adaptation. Cheltenham, UK, Edward Elgar Publishing Ltd. Pages 53-74.

The potential impacts of climatic change on water resources in the Middle East region are discussed, with simulations of climatic change predictions from several general circulation models (GCMs) used to evaluate impacts on water resources. Tabulated data are given showing some impacts on the biophysical and socioeconomic aspects of water resources expected with changing climate, as well as the socioeconomic indicators, annual water resources in some Middle East countries (viz., Iraq, Israel, Jordan, Lebanon, Palestinian Authority and Syria), current and projected water demand for the region, and climatic change parameters. Finally, socioeconomic implications of the projected impacts are outlined and technical adaptation measures and non-conventional water resources are addressed in the context of regional analysis.

Enzel, Y., L. L. Ely, S. Mishra, R. Ramesh, R. Amit, B. Lazar, S. N. Rajaguru, V. R. Baker, A. Sandler. (1999). "High-resolution Holocene environmental changes in the Thar desert, northwestern India." Science **284**: 125-128.

Sediments from Lunkaransar dry lake in northwestern India reveal regional water table and lake level fluctuations over decades to centuries during the Holocene that are attributed to changes in the southwestern Indian monsoon rains. The lake levels were very shallow and fluctuated often in the early Holocene and then rose abruptly around 6300 carbon-14 years before the present (^{14}C yr B.P.). The lake completely desiccated around 4800 ^{14}C yr B.P. The end of this 1500-year wet period coincided with a period of intense dune destabilization. The major Harrapan-Indus civilization began and flourished in this region 1000 years after desiccation of the lake during arid climate and was not synchronous with the lacustral phase... This drying phase precedes by 800 to 1000 years the rise of the Early and Mature Harappan phases of the Indus civilization from 4100 to 3500 ^{14}C yr B.P. (2600 to 2000 B.C.). This contradicts the climate-culture hypothesis for northwestern India and Pakistan. Improved climatic conditions did not lead to the rise of this major urban civilization, as has been suggested. The collapse of the Indus culture in 3400 to 3300 ^{14}C yr B.P. (1700 to 1900 B.C.) has been attributed to a change to a more arid climate at the end of the middle Holocene wet period. Our chronology indicates that there is no relation between the proposed drought that caused the desiccation of the lakes and the collapse of the Indus culture, as the lakes dried out >1500 years earlier. The wet climate-Indus civilization relationship was previously challenged, but it remains a prime example of a climate-civilization relationship]. The Indus civilizations flourished mainly along rivers during times when northwestern India experienced semiarid climatic conditions that are similar to those at present.

Erda, L. (1996). "Agricultural vulnerability and adaptation to global warming in China." Water, Air, and Soil Pollution **92**(1/2): 63-73.

This paper discusses the vulnerability and adaptation of the agricultural sector of China to global warming. Based on Chinese agricultural and general circulation model trends, adverse impacts on China's agriculture caused by a warming and drying climate were identified. Because of limited irrigation potential, the sustainable development of Chinese agriculture will be difficult. Six sensitive agricultural areas located on the edges of different agroecological zones, and seven provinces with high vulnerability to the impacts on agriculture, were identified. On the basis of an estimation of the potential supply of agricultural products and demand for food, the annual incremental costs for adaptation to climate change would be \$800-\$3480 million; without adaptation, the annual agricultural loss due to global warming would be \$1370-\$79 980 million from 2000 to 2050. Adaptive measures discussed include intensive management and the possibility of a tripartite structure of planting that would entail coordinated development of grain crops, feed crops and cash crops.

Erickson, C.L. (1999). "Neo-environmental determinism and agrarian 'collapse' in Andean prehistory." Antiquity **73**(281): 634-642.

In early anthropology, environmental determinism was used to explain race, human demography, material culture, cultural variation and cultural change. As anthropological interpretation evolved, simplistic reductionist thinking was replaced with more complex socio-cultural explanations. Despite these theoretical advances, environmental determinism continues to be invoked to explain Andean prehistory. The rise and fall of Andean civilizations are 'mapped onto' sediment cores, pollen diagrams and ice cores and somehow this 'explains' cultural change. In the extreme incarnations of neo-environmental determinism, humans are considered passive pawns at the mercy of droughts and floods. Author evaluates a recent hypothesis proposed to explain the collapse of the Tiwanaku State and raised-field agriculture from a landscape perspective informed by a 'bottom-up approach' to Pre-Columbian farming systems, the ethnography of wetland peoples and insights from the New Ecology.

Etterson, J. R. and R. G. Shaw (2001). "Constraint to Adaptive Evolution in Response to Global Warming." Science **294**(5540): 151-154.

Authors characterized the genetic architecture of three populations of a native North American prairie plant in field conditions that simulate the warmer and more arid climates predicted by global climate models. Despite genetic variance for traits under selection, among-trait genetic correlations that are antagonistic to the direction of selection limit adaptive evolution within these

populations. Predicted rates of evolutionary response are much slower than the predicted rate of climate change.

Fagan, B. (1999). Floods, Famines, and Emperors: El Niño and the Fate of Civilizations. New York: Perseus Books Group, 284 pages.

In 1997 and 1998, one of the most powerful El Ninos ever recorded disrupted weather patterns all over the world. Europe suffered through a record freeze as the American west was hit with massive floods and snow-storms; in the Western Pacific, meanwhile, some island nations literally went bone dry and had to have water flown in on transport planes. In this book, archaeologist Brian Fagan shows that such effects are not new - El Nino has been disrupting weather patterns on and off for at least 5000 years, sometimes with catastrophic effects on civilizations. El Nino-driven droughts have brought on the collapse of dynasties in Egypt; El Nino monsoon failures have caused historic famines in India; and El Nino floods have destroyed whole civilizations in Peru and changed the course of European exploration. These events were not isolated but had a lasting influence on the later course of these civilizations for centuries. Table of contents include: (1) The Christmas Child: The Great Visitation; Guano Happens; ENSO; The North Atlantic Oscillation; (2) El Niños in Antiquity: A Time of Warming; Pharaohs in Crisis; The Moche Lords; The Classic Maya Collapse; The Ancient Ones (3) Climate Change and The Stream of Time: The Little Ice Age; "Drought Follows the Plow"; El Niños That Shook the World; The Fate of Civilizations.

Fagan, B. (2004). The Long Summer: How Climate Changed Civilization. Basic Books, New York, NY. 320 pages.

Humanity evolved in an Ice Age in which glaciers covered much of the world. But starting about 15,000 years ago, temperatures began to climb. Civilization and all of recorded history occurred in this warm period, the era known as the Holocene-the long summer of the human species. In The Long Summer, Brian Fagan brings us the detailed record of climate change during these 15,000 years of warming, and shows how this climate change gave rise to civilization. A thousand-year chill led people in the Near East to take up the cultivation of plant foods; a catastrophic flood drove settlers to inhabit Europe; the drying of the Sahara forced its inhabitants to live along the banks of the Nile; and increased rainfall in East Africa provoked the bubonic plague. The Long Summer illuminates for the first time the centuries-long pattern of human adaptation to the demands and challenges of an ever-changing climate-challenges that are still with us today.

Fall P.L., L. Lines, S. E. Falconer. (1998). "Seeds of civilization: Bronze Age rural economy and ecology in the Southern Levant." Annals of the Association of American Geographers **88**(1): 107-125.

This paper considers the economic and environmental impacts of emerging regional commerce that accompanied the rise and collapse of early Near Eastern urbanism. Authors integrate regional data on settlement and vegetation with detailed evidence of rural agriculture from two Bronze Age villages in the Jordan Valley. This approach is explicitly rural, in light of the largely rural character of Levantine civilization, and in response to more orthodox analytical perspectives focused on the first cities. Long-standing interest in the advent of agriculture now reveals that intensive localized depletion of woodland resources followed the aggregation of sedentary agrarian communities in the eighth through sixth millennia B.C., while the development of specialized pastoralism established one potential source of more extensive, subsequent defoliation. Authors argue, however, that regional human impacts on Levantine vegetation were triggered only with the genesis of Bronze Age cities and urbanized economies in the third and second millennia B.C. Thereafter, these regional impacts molded an ever-shifting mosaic of anthropogenic and natural landscapes. Rank-size analysis illustrates the modestly integrated, largely rural nature of Bronze Age settlement in the southern Levant. In this context, Tell Abu en-Ni`aj and Tell el-Hayyat provide appropriate examples of the resilient agrarian villages that persisted through the dramatic collapse and rebirth of early Levantine cities. Excavated plant remains and animal bones show that their inhabitants responded to the development of Bronze Age urbanism with a shift toward increased management of taxa with greater market potential, tempered by some retention of local economic autonomy. Shifts to greater sheep husbandry and, most significantly, cultivation of orchard crops like olives, figs, and grapes, signal a second wave of economic innovation that fundamentally altered the agricultural strategies of village farmers and their exploitation of the surrounding countryside. Thus the mixed cultural and natural landscapes that have supported long-term agriculture in the Levant reflect a legacy of discontinuous changes in rural economy and ecology in response to the waxing and waning of urbanized society and regional mercantile exchange.

Fankhauser, S., J. B. Smith, R. S. J. Tol. (1999). "Weathering climate change: some simple rules to guide adaptation decisions." Ecological Economics **30**(1): 67-78.

This paper discusses some of the elements that may characterise an efficient strategy to adapt to a changing climate. Such a strategy will have to reflect the long time horizon of, and the prevailing uncertainties about, climate change. An intuitively appealing approach therefore seems to be to enhance the flexibility and resilience of systems to react to and cope with climate shocks and extremes,

as well as to improve information. In addition, in the case of quasi-irreversible investments with a long lifetime (e.g. infrastructure investments, development of coastal zones), precautionary adjustments may be called for to increase the robustness of structures, or to increase the rate of depreciation to allow for earlier replacement. Many of these measures may already have to be considered now, and could be worthwhile in their own right, independent of climate change considerations.

Faust, B. B. (2001). "Maya environmental successes and failures in the Yucatan Peninsula." Environmental Science & Policy 4: 153-169.

This is a case study of environmental management by an indigenous people, the Mayas of the Yucatan Peninsula, a geographic area shared by Mexico, Belize, and northern Guatemala. The purpose is to contribute information to the debate among environmental policy makers concerning indigenous peoples and their local knowledge. It summarizes recent findings that call into question older theories, often referred to in this debate. The focus is on the evidence for changes in resource use over time: the adoption and abandonment of technologies as affected by climate change and population pressures, including evidence concerning variations in the resources themselves.

Finlayson, C. (2004). Neanderthals and Modern Humans: An Ecological and Evolutionary Perspective. Cambridge University Press, New York, 265 pp.

The author argues that the disappearance of the Neanderthals was driven by changing climate rather than competitive advantages enjoyed by early modern humans.

Fischer, G., K. Froberg, M. L. Parry, C. Rosenzweig, and R. S. Chen. (1994). "Climate change and world food supply, demand and trade. Who benefits, who loses?" Global Environmental Change 4(1): 7-23.

This paper summarizes the findings of a major interdisciplinary research effort by scientists in 25 countries. The study examined the potential biophysical responses of major food crops to changing atmospheric composition and climate, and projected potential socioeconomic consequences. In a first step, crop models were used to estimate how changing climatic conditions might alter yields of major crops at a number of sites representing both major production areas and vulnerable regions at low, mid and high latitudes. Then a dynamic recursive national-level model of the world food system was used to assess socioeconomic impacts for the period 1990 up to year 2060. Results indicate that the effects on crop yields in mid- and high-latitude regions appear to be positive, or less adverse than those in low-latitude regions, provided the potentially beneficial direct

physiological effects of CO₂ on crop growth can be fully realized. The ability of the world food system to absorb negative yield impacts decreases with the magnitude of the impact. In all climate change yield impact scenarios, relative productivity of agriculture changes in favour of developed countries, with implications for resource allocation. Economic feedback mechanisms are likely to emphasize and accentuate the uneven distribution of climate change impacts, resulting in net gains for developed countries under most scenarios and a noticeable loss to developing countries. As a result, net imports of cereals into developing countries increase in all climate change yield impact scenarios, in the order of 20%-50% compared to trade in the reference scenario. Including direct physiological effects of CO₂ on crop yields, world cereal production is estimated to decrease between 1% and 7%, depending on the climate scenario. Assuming adaptation to climate change at farm level, cereal production would still be reduced between 0% to 5%. The largest negative changes would occur in developing countries, averaging around -10%. This loss of production in developing countries, together with rising agricultural prices, is likely to increase the number of people at risk of hunger, in the order of 5%-50%, depending on the scenario.

Fleitmann, D., S. J. Burns, M. Mudelsee, U. Neff, J. Kramers, A. Mangini, and A. Matter. (2003). "Holocene forcing of the Indian monsoon recorded in a stalagmite from southern Oman." *Science* **300**(5626): 1737-1739.

A high-resolution oxygen-isotope record from a thorium-uranium-dated stalagmite from southern Oman reflects variations in the amount of monsoon precipitation for the periods from 10.3 to 2.7 and 1.4 to 0.4 thousand years before the present (ky B.P.). Between 10.3 and 8 ky B.P., decadal to centennial variations in monsoon precipitation are in phase with temperature fluctuations recorded in Greenland ice cores, indicating that early Holocene monsoon intensity is largely controlled by glacial boundary conditions. After [~]8 ky B.P., monsoon precipitation decreases gradually in response to changing Northern Hemisphere summer solar insolation, with decadal to multidecadal variations in monsoon precipitation being linked to solar activity.

Frederick, K. D. (1997). "Adapting to climate impacts on the supply and demand for water." *Climatic Change* **37**(1): 141-156.

The prospect of climate change adds to future water supply and demand uncertainties and reinforces the need for institutions that facilitate adaptation to changing conditions and promote efficient management of supplies and facilities. High costs and limited opportunities for increasing water supplies with dams, reservoirs, and other infrastructure have curbed the traditional supply-side

approach to planning in recent decades. Although new infrastructure may be an appropriate response to climate-induced shifts in hydrologic regimes and water demands, it is difficult to plan for and justify expensive new projects when the magnitude, timing, and even the direction of the changes are unknown. On the other hand integrated river basin management can provide cost-effective increases in reliable supplies in the event of greenhouse warming. With water becoming scarcer and susceptible to variations and changes in the climate, demand management is critical for balancing future demands with supplies. Federal water planning guidelines allow for consideration of plans incorporating changes in existing statutes, regulations, and other institutional arrangements that might be needed to facilitate water transfers and promote efficient management practices in response to changing supply and demand conditions.

Frederick, K. D. (2002). Water resources and climate change. Cheltenham, UK, Edward Elgar Publishing. PP. 514.

This book contains essays and articles which consider: (1) current perspectives on how an anthropogenically-induced greenhouse warming might affect global and regional water resources; (2) evidence of trends in hydrologic and climate variables that might reflect the influence of past climatic changes; (3) potential impacts on ecosystems, water quality and supplies; (4) potential impacts on water demands; (5) methodological issues in assessing the socioeconomic impacts of climate change; (6) case studies of the socioeconomic impacts of alternative climate scenarios; and (7) planning and adaptation strategies.

Froud-Williams, R. J. (1996). "Weeds and climate change: implications for their ecology and control." Aspects of Applied Biology(No. 45): 187-196.

Implications of climate change for weeds, their ecology and control are discussed in the context of a warmer and drier climate and CO₂ enrichment. The potential range extension of thermophilous weeds is discussed in relation to expansion of warm-season crops. The biology of associated weeds is reviewed in terms of adaptation of C₃ and C₄ species. It is concluded that the former will benefit from CO₂ enrichment, but that a potentially drier environment may favour C₄ species of greater water use efficiency. Effects of maternal environment on seed production are considered in relation to dormancy and germination requirements. In conclusion, relative to agronomic events such as cultural practices and economic factors that influence crop production, climate change is unlikely to have immediate consequences for arable weed floras. Biological attributes, including competitive ability, formation of seed banks and phenotypic plasticity will serve to buffer weeds against vagaries of climate.

Fukushima, T., M. Kureha, N. Ozaki, Y. Fujimori, and H. Harasawa. (2002). "Influences of air temperature change on leisure industries: case study on ski activities." Mitigation and Adaptation Strategies for Global Change 7(2): 173-189.

To evaluate the influences of air temperature change on ski activities, the changes in the numbers of skiers visiting seven ski areas in Japan were predicted in conjunction with climate change. First, having built a model for predicting snow depth based on the budgets of water and heat using the air temperature and precipitation data collected nationwide, authors demonstrated good agreement between the predicted and observed snow depths ($p < 0.01$ and the ratios for more than 81% cases ranged from 0.5 to 2). Second, the relationship between the number of skiers and the depth of snow at one of the seven ski areas was analysed statistically on a daily basis. In addition, authors did the same on a monthly basis at six other ski areas and compared the observed and predicted numbers of skiers ($p < 0.01$ and the ratios for more than 94% cases ranged from 0.5 to 2). Using this model and the relationship between daily snow depth and number of skiers, the changes in skier numbers in the seven ski areas were predicted for several scenarios with respect to air temperature changes; e.g. a more than 30% drop in visiting skiers was forecast in almost all ski areas in Japan except northern region (Hokkaido) and/or high altitude regions (centre of the Main Island) under the condition of a 3 deg C increase in air temperature. The vulnerability of the ski industry and its adaptation to climate change are discussed.

Gasse, F. (2002). "Diatom-inferred salinity and carbonate oxygen isotopes in Holocene waterbodies of the western Sahara and Sahel (Africa)." Quaternary Science Reviews 21(7): 737-767.

Thirteen Holocene palaeolakes in the western Sahara and Sahel have provided diatom records, with carbonate oxygen isotope profiles available from eight of them. Most of these palaeolakes were groundwater-fed. Lake water chemistry is reconstructed using diatom transfer functions. Lake water salinity and ^{18}O records are assembled with some isotopic and chemical groundwater data to better understand the response of the hydrological systems to climate changes over the past 15,000 yr. Data are in general agreement with climate simulations using coupled atmosphere-ocean-vegetation models which show a mid-Holocene wetting over the whole of northwest Africa, and a rapid drying by 6-4 ka. The lake record also shows that at many sites the major lake infilling lags the end of the Younger Dryas by 1-2 ka. Regional differences also appear in the timing of the lake hydrological optimum: ca. 10.5-8.5 and 7.5-4.5 in the northern Sahara, 10-8.5 ka in the Air-Tenere, 10-5.7 or 4.5 in the Sahel, and 7.5 ka in Lake Chad. The whole of the Holocene is punctuated by short-term drying events. Changes in water isotopic composition through time are partly explained by changes in

rainfall amount and air humidity. During the wet Holocene period however, the very low [δ] values in the southern Sahara also imply changes in the moisture transport pattern or rainfall mechanisms. Data suggest an apparent decrease in ^{18}O content of precipitation along the monsoon flow, in contrast with modern patterns. Changes in water availability and quality have driven population migrations in and out of the Sahara-Sahel, but relationships between climate and cultures are complex. Short-term dry events might have driven inventive adaptations. In the Sahara, drying at 5-4.5 ka coincides with both the collapse of the classical Neolithic civilization and the settlement of new cultures.

Gasse, F. and E. Van Campo (1994). "Abrupt post-glacial climate events in West Asia and North Africa monsoon domains." Earth and Planetary Science Letters **126**(4): 435-456.

Regions beyond the present or past penetration of the Indian and African monsoons have experienced several large and abrupt climatic fluctuations over the past 13 14C kyr. Pollen and lake records from West Asia (Western Tibet and Rajasthan), East Africa (Ethiopia) and West Africa (Western Sahara, Sahel and subequatorial Africa) were selected on the basis of chronological control, sensitivity of both site and environmental indicators to climate change, the continuity of the record, and interdisciplinary control of the palaeoclimatic interpretation. Conditions wetter than those of today prevailed during the early-mid-Holocene period, but major dry spells are recorded at all sites during the intervals ~ 11.0 -9.5 kyr BP, ~ 8 -7 kyr BP and 3-4 kyr BP. Several records also suggest dry events of minor amplitude around 6 kyr BP. Potential boundary forcings of insolation and sea surface and tropical land surface conditions are discussed. The solar radiation accounts for the general envelop of the post-glacial monsoon fluctuations, but explains neither the timing nor the amplitude of the short-term changes. In spite of apparent covariation between fluctuations in sea surface conditions in the North Atlantic and the monsoon record, no direct mechanism could be found relating the intensity of the oceanic thermohaline conveyor belt to the monsoon strength. Changes in tropical land surface conditions (soil moisture negative feedback, and changes in CH_4 production from wetlands) provide a more satisfactory hypothesis for explaining abrupt reversal events.

Gera, M., N. S. Bisht, N. Gera. (2003). "Carbon sequestration through community based forest management - a case study from Sambalpur Forest Division, Orissa." Indian Forester **129**(6): 735-740.

The worldwide concern over global warming led to the formation of United Nations Framework Convention on Climate Change (UNFCCC) in 1992 to deal with GHG emissions. As per the Kyoto protocol of 1997, the

industrialized countries are expected to reduce the GHG emissions by 5.5% by 2008-2012 over 1990 levels. Such countries are expected to buy carbon credits from developing countries under the Clean Development Mechanism (CDM). Global negotiations are on for operationalization of the CDM mechanism. Afforestation and reforestation have already been included under CDM, and forest conservation activities are also likely to be considered under adaptation measures. A study was carried out to estimate the creation of carbon sinks and sequestration achieved in community-protected forests of Sambalpur Forest Division, Orissa, India. The results have shown that 1.53 to 3.01 tonnes of carbon is being sequestered per ha per year with only protection, which can be enhanced through proper implementation of the management prescriptions. Enormous opportunities exist to sequester carbon and to mitigate climate change patterns through regeneration in India's forests.

Gillson, L. and Willis K. J. (2004). "As Earth's testimonies tell: wilderness conservation in a changing world." *Ecology Letters* 7(10): 990-998.

Too often, wilderness conservation ignores a temporal perspective greater than the past 50 years, yet a long-term perspective (centuries to millennia) reveals the dynamic nature of many ecosystems. Analysis of fossil pollen, charcoal and stable isotopes, combined with historical analyses and archaeology can reveal how ongoing interactions between climatic change, human activities and other disturbances have shaped today's landscapes over thousands of years. This interdisciplinary approach can inform wilderness conservation and also contribute to interpreting current trends and predicting how ecosystems might respond to future climate change. In this paper, authors review literature that reveals how increasing collaboration among palaeoecologists, archaeologists, historians, anthropologists and ecologists is improving understanding of ecological complexity. Drawing on case studies from forested and non-forested ecosystems in Europe, the Americas, Africa and Australia, authors discuss how this integrated approach can inform wilderness conservation and ecosystem management.

Giupponi, C. and M. Shechter (2003). Climate change in the Mediterranean: socio-economic perspectives of impacts, vulnerability and adaptation. Cheltenham, UK, Edward Elgar Publishing Ltd.

Provides overview of water resources and assesses a range of potential problems such as increasing droughts, adequate irrigation, reduced water quality and population migration due to severe shortages. Authors also discuss land use including desertification, degradation, agriculture and waste management. Finally, they investigate the coastal zones of the Mediterranean that are economically vulnerable to variations in climate due to their reliance on tourism.

Gnecco, C. (1999). "An archaeological perspective of the Pleistocene/Holocene boundary in northern South America." Quaternary International **53-54**: 3-9.

In this paper, author examines Late Pleistocene/Early Holocene adaptations of hunter-gatherers to different ecosystems in northern South America. The role played by the climatic events associated with the Pleistocene/Holocene boundary in the evolution of culture in that part of the Americas is assessed in the light of those adaptations. The conclusion is that the Pleistocene/Holocene boundary is not very useful in understanding the human process of early colonization and adaptation to the various ecosystems of northern South America, because a mechanism of cultural change cannot be linked to that boundary.

Golyeva, A. A., O. A. Chichagova, Y. V. Tsutskin. (2003). "Buried paleosols in balks of Kalmykiya as a record of late Holocene nature and society interaction." Quaternary International **106-107**: 103-109.

Modern and buried soils under valley sediments have been compared on the Southern Russian Plain (Kalmykiya) in the arid zone. The buried soil contains more humus and less carbonates, and pH values are lower. The humus content in this soil is comparable with that of modern Haplic Kastanozems and Gleyic Phaeozems. The comparison of differences in properties of buried soil at specific times and historical data on **cultures'** functioning in these periods has allowed us to reveal the interrelation of nature and society processes development in South Kalmykia since the middle Holocene. Three stages of landscape development are recognized: (1) stable stage, at least 3000 years long (from the 2nd millennium BC until the 1st millennium AD), characterized by the formation of meadow-steppe soils; (2) dynamic stage, likely short, when deposits were accumulated, and soils were buried; and (3) modern stable stage, at least 500 years long (up to the present time), characterized by the formation of meadow-saline soils (Molli-Endogleyic Solonetz) on deposits in valleys. A strong ecological crisis was evident in the territory of modern Kalmykia about 1000 years ago, resulting from the collapse of the Khazar state. As a result, meadow-steppe soils were buried, and Saline Molli-Endogleyic soils were formed.

Golubtsov, V. V., V. I. Lee, I. I. Scotselyas. (1996). "Vulnerability assessment of the water resources of Kazakhstan to anthropogenic climate change and the structure of adaptation measures." International Journal of Water Resources Development **12(2)**: 193-208.

A brief summary of water resources and water use in Kazakhstan is presented. Input data and methods for water resource vulnerability assessments, taking into account climate change, are given. The results are discussed and the

structure of measures of adaptation to water resources change under anticipated future climatic conditions is suggested.

Gómez-Pompa, A., M. F. Allen, S. L. Fedick, J. J. Jiménez-Osornio, Eds. (2003). *The Lowland Maya Area: Three Millennia at the Human-Wildland Interface*. Food Products Press/ The Haworth Press, New York, USA.

What can we learn from the people of the Maya Lowlands? Integrating history, biodiversity, ethnobotany, geology, ecology, archaeology, anthropology, and other disciplines, *The Lowland Maya Area* is a valuable guide to the fascinating relationship between man and his environment in the Yucatán peninsula. This book covers virtually every aspect of the biology and ecology of the Maya Lowlands and the many ways that human beings have interacted with their surroundings in that area for the last three thousand years. You'll learn about newly discovered archaeological evidence of wetland use; the domestication and use of cacao and henequen plants; a biodiversity assessment of a select group of plants, animals, and microorganisms; the area's forgotten cotton, indigo, and wax industries; the ecological history of the Yucatán Peninsula; and much more. This comprehensive book will open your eyes to all that we can learn from the Maya people, who continue to live on their native lands, integrating modern life with their old ways and teaching valuable lessons about human dependence on and management of environmental resources.

The Lowland Maya Area explores: the impact of hurricanes and fire on local environments, historic and modern Maya concepts of forests, the geologic history of the Yucatán, challenges to preserving Maya architecture, newly-discovered evidence of fertilizer use among the ancient Maya, cooperation between locals and researchers that fosters greater knowledge on both sides, and recommendations to help safeguard the future.

This book is an ideal single source for reliable information on the many ecological and social issues of this dynamic area. Providing you with the results of the most recent research into many diverse fields, including traditional ecological knowledge, the difficult transition to capitalism, agave production, and the diversity of insect species, this book will be a valuable addition to your collection.

As the editors of book say in their concluding chapter: "If we are to gain global perspective from the changing Maya world, it is that understanding space and time is absolutely critical to human persistence." Understanding how the Maya have interacted with their environment for thousands of years while maintaining biodiversity will help us understand how we too can work for sustainable development in our own environments.

Goyal, R. K. (2004). "Sensitivity of evapotranspiration to global warming: a case study of arid zone of Rajasthan (India)." *Agricultural Water Management* **69**(1): 1-11.

Global warming due to greenhouse effect is expected to cause major changes in climate of some areas. The change in climate is likely to have a profound effect on hydrological cycle viz. precipitation, evapotranspiration, soil moisture etc. Evapotranspiration (ET) being the major component of hydrological cycle will affect crop water requirement and future planning and management of water resources. In the present study, an attempt has been made to study the sensitivity of evapotranspiration to global warming for arid regions of Rajasthan (India). The Penman–Monteith equation was used to estimate reference evapotranspiration, and sensitivity of ET has been studied in terms of change in temperature, solar radiation, wind speed and vapor pressure within a possible range of $\pm 20\%$ from the normal long-term meteorological parameters of 32 years (1971–2002). Changes in precipitation and stomatal resistance to increased CO₂ concentration have not been considered in the present study. The study suggests an increase of 14.8% of total ET demand with increase in temperature by 20% (maximum 8 °C). ET is less sensitive (11%) to increase in net solar radiation, followed by wind speed (7%) in comparison to temperature. Increase in vapor pressure (20%) has a small negative effect on ET (–4.31%). A 10% increase in temperature and actual vapor pressure coupled with 10% decrease in net solar radiation could result even in marginal decrease of total ET (0.30%). Increase of 10% in temperature alone, with 10% decrease in net solar radiation, actual vapor pressure and wind velocity could also result in marginal decrease in total ET (0.36%). A marginal increase in ET demand due to global warming will have a larger impact on resource-poor, fragile arid zone ecosystem of Rajasthan. It is high time for planners/users to think in terms of expected change in water requirement due to global warming while planning for development of future water resources in the arid region of Rajasthan. A wide spectrum climate change scenario is discussed in the paper as guideline for future development of water resources.

Gregory, P. J. and J. S. I. Ingram (2003). Global environmental change and future crop production: Solutions for a better environment. Proceedings of the 11th Australian Agronomy Conference, Geelong, Victoria, Australia, 2-6 February 2003, Horsham, Australia, Australian Society of Agronomy Inc., Victorian Institute for Dryland Agriculture.

Global environmental change (GEC) is a consequence of a range of human activities and includes elements such as increasing concentrations of gases in the atmosphere, climate variation and change, rising sea level, loss of biodiversity, and changes in water and nitrogen cycling. Crop production is both affected by and contributes to GEC. Estimates of future global crop production show that most

of the required increases in production will come about by greater intensification with substantial extensification only in limited areas. Production systems demonstrate a spectrum of intensification practices that can be characterized by different methods of site preparation and pest control, and inputs of germplasm, nutrients and water. Collectively, intensification has contributed to GEC particularly through changes to the nitrogen cycle and increasing atmospheric concentrations of gases contributing to global warming. The environmental consequences of the increased production may occur either on-or off-site or both, and will vary regionally depending on whether intensification or extensification is the main pathway for achieving the increases. Changes in extremes of weather associated with increased climate variability in the short term, and in mean values of temperature and rainfall associated with climate change in the long term, contribute to the uncertainties introduced by GEC. In Australia, average annual temperatures are predicted to be 0.4 to 2.0 deg C higher over most of the continent by 2030 with generally lower rainfall in winter and spring (-10% to +5%). Projected decreases are greater in the southwest (-20% to +5%). Crop models incorporating doubling of atmospheric CO₂ to 700 ppm show a yield response for wheat of +15% to +25% as mean temperature increases in the range 0 to 4 deg C, but this response decreases to a range of +4% to -8% if rainfall simultaneously decreases by 20%. Adaptation of crop production to cope with GEC and the feedback of the adapted production systems to GEC have been much less studied and is research that is needed for goals of both production and sustainability. The real challenge, then, is to develop crop production systems that are more productive and more environmentally benign.

Grosjean, M. , L. Núñez, I. Cartajena, B. Messerli. (1997). "Mid-Holocene Climate and Culture Change in the Atacama Desert, Northern Chile." Quaternary Research **48**(2): 239-246.

Twenty archaeological campsites intercalated between more than 30 debris flows caused by heavy rainfall events between 6200 and 310014C yr B.P. have recently been discovered at Quebrada Puripica in the Atacama Desert of northern Chile. This record provides detailed information about extreme, short-lived climatic events during the hyperarid mid-Holocene period. For the first time, authors found evidence of continuous human occupation in this area, filling the regional hiatus in the Atacama basin ("Silencio Arqueológico") between 8000 and 480014C yr B.P. The transformation of Early Archaic hunters into the complex Late Archaic cultural tradition was an adaptive process. During this time, the site was a local ecological refuge with abundant resources in a generally hostile environment.

Grove, R. H. (1998). "Global impact of the 1789-93 El Niño." *Nature* **393**: 318 – 319.

It has been suggested that global warming has caused the El Niño/Southern Oscillation (ENSO) climatic events to become more frequent and intense. However, several ENSO events that occurred before 1880 had effects at least as intense and wide-ranging as those associated with the current event. This is the case particularly for the events in 1396, 1685-88, 1789-93 and 1877-79. Here author discusses archival evidence, notably from South Asia and above all for the 1789-93 ENSO, for the strength of these historical effects. In peninsular India, every major drought between 1526 and 1900 has been closely associated with the eastern Pacific El Niño. The 1789-93 ENSO event produced prolonged droughts, especially in South Asia, a region where the association between ENSO and the monsoon is well established. The global impact of this event was recognized in 1816 by Alexander Beatson, governor of St Helena, who suggested that the 1791 droughts in India, St Helena and Montserrat were part of a single, connected phenomenon. The earliest indications of the event in the tropics were meteorological observations, based on a 14-year data set started in the early 1770s by William Roxburgh at Samulcottah (Samalkot) in southern India. He recognized the exceptional nature of the droughts beginning in 1789 and believed that their severity had only been approached by those in 1685-87. Those years are now known to have been characterized by 'very severe' El Niño in the eastern Pacific in 1687-88. Roxburgh recorded the continuous failure of the South Asian monsoon between 1789 and 1792, the severest failure being in 1790. The first major rainfall reduction was in 1789 in southern India, more than a year before similar droughts occurred in Australia, Mexico, the Atlantic islands and southern Africa. By November 1792, 600,000 deaths were attributed to the resultant droughts in the northern Madras Presidency alone, where half the population died. The long droughts were interspersed with short periods of highly destructive rainfall. In three days at Madras in late October 1791, 25.5 inches of rain fell, "more than... has been known within the memory of man". Unseasonal severe droughts were experienced in Java, and in New South Wales, Australia, in the same year. On 5 November 1791, the governor of this colony, Arthur Phillip, reported that the normally perennial 'Tank Stream' river flowing into Sydney Harbour had been dry for "some months". It did not flow again until 1794. Phillip marks the start of the droughts in July 1790; no rain had fallen by August 1791. In Mexico, the level of Lake Pátzcuaro fell steadily between 1791 and 1793, giving rise to disputes over the ownership of the land that emerged. By mid-August 1791, the desiccating effects on the islands of the Antilles were the severest since 1700, and no rain had fallen on the islands of St Vincent and Montserrat. The drought continued on Montserrat until November 1792. Droughts on St Helena were later than those in the Caribbean, lasting from late 1791 to mid-1794. The River Nile fell to very low

levels from 1790 to 1797, as a result of reduced rainfall in the Ethiopian highlands. Evidence from the rest of Africa is scanty, but prolonged droughts in Natal and Zululand between 1789 and 1799 resulted in the Mahlatule famine, the severest known to have affected Southern Africa before 1862. This evidence that the 1789-93 ENSO had a strong global impact indicates that it was one of the most severe on record. An early precursor of the event may have been an unusually cold winter in western Europe in 1787-88, followed by a late and wet spring and summer drought, resulting in the crop failures preceding the French Revolution. This may have resulted from a weak phase in the North Atlantic Oscillation, which would fit an established correlation between interannual variability in the North Atlantic Oscillation and Indian summer monsoon rainfall. Indeed, the Indian monsoon is an active feature of tropical circulation and monsoon failure is efficient in foreshadowing ENSO. As with the 1685-88 ENSO, the early stages of the 1789-93 event were observable in southern India more than a year before the El Niño effect was recorded in the Pacific basin. However, a few ENSO events, including the present event of 1997-98, coincide with a failure of the Southeast Asian monsoon rather than that of South Asia. In the case of the 1789-93 ENSO event, the monsoon failed in both regions. So the developmental sequence of the 1789-93 ENSO is important as a basis for comparison with other, very severe, ENSO events.

Gundimeda, H. (2004). "How 'sustainable' is the 'sustainable development objective' of CDM in developing countries like India?" Forest Policy and Economics 6(3-4): 329-343.

The rural poor and landless require resilient, sustainable livelihood systems that are flexible in the short term due to dependence on multiple products. The Kyoto Protocol requires that Clean Development Mechanism (CDM) projects result in long-term benefits related to the mitigation of climate change. This long-term requirement to keep carbon in storage may conflict with the short-term needs of the poor. The objective of this paper is to examine the potential implications of the Land use change and forestry (LUCF) projects to the rural livelihoods in India. For this purpose the paper uses a linearised version of the almost ideal demand system (LA-AIDS) to analyse data collected from 69 206 rural households in India. Based on the analysis, the paper concludes that for CDM to be sustainable and result in sustainable development of the local people, three important criteria should be satisfied: (1) Integrating the energy substitution possibilities in the objectives of carbon sequestration; (2) Management of the CPR lands by the rural poor through proper design of the rules for sustenance of user groups; and (3) Ensuring that the maximum revenue from carbon sequestration is channelled to the rural poor. Otherwise CDM would

just result in either leakage of carbon benefits or have negative welfare implications for the poor.

Gupta, A. K. (2004) Origin of agriculture and domestication of plants and animals linked to early Holocene climate amelioration. Current Science **87**(1): 54-59.

Domestication of plants and animals was necessary for the evolution of agriculture, spatial expansion and population increase of humans during the Holocene, which facilitated the evolution of technically innovative societies. The agricultural practices enabled people to establish permanent settlements and expand urban-based societies. Domestication of plants and animals transformed the profession of the early humans from hunting and gathering to selective hunting, herding and settled agriculture. The earliest archaeological evidences, found throughout the tropical and subtropical areas of southwestern and southern Asia, northern and central Africa and Central America, suggest rapid and large-scale domestication of plants and animals ca. 10,000-7000 cal years BP. This interval corresponds to an intense humid phase and equable climates, as observed in numerous paleo records across the regions. Author suggest that domestication of plants and animals and subsequent beginning of agriculture were linked to climate amelioration in the early Holocene.

Gupta, A. K., D. M. Anderson, and J. T. Overpeck. (2003). "Abrupt changes in the Asian southwest monsoon during the Holocene and their links to the North Atlantic Ocean." Nature **421**(6921): 354-357.

During the last ice age, the Indian Ocean southwest monsoon exhibited abrupt changes that were closely correlated with millennial-scale climate events in the North Atlantic region, suggesting a mechanistic link. In the Holocene epoch, which had a more stable climate, the amplitude of abrupt changes in North Atlantic climate was much smaller, and it has been unclear whether these changes are related to monsoon variability. Here authors present a continuous record of centennial-scale monsoon variability throughout the Holocene from rapidly accumulating and minimally bioturbated sediments in the anoxic Arabian Sea. Monsoon proxy record reveals several intervals of weak summer monsoon that coincide with cold periods documented in the North Atlantic region--including the most recent climate changes from the Medieval Warm Period to the Little Ice Age and then to the present. Authors detect continued variability in monsoon intensity, including a shift from strong to weak monsoon during the transition from the Medieval Warm Period (AD 800–1300) to the Little Ice Age (AD 1300–1870). Authors suggest that the link between North Atlantic climate and the Asian monsoon is a persistent aspect of global climate.

Gupta, R. K. (1971). "Ecology of pastoral areas in the arid zone of Rajasthan." Annals of Arid Zone **10**(2/3): 136-137.

Literature on area, land use and climate of pastoral areas of arid W. Rajasthan is reviewed. Grasslands are classified according to drought resistance into 4 categories: ephemeral drought evading, perennial drought evading, perennial drought resistant, and perennial drought resistant semi-succulent type. The distribution of the main grassland types in relation to climate and soil and the relationship between grasslands, animal population and stocking rate are discussed. Suggestions for collecting data on consumers of the native vegetation and soil decomposers to achieve a better understanding of the range ecosystem in the arid regions of Rajasthan are given.

Gupta, S. S. and R. C. Verma (1993). "Stabilization of farm income and employment under water scarcity conditions." Annals of Arid Zone **32**(3): 183-186.

This study was conducted in Naga-Ki-Dhani village in Jaipur district, Rajasthan, India. Four optimum crop plans to stabilize farm income and employment during drought years were developed using linear programming techniques. The results of the optimum plans showed that use of improved varieties of crops developed specifically for water scarcity conditions, would increase farm income. The employment opportunities under the optimum plans developed with cash borrowing did not increase significantly over those of the plans developed with the existing level of resources. However, available working capital during drought years would not enable full use of whatever little irrigation water was available in the open wells, and hence credit should be made available to farmers in drought years.

Haberle, S. G. and A. Chepstow Lusty. (2000). "Can Climate Influence Cultural Development? A View through Time." Environment and History **6**(3): 349-369.

Despite the devastating impact that flooding, drought and fire associated with the 1982/3 and 1997/8 El Nino events had on both the natural environment and human society, there is little information on the persistence or impact similar events may have had in the 'deeper' past. Palaeoecologists can offer insight into the nature of environmental change over a range of spatiotemporal scales, utilising high-resolution techniques that can broaden the interpretation of issues that are specifically relevant to historians, geographers and anthropologists. In some cases there appears to be a correspondence between major climatic events and a change in cultural development that leads us to ask the question, 'How significant has climate change been in the development of human society?' We discuss the role of environmental history in studies of cultural change, and critically assess four case

studies where climate may have had a significant impact on the development of human society: human evolution in Africa, development of agriculture in New Guinea, urban collapse in Central and South America, and Pacific island occupation.

Haberle, S. G., B. David. (2004). Climates of change: human dimensions of Holocene environmental change in low latitudes of the PEPHII transect. Quaternary International **118-19**: 165-179.

Rapid climate change events can have devastating impacts upon agricultural production and human society. Advances in spatial and temporal resolution of palaeoenvironmental and archaeological data enable detailed examination of the nature of human-environment interactions. Recent studies have shown that throughout the Holocene human populations responded to rapid climate change events by existing subsistence strategies adopting to novel environmental conditions. In the case of agriculturalists in New Guinea and hunter-gatherers in northern Australia, climate change set in motion a range of biological and demographic possibilities and restrictions that had long-term consequences for each region. The early Holocene climatic and ensuing environmental transformations heightened natural biomass production and Population increases. Consequently, later rapid changes in climate centred around 6000 and 3500 cal yr BP, resulted in the adoption of innovative technologies and diverse subsistence strategies throughout the region that reduced the vulnerability of people in an environment of increasing unpredictable climate variability.

Haddad, B. M. (2005). "Ranking the adaptive capacity of nations to climate change when socio-political goals are explicit." Global Environmental Change Part A **15**(2): 165-176.

The typical categories for measuring national adaptive capacity to climate change include a nation's wealth, technology, education, information, skills, infrastructure, access to resources, and management capabilities. Resulting rankings predictably mirror more general rankings of economic development, such as the Human Development Index. This approach is incomplete since it does not consider the normative or motivational context of adaptation. For what purpose or toward what goal does a nation aspire, and in that context, what is its adaptive capacity? This paper posits 11 possible national socio-political goals that fall into the three categories of teleological legitimacy, procedural legitimacy, and norm-based decision rules. A model that sorts nations in terms of adaptive capacity based on national socio-political aspirations is presented. While the aspiration of maximizing summed utility matches typical existing rankings, alternative aspirations, including contractarian liberalism, technocratic

management, and dictatorial/religious rule alter the rankings. An example describes how this research can potentially inform how priorities are set for international assistance for climate change adaptation.

Handmer, J. W., S. Dovers, and T. E. Downing. (1999). "Societal Vulnerability to Climate Change and Variability." Mitigation and Adaptation Strategies for Global Change 4(3-4): 267-281.

Institutions in many wealthy industrialised countries are robust and their societies appear to be relatively well insulated against the impacts of climate variability, economic problems elsewhere and so on. However, many countries are not in this position, and there is a growing group of humanity which is not benefiting from the apparent global adaptive trends. Worst case scenarios reinforce the impact of this uneven distribution of adaptive capacity, both between and within countries. Nevertheless, at the broad global scale human societies are strongly adaptive and not threatened by climate change for many decades. At the local level the picture is quite different and the survival of some populations at their present locations is in doubt. In the absence of abatement, the longer term outlook is highly uncertain. Adaptation research needs to begin with an understanding of social and economic vulnerability. It requires a different approach to the traditional IPCC impacts assessment, as human behaviour, institutional capacity and culture are more important than biophysical impacts. This is consistent with the intellectual history of the IPCC which has gradually embraced an increasing range of disciplines.

Hartig, E. K., O. Grozev, C. Rosenzweig. (1997). "Climate change, agriculture and wetlands in Eastern Europe: vulnerability, adaptation and policy." Climatic Change 36(1/2): 107-121.

Naturally-occurring wetlands perform such functions as flood control, pollution filtration, nutrient recycling, sediment accretion, groundwater recharge and water supply, erosion control, and plant and wildlife preservation. A large concentration of wetlands is located in Eastern Europe. A significant amount of Eastern European wetlands has been converted to agricultural use in the past, and remaining wetlands are subject to agricultural drainage. Drained wetlands are used as prime agriculture lands for a variety of food crops, for growing *Phragmites australis* (common reed) for thatch and livestock feed, to collecting peat for heating and cooking fuel. Altered hydrological regimes due to global climate change could further exacerbate encroachment of agricultural land use into wetlands. The vulnerability and adaptation studies of the US Country Studies Program were used to analyse where climate change impacts to agriculture may effect wetland areas. Freshwater wetlands are potentially vulnerable in Bulgaria, Czech Republic, and

Russia, and coastal wetlands are at risk in Estonia. Runoff is identified as a key hydrological parameter affecting wetland function. Since wetland losses may increase as a result of climate-change-induced impacts to agriculture, precautionary management options are reviewed, such as establishing buffer areas, promoting sustainable uses of wetlands, and restoration of farmed or mined wetland areas.

Haug, G. H., Gunther, D., Peterson, L. C., Sigman, D. M., Hughen, K. A., Aeschlimann, B. (2003). Climate and the Collapse of Maya Civilization. Science 299: 1731-1735.

In the anoxic Cariaco Basin of the southern Caribbean, the bulk titanium content of undisturbed sediment reflects variations in riverine input and the hydrological cycle over northern tropical South America. A seasonally resolved record of titanium shows that the collapse of Maya civilization in the Terminal Classic Period occurred during an extended regional dry period, punctuated by more intense multiyear droughts centered at approximately 810, 860, and 910 A.D. These new data suggest that a century-scale decline in rainfall put a general strain on resources in the region, which was then exacerbated by abrupt drought events, contributing to the social stresses that led to the Maya demise.

Henderson, C. E. (1989). "Life in the land of death: famine and drought in arid western Rajasthan." Dissertation Abstracts International. A, Humanities and Social Sciences 50(5): pp.1349-1350.

This research examines adjustment and adaptation to frequent drought in Rajasthan's Thar desert and the ways in which economic stratification, community organization, and links to outside regions promote or hinder survival. These data provide a basis for examining the impact of external economic ties on vulnerability to drought, as hypothesized in earlier works on famines in India. The research, based on fieldwork conducted in a village of India's Thar desert in 1981/82 when the rains failed for the third consecutive year, indicates that resistance to drought varies according to the resource base of households. A household's wealth is positively associated with its structure and ability to diversify production into the three components of crops, livestock and outside work migration. The risk of failure is also reduced through the use of actual and fictional kin relationships which facilitate access to resources outside the village. Beyond their positive functional value, these adaptations to drought suggest that the area is integrated into a broad set of economic and political relationships centred on market relations for the sale of livestock products and urban wage- labour. The ability to exploit these opportunities is unequally experienced by different wealth groups and in turn leads to economic differentiation based more on inequality of access than on intracommunity wealth transfers.

Henderson, S. A. (1996). "Climate modelling, uncertainty and responses to predictions of change." Mitigation and Adaptation Strategies for Global Change **1**(1): 1-21.

Article 4.1(F) of the Framework Convention on Climate Change commits all parties to take climate change considerations into account and to employ methods such as impact assessments to minimize adverse effects of climate change. This could be achieved by, *inter alia*, incorporating climate change risk assessment into development planning processes. The basis for the confidence in global-scale climate change predictions and the reasons for the uncertainties in regional-scale changes are discussed. The mismatch between predictions of global climatic change and the need for information on local to regional change in order to develop adaptation strategies is examined. These topics are explored using the specific example of the prediction of land-surface climate changes.

Hassan, F. A. (1998). "Climatic change, Nile floods and civilization." Nature and Resources **34**(2): 34-40.

There is increasing evidence from many parts of the world that climate can change over quite short periods of time. In Egypt, climatic change influences the height of Nile floods, which in turn determines the prosperity of the country. Following the emergence of the Egyptian civilization and a period of pyramid building, low floods led to the dissolution of centralized government and plunged the country into chaos. Order was re-established through administrative reforms by the first kings of the Middle Kingdom who also embarked on a major national economic development project in the Faiyum province. Low floods associated with famines and plagues recurred during the Ramesside period and again in more recent historical times. As late as the 18th century, famines and plagues caused by low floods were common. At present, with as many as 20 times the population of ancient Egypt and rising expectations, the country faces potential water shortages, especially given the wild climatic oscillations which affect the volume of Nile floodwater discharge.

Heckenberger, M. J., A. Kuikuro, U. T. Kuikuro, J. C. Russell, M. Schmidt, C. Fausto, B. Franchetto. (2003). "Amazonia 1492: Pristine forest or cultural parkland?" Science **301**: 1710-1714.

Archaeology and indigenous history of Native Amazonian peoples in the Upper Xingu region of Brazil reveal unexpectedly complex regional settlement patterns and large-scale transformations of local landscapes over the past millennium. Mapping and excavation of archaeological structures document pronounced human-induced alteration of the forest cover, particularly in relation to large, dense late-prehistoric settlements (circa 1200 to 1600 A.D.). Mapped

archaeological features correspond to patches of acutely modified secondary growth, distinctive from surrounding forest and easy to recognize in satellite images. These patches or islands are identified in the indigenous knowledge systems, including diverse species whose distributions are generally restricted to anthrosols (dark earth)—called egepe by the Kuikuro—associated with ancient settlements. The findings contribute to debates on human carrying capacity, population size and settlement patterns, anthropogenic impacts on the environment, and the importance of indigenous knowledge, as well as contributing to the pride of place of the native peoples in this part of the Amazon.

Higgins, P. A. T. and M. Vellinga (2004). "Ecosystem responses to abrupt climate change: teleconnections, scale and the hydrological cycle." *Climatic Change* **64**(1/2): 127-142.

The occurrence of past and future abrupt climate change, such as could occur under thermohaline circulation (THC) weakening, is increasingly evident in the paleoclimate record and model experiments. Authors examine potential responses of ecosystem structure and function to abrupt climate change using temperature and precipitation patterns generated by HadCM3 in response to forced THC weakening. The large changes in potential ecosystem structure and function that occur are not focused in the North Atlantic region where temperature sensitivity to THC is highest but occur throughout the world in response to climate system teleconnections. Thus, THC weakening, which is often viewed as a European problem, has globally distributed ecosystem implications. Although temperature changes associated with THC weakening affect the extent of several high latitude biomes, the distribution of ecosystem change results primarily from changes in the hydrological cycle. Currently there remains large uncertainty in climate model projections of the hydrological cycle. Therefore, the predictions of the magnitude and location of ecosystem perturbations will also be characterized by large uncertainty, making impact assessment, and thus adaptation, more difficult. Finally, these results illustrate the importance of scale and disaggregation in assessing ecosystem responses. Small globally aggregated ecosystem responses to THC weakening, approximately five percent for NPP and biomass, mask large local and regional changes.

Hodell, D. A., J. H. Curtis, M. Brenner. (1995). "Possible role of climate in the collapse of Classic Maya civilization." *Nature* **375**: 391 – 394.

The Maya civilization developed around 3,000 years ago in Mesoamerica, and after flourishing during the so-called Classic period, it collapsed around 750-900 AD. It has been speculated that climate change may have played a part in this collapse. But efforts to reconstruct the last three millennia of

Mesoamerican climate using palynological methods have met with equivocal success, because human-mediated deforestation has altered regional vegetation in ways that mimic climate shifts, making it difficult to discriminate between natural and anthropogenic changes⁷¹⁵. Here authors use temporal variations in oxygen isotope and sediment composition in a 4.9-m sediment core from Lake Chichancanab, Mexico, to reconstruct a continuous record of Holocene climate change for the central Yucatan peninsula. The interval between 1,300 and 1,100 yr BP (AD 8001,000) was the driest of the middle to late Holocene epoch, and coincided with the collapse of Classic Maya civilization. This continuous climate proxy record thus provides evidence of climate deterioration in the Maya region during the terminal Classic period.

Hodell, D. A., M. Brenner, J. H. Curtis, T. Guilderson. (2001). "Solar forcing of drought frequency in the Maya lowlands." Science **292**: 1367-1370.

Authors analyzed lake-sediment cores from the Yucatan Peninsula, Mexico, to reconstruct the climate history of the region over the past 2600 years. Time series analysis of sediment proxies, which are sensitive to the changing ratio of evaporation to precipitation (oxygen isotopes and gypsum precipitation), reveal a recurrent pattern of drought with a dominant periodicity of 208 years. This cycle is similar to the documented 206-year period in records of cosmogenic nuclide production (carbon-14 and beryllium-10) that is thought to reflect variations in solar activity. It is concluded that a significant component of century-scale variability in Yucatan droughts is explained by solar forcing. Furthermore, some of the maxima in the 208-year drought cycle correspond with discontinuities in Maya cultural evolution, suggesting that the Maya were affected by these bicentennial oscillations in precipitation.

Hong, Y. T., B. Hong, Q. H. Lin, Y. X. Zhu, Y. Shibata, M. Hirota, M. Uchida, X. T. Leng, H. B. Jiang, and H. Xu. (2003). "Correlation between Indian Ocean summer monsoon and North Atlantic climate during the Holocene." Earth and Planetary Science Letters **211**(3-4): 371-380.

There has been a number of investigations for the correlation between the Asia monsoon and the North Atlantic climate for the last glacial; however, little research has been done for the present interglacial, the Holocene. Here authors present for the first time a high-resolution composite proxy record for the Indian Ocean summer monsoon spanning around 12000 years based on the $\delta^{13}C$ time series of both a single plant species (*Carex muliensis*) remains cellulose and the total plant assemblage cellulose in the Hongyuan peat bog from the Tibet Plateau. The records show that the strength of the Indian Ocean summer monsoon had abrupt variations during the last 12000 years. The weakest monsoon

occurred in the Younger Dryas period. Following rapid strengthening from around 11200 to 10800 a BP the monsoon kept a generally strong level for around 5300 years. From around 5500 a BP onwards the monsoon strength tended to gradual decrease. In addition, there are a series of abrupt variation events of the monsoon strength on centennial to millennial time scales, which superimpose the general tendency of the monsoon variation. In every case when the ice-rafted debris events in the North Atlantic occurred, the summer monsoon strength decreased correspondingly. These evidences show that teleconnection between the Indian Ocean summer monsoon and the North Atlantic climate is present not only in the last glacial but also in the Holocene, which may be linked to abrupt reorganizations of the ocean thermohaline circulation, leading to redistribution of energy, changing temperature and moisture gradient over the southern subtropical Indian Ocean, and eventually controlling the variability of the Indian Ocean summer monsoon.

Chun Chang Huang, Jiangli Pang, Qunying Zhou and Shu'e Chen. (2004). "Holocene pedogenic change and the emergence and decline of rain-fed cereal agriculture on the Chinese Loess Plateau." *Quaternary Science Reviews* **23**(23-24): 2525-2535.

Multi-disciplinary investigations were carried out in a Holocene eolian loess-soil profile in the centre of the Chinese Loess Plateau at the transition between the arid Mongolian steppe and the semi-arid mixed forest, and also the transitional zone between nomadism and the rain-fed cereal agriculture in history. The cultural remains of an earliest rain-fed cereal agriculture, and also the remains of a Bronze Age nomadic community identified in the profile indicate that the regional emergence and decline of the rain-fed cereal agriculture was closely connected with the change in dust accumulation and soil formation. The climatic proxies derived from the profile show that monsoonal climatic variation, especially precipitation behind the pedogenic change, was ultimately responsible for the cultural and land-use change over the Loess Plateau. Increased precipitation brought on by southeast monsoon, conditioned the domestication and cultivation of millets in the southern part of the region during 8000–7000 a BP at the beginning of the Holocene climatic optimum. Sufficient precipitation and the well-developed fertile soils facilitated the expansion of millets cultivation to the northern Loess Plateau and the southern Mongolian Plateau between 7000 a BP and 3600 a BP. Reduced precipitation and deteriorated land-use conditions because of intensified northwest monsoon at the end of the Holocene climatic optimum caused a regional desertion by the arable farming communities and the invasion of the nomads in the northern part of the Loess Plateau from ca. 3600 a BP during the Bronze Age. Monsoonal climatic change and the resultant

pedogenic change dramatically affected the cultural development over the Loess Plateau during the Holocene.

Huang, G. H., S. J. Cohen, Y. Y. Yin, B. Bass. (1998). "Land resources adaptation planning under changing climate - a study for the Mackenzie Basin." Resources, Conservation and Recycling **24**(2): 95-119.

An inexact-fuzzy multiobjective programming model is proposed for adaptation planning of land resources management in the Mackenzie Basin under changing climate. This integrated adaptation planning enables the inclusion of systems interaction and feedback mechanisms and can therefore yield insights that scattered information cannot offer. Many sectors were considered, including agriculture, forest, wildlife habitat preservation, wetland preservation, hunting, recreation, and soil conservation, as well as their interactive relationships. The results indicate that uncertain, multiobjective, dynamic and interactive features of the study system have been effectively reflected. Temporal variations of land characteristics and land-use activities exist due to changes in climatic, economic and environmental conditions. However, through effective systems analysis and planning, the desired land-use patterns for adapting to the changing climate and compromising objectives from different stakeholders could be obtained.

Huang, C. C., J. Pang, P. Li. (2002). "Abruptly increased climatic aridity and its social impact on the Loess Plateau of China at 3100 a B.P." Journal of Arid Environments **52**(1): 87-99.

A multi-disciplinary research with integration of the theory and methods of climatic change and history was carried out in the southern Loess Plateau of China. High-resolution soil-sedimentary data define an abruptly increased climatic aridity at 3100 a B.P. on the southern Loess Plateau. It was caused by a shift from the dominance of the maritime monsoon to the continental monsoon in the East Asia. The marked aridity induced a considerable deterioration of environment and degradation of land resources. Consequently, both the livestock failure of the nomadic tribes in the north and the crop failure of the Han Chinese in the south resulted in large-scale nomadic southward migration, and dislocations of the political capital and capital cities of the predynastic Zhou culture. Land use of arable farming was replaced largely by pastoral farming on the plateau. The combination of severe drought and resultant great famine was the fundamental cause of social instability and eventual collapse of the Shang Dynasty at 3000 a B.P. This suggests that the impact of abrupt climatic change was profound at 3100 a B.P. in the present semi-arid zone.

Huang, C. C., S. Zhao, J. Pang, Q. Zhou, S. Chen, P. Li, L. Mao, M. Ding. (2003). "Climatic aridity and the relocations of the Zhou Culture in the southern loess plateau of China." *Climatic Change* **61**(3): 361-378.

Several Holocene loess-soil profiles at the archaeological sites of the political center, and later, the capital cities of the predynastic Zhou and Western Zhou Dynasty (ca. 1400–771 B.C.) in the southern Loess Plateau were studied multi-disciplinarily. It provides insights into monsoonal climatic change and the relocations of the Zhou culture in this climatically sensitive semiarid zone. Both the analytical data and written records indicate that increased climatic aridity at 1150 B.C. induced a considerable environmental deterioration and degradation of natural resources, especially water shortages, decreases in precipitation and deficits in soil moisture. These resulted in poor harvest and great famines, plagues, domestic upheavals, population migrations, and even conflicts between Zhou people who subsisted on dry farming and nomadic tribes on the northern steppe during the development of the Zhou culture. It seems that persistent droughts forced Zhou people to move from the upland plateau to the lowland riverbanks step by step through relocations, following a direction of increasing climatic humidity, soil moisture, water availability and biodiversity. The southward migration of the nomads on the steppe of the northern Loess Plateau and the Mongolia Plateau in response to the climatic aridity was another dynamic force that caused the relocations of the Zhou culture.

Huckleberry, G., C. Beck, C. Beck, G. T. Jones, A. Holmes, M. Cannon, S. Livingston, and J. M. Broughton. (2001). "Terminal Pleistocene/Early Holocene Environmental Change at the Sunshine Locality, North-Central Nevada, U.S.A." *Quaternary Research* **55**(3): 303-312.

Sedimentological, faunal, and archaeological investigations at the Sunshine Locality, Long Valley, Nevada reveal a history of human adaptation and environmental change at the last glacial-interglacial transition in North America's north-central Great Basin. The locality contains a suite of lacustrine, alluvial, and eolian deposits associated with fluviually reworked faunal remains and Paleoindian artifacts. Radiocarbon-dated stratigraphy indicates a history of receding pluvial lake levels followed by alluvial downcutting and subsequent valley filling with marsh-like conditions at the end of the Pleistocene. A period of alluvial deposition and shallow water tables (9,800 to 11,000 14C yr B.P.) correlates to the Younger Dryas. Subsequent drier conditions and reduced surface runoff mark the early Holocene; sand dunes replace wetlands by 8,000 14C yr B.P. The stratigraphy at Sunshine is similar to sites located 400 km south and supports regional climatic synchronicity in the central and southern Great Basin during the terminal Pleistocene/early Holocene. Given regional climate change and recurrent

geomorphic settings comparable to Sunshine, authors believe that there is a high potential for buried Paleoindian features in primary association with extinct fauna elsewhere in the region yet to be discovered due to limited stratigraphic exposure and consequent low visibility.

Hughes, T. P., A. H. Baird, D. R. Bellwood, M. Card, S. R. Connolly, C. Folke, R. Grosberg, O. Hoegh-Guldberg, J. B. C. Jackson, J. Kleypas, J. M. Lough, P. Marshall, M. Nystrom, S. R. Palumbi, J. M. Pandolfi, B. Rosen, and J. Roughgarden. (2003). "Climate change, human impacts, and the resilience of coral reefs." *Science* **301**(5635): 929-933.

The diversity, frequency, and scale of human impacts on coral reefs are increasing to the extent that reefs are threatened globally. Projected increases in carbon dioxide and temperature over the next 50 years exceed the conditions under which coral reefs have flourished over the past half-million years. However, reefs will change rather than disappear entirely, with some species already showing far greater tolerance to climate change and coral bleaching than others. International integration of management strategies that support reef resilience need to be vigorously implemented, and complemented by strong policy decisions to reduce the rate of global warming.

Hugo, G. (1996). "Environmental concerns and international migration." *The International Migration Review* **30**(1): 105-131.

According to Nobel, the definition of the contemporary refugee has been modified by the UN High Commission for Refugees (UNHCR) to include well-founded fear of being persecuted for reasons mentioned in the Geneva Convention as well as external aggression, occupation, foreign domination, and massive human rights violations. Additionally, Olson's definition includes physical dangers (floods, volcanic eruptions) and economic insufficiency (drought, famine). The term environmental refugee has gained wide usage lately. Richmond's model recognizes the predisposing factors: the nature of the biophysical environment, structural constraints, facilitating factors, precipitating events, and the feedback effects of the environmentally induced migration. As to environmental factors as a cause of migration, a global survey of natural disasters for the period of 1947-1980 indicated that the overall number of disasters is increasing and 86% of the lives lost occurred in Asia. China and India dominated in the number of environmental refugees during 1976-1994. Furthermore, the droughts of 1968-73 and 1982-84 led to millions of environmental refugees in Africa. There were 1 million environmental refugees in Burkina Faso alone. The precipitating events and conditions were population growth, widespread poverty, food production efforts, loosened regulations, lacking environmental legislation, and climate change. The

bulk of refugees move within the national boundaries, but there has been an increasing trend of South-North international migration in the last decade and the emergence of an international immigration industry. The environmental impacts of international migration has surfaced in Australia because of detrimental effects on the national ecology, but resource management policies could handle environmental concerns. Ethical and policy implications mean that much of contemporary environmental degradation in developing countries are rooted in colonial expansion and the problem will require a global solution.

Hulme, M. (2003). "Abrupt climate change: can society cope?" Philosophical Transactions. Series A, Mathematical, Physical, And Engineering Sciences **361**(1810): 2001-2019; discussion 2019-2021.

Consideration of abrupt climate change has generally been incorporated neither in analyses of climate-change impacts nor in the design of climate adaptation strategies. Yet the possibility of abrupt climate change triggered by human perturbation of the climate system is used to support the position of both those who urge stronger and earlier mitigative action than is currently being contemplated and those who argue that the unknowns in the Earth system are too large to justify such early action. This paper explores the question of abrupt climate change in terms of its potential implications for society, focusing on the UK and northwest Europe in particular. The nature of abrupt climate change and the different ways in which it has been defined and perceived are examined. Using the example of the collapse of the thermohaline circulation (THC), the suggested implications for society of abrupt climate change are reviewed; previous work has been largely speculative and has generally considered the implications only from economic and ecological perspectives. Some observations about the implications from a more social and behavioural science perspective are made. If abrupt climate change simply implies changes in the occurrence or intensity of extreme weather events, or an accelerated unidirectional change in climate, the design of adaptation to climate change can proceed within the existing paradigm, with appropriate adjustments. Limits to adaptation in some sectors or regions may be reached, and the costs of appropriate adaptive behaviour may be large, but strategy can develop on the basis of a predicted long-term unidirectional change in climate. It would be more challenging, however, if abrupt climate change implied a directional change in climate, as, for example, may well occur in northwest Europe following a collapse of the THC. There are two fundamental problems for society associated with such an outcome: first, the future changes in climate currently being anticipated and prepared for may reverse and, second, the probability of such a scenario occurring remains fundamentally unknown. The implications of both problems for climate policy and for decision making have not been researched. It is premature to argue therefore that abrupt climate change - in the

sense referred to here - imposes unacceptable costs on society or the world economy, represents a catastrophic impact of climate change or constitutes a dangerous change in climate that should be avoided at all reasonable cost. Author concludes by examining the implications of this contention for future research and policy formation.

Hulme, M., E. M. Barrow, N. W. Arnell, P. A. Harrison, T. C. Johns, and T. E. Downing. (1999) "Relative impacts of human-induced climate change and natural climate variability." Nature **397**(6721): 688-691.

Assessments of the regional impacts of human-induced climate change on a wide range of social and environmental systems are fundamental for determining the appropriate policy responses to climate change. Yet regional-scale impact assessments are fraught with difficulties, such as the uncertainties of regional climate change prediction, the specification of appropriate environmental-response models, and the interpretation of impact results in the context of future socio-economic and technological change. The results from recent global climate simulations and two environmental response models were used to consider systematically the effects of natural climate variability (30-year timescales) and future climate change uncertainties on river runoff and agricultural potential in Europe. For some regions the impacts of human-induced climate change by 2050 will be undetectable relative to those due to natural multi-decadal climate variability. If misleading assessments of - and inappropriate adaptation strategies to - climate change impacts are to be avoided, future studies should consider the impacts of natural multi-decadal climate variability alongside those of human-induced climate change.

Huq, S., Z. Karim, M. Asaduzzaman, F. Mahtab, (eds.) (1999). Vulnerability and adaptation to climate change for Bangladesh. Dordrecht, Netherlands, Kluwer Academic Publishers, PP. 147.

Discusses: (1) overview; (2) development of climate change scenarios with general circulation models; (3) water resources vulnerability to climate change with special reference to inundation; (4) climate change vulnerability of crop agriculture; (5) assessment of food grain production loss due to climate induced enhanced soil salinity; (6) beach erosion in the Eastern Coastline of Bangladesh; (7) vulnerability of forest ecosystems of Bangladesh to climate change; (8) fish resources vulnerability and adaptation to climate change in Bangladesh; and (9) adaptation to climate change in Bangladesh: future outlook.

Hurd, B. H., M. Callaway, J. Smith, P. Kirshen. (2004). "Climatic change and U.S. water resources: from modelled watershed impacts to national estimates." Journal of the American Water Resources Association **40**(1): 129-148.

Water is potentially one of the most affected resources as climate changes. Though knowledge and understanding has steadily evolved about the nature and extent of many of the physical effects of possible climate change on water resources, much less is known about the economic responses and impacts that may emerge. Methods and results are presented that examine and quantify many of the important economic consequences of possible climate change on U.S. water resources. At the core of the assessment is the simulation of multiple climate change scenarios in economic models of four watersheds. These Water Allocation and Impact Models (Water-AIM) simulate the effects of modelled runoff changes under various climate change scenarios on the spatial and temporal dimensions of water use, supply, and storage and on the magnitude and distribution of economic consequences. One of the key aspects and contributions of this approach is the capability of capturing economic response and adaptation behaviour of water users to changes in water scarcity. By reflecting changes in the relative scarcity (and value) of water, users respond by changing their patterns of water use, intertemporal storage in reservoirs, and changes in the pricing of water. The estimates of economic welfare change that emerge from the Water-AIM models are considered lowerbound estimates owing to the conservative nature of the model formulation and key assumptions. The results from the Water-AIM models form the basis for extrapolating impacts to the national level. Differences in the impacts across the regional models are carried through to the national assessment by matching the modelled basins with basins with similar geographical, climatic, and water use characteristics that have not been modelled and by using hydrologic data across all U.S. water resources regions. The results from the national analysis show that impacts are borne to a great extent by nonconsumptive users that depend on river flows, which rise and fall with precipitation, and by agricultural users, primarily in the western United States, that use a large share of available water in relatively low-valued uses. Water used for municipal and industrial purposes is largely spared from reduced availability because of its relatively high marginal value. In some cases water quality concerns rise, and additional investments may be required to continue to meet established guidelines.

Iglesias, A., L. Erda, C. Rosenzweig. (1996). "Climate change in Asia: a review of the vulnerability and adaptation of crop production." Water, Air, and Soil Pollution **92**(1/2): 13-27.

A number of studies which have provided quantitative assessments of the potential climate change impacts on crop production in Asia are presented and discussed. These estimates take into account: (a) the uncertainty in the levels of climate change expected, using a range of climate change scenarios; (b) the physiological effects of carbon dioxide on the crops; and (c) different adaptive responses. In all cases, the effects of climate change induced by increased

atmospheric CO₂ depended upon the counteracting effects of increased daily evapotranspiration rates, the shortening of crop growth duration and changes in precipitation patterns, as well as the effects of CO₂ on crop growth and water-use efficiency. Although results varied depending on geographical location, the production of rice (the main food crop in the region) did not benefit from climate change in general. In South and Southeast Asia, concern about how climate change may affect El Niño/Southern Oscillation events is highlighted, since these play a key role in determining agricultural production. The problems arising from the variation in water availability and soil degradation (which are currently major challenges to agriculture in the region), and their possible exacerbation if global climate change projections are realized, are discussed. It is noted that many studies have considered strategies for improving agricultural management, based on the optimization of crop management decisions and it is suggested that climate change analyses could be further strengthened by economic studies that integrate the potential use of natural resources across sectors.

Ikeme, J. (2003). "Climate change adaptational deficiencies in developing countries: the case of sub-Saharan Africa." Mitigation and Adaptation Strategies for Global Change 8(1): 29-52.

Adaptation is now recognized as an inevitable component of the overall climate change response strategy. For a developing region like sub-Saharan Africa with low greenhouse gas emissions and high vulnerability to the impacts of climate change, the importance of adaptation in climate change policy is even more fundamental. This paper examined a look at the adaptational preparedness of the sub-Saharan African region to climate change. Clearly evident in the environmental strategy and development focus of these countries is lack of recognition of the need to adapt, poor incentive to adapt and low capacity to adapt to climate change. This further exacerbates their vulnerability and has implications for the global climate change response strategy. Unfortunately, few attempts have been made to understand the structural reasons underlying the pervasive pattern of adaptational unpreparedness in the region, neither has there been a comprehensive and systematic analysis of how to remedy this problem. This paper is a contribution in this regard. It also highlights the factors to which international community need to pay attention, if it truly wishes to make its efforts at adaptation more global in scope.

Issar, A. S. and M. Zohar. (2004). Climate Change - Environment and Civilization in the Middle East. Springer Verlag 252 p.

Survey of the ancient levels of lakes, rivers and the sea, as well as changes in the compositions of stalagmites and sediments showed an astonishing correlation

of climate changes with the emergence and collapse of civilizations in the Middle East. Each warm period was characterized by aridization, economic crisis and mass migration. Whereas cold periods brought abundant rain, prosperity and settlement in the arid lands. Authors argue that the agricultural evolution was generated in principle by the warming and aridization of the Near East, with human societies reacting to survive these changes. Similarly, the urban revolution and flourish of the Early Bronze, the renewal of relative prosperity during the Middle Bronze and of the Iron Age were due primarily to the abundant precipitation that enabled the accumulation of resources by all levels societies. Decline came when these conditions worsened. The authors thus concluded, that climate change was the decisive factor in the history surrounding the origins of the "cradle of civilization".

Ivey, J. L., J. Smithers, R. C. de Loë, R. D. Kreutzwiser. (2004). "Community capacity for adaptation to climate-induced water shortages: linking institutional complexity and local actors." Environmental Management **33**(1): 36-47.

There is growing concern for the capacity of urban and rural communities to manage current water shortages and to prepare for shortages that may accompany predicted changes in climate. In this paper, concepts relating to the notion of climate adaptation and particularly "capacity building" are used to elucidate several determinants of community-level capacity for water management. These concepts and criteria are then used to interpret empirically derived insights relating to local management of water shortages in Ontario, Canada. General determinants of water-related community capacity relate to upper tier political and institutional arrangements; the characteristics of, and relationships among, pertinent agencies, groups, or individuals involved in water management; and the adequacy of financial, human, information, and technical resources. The case analysis illustrates how general factors play out in local experience. The findings point to geographically specific factors that influence the effectiveness of management. Key factors include collaboration between water managers, clarification of agency roles and responsibilities, integration of water management and land-use planning, and recognition and participation of both urban and rural stakeholders, whose sensitivities to water shortages are spatially and temporally variable.

Janssen, M. A., T. A. Kohler, M. Scheffer. (2003). "Sunk-cost effects and vulnerability to collapse in ancient societies." Current Anthropology **44**(5): 722-728.

Janssen, M. A. and M. Scheffer. 2004. "Overexploitation of renewable resources by ancient societies and the role of sunk-cost effects." *Ecology and Society* **9**(1): 6. [online] URL: <http://www.ecologyandsociety.org/vol9/iss1/art6>.

One of the most persistent mysteries in the history of humankind is the collapse of ancient societies. It is puzzling that societies that achieved such high levels of development disappeared so suddenly. It has been argued that overexploitation of environmental resources played a role in the collapse of such societies. In this paper, authors propose an explanation why overexploitation seems more common in ancient societies that built larger structures. This explanation is based on the well-studied sunk-cost effect in human decision making: decisions are often based on past investments rather than expected future returns. This leads to an unwillingness to abandon something (e. g., a settlement) if a great deal has been invested in it, even if future prospects are dim. Empirical study suggests that there are indications of sunk-cost effects in the histories of several ancient societies. A stylized model is used to illustrate under which conditions societal collapse may be expected. Finally, authors discuss the consequences of these insights for current societies.

Jat, M. L., R. Singh, B. S. Kumpawat, J. K. Balyan. (2003). "Rainy season and its variability for crop planning in Udaipur region." *Journal of Agrometeorology* **5**(2): 82-86.

Rainy season and its variability in Udaipur region, Rajasthan, India have been studied for the period 1981-2000. The onset, withdrawal and length of rainy season were worked out by forward and backward accumulation method. Daily rainfall data of 20 years (1981-2000) collected from the College of technology and Engineering in Udaipur, were used. The study reveals that off-season tillage and primary tillage may be started from 24th week and sowing of crop from 26th week. Occurrences of two consecutive dry weeks were analysed using Markov-Chain model. Mid-season drought is likely in 31st-34th week and terminal drought in the 35th week in the region.

Jodha, N. S. (1975). "Famine and famine policies: some empirical evidence." *Economic and Political Weekly* **10**(41): 1609-1623.

The famine relief policies of the Indian government have been criticised for being too liberal, wasteful and devoid of any economic rationality. It has been argued by scholars that the lack of understanding by the administrators of the true nature of the distress caused by drought or famine is responsible for these deficiencies. The validity of these criticisms is examined, using empirical evidence from the arid region of Western Rajasthan, one of the drought prone areas in India. The study concludes that ignorance about the true nature of distress on the

part of administrators is not an important factor responsible for the deficiencies of famine policies. Lack of economic rationality in famine policies is ascribed to the generalized distortions of the system.

Jodha, N. S. (1989). "Potential strategies for adapting to greenhouse warming: perspectives from the developing world." In, Greenhouse warming: abatement and adaptation. Proceedings of a workshop held in Washington, D.C., June 14-15, 1988., Washington, D.C., USA, Resources for the Future.

The paper discusses how developing countries, particularly those in the semiarid tropical zone, may adapt to greenhouse warming. The relatively large size of the agricultural sector is a common feature that makes developing countries particularly sensitive to climatic change. Specific agricultural vulnerabilities are illuminated. Possible adaptation strategies are assessed that would build on developing countries' past experience of adjusting to risk and crises both at the farm level and at the policy and programme levels. Adjustments to risks and crises caused by factors other than climate change are also illustrated to indicate how those experiences can help in assessing options for adapting to any future impacts of climatic change. The need for greater information on all facets of the greenhouse effect is stressed.

Jodha, N. S. (1988). "Farmers adjustment strategies against rainfall variability in dry regions of India." Fertiliser News **33**(4): 67-72.

The paper presents: (1) the differences in structural and operational features of farming systems in areas with different degrees of weather risk, to indicate farmers' adaptations to the long-term behaviour of rainfall; (2) differences in cropping decisions in response to different soil moisture situations during the planting season at the same locations, to illustrate adjustment measures against inter-year differences in seasonal rainfall; (3) differences in input use and farm practices during drought year and normal rainfall year at the same locations, to indicate the degree of flexibility and short-term adjustments to serious deficit in rainfall; and (4) differences in households' non-crop decisions and actions during drought year and non-drought year, to illustrate another aspect of adjustment to weather risk. The areas studied are Akola and Sholapur in Maharashtra, and Jodhpur in Rajasthan.

Johnson, N., C. Revenga, J. Echeverria. (2001). "Managing water for people and nature." Science **292**(5519): 1071-1072.

Growing water scarcity and rapid declines in aquatic biodiversity indicate water policies are failing to protect life's most vital resource. A major reason for growing water scarcity and freshwater ecosystem decline is that water is

undervalued the world over. In this Policy Forum, the authors recommend equitable market-oriented mechanisms, including realistic pricing, integrating watershed protection costs into water prices, and charging polluters for their effluents. Science plays an essential role in providing information needed to make these mechanisms work effectively.

Jones, T. L., G. M. Brown, L. M. Raab, J. L. McVickar, W. G. Spaulding, D. J. Kennett, A. York, and P. L. Wlaker. (1999). "Environmental imperatives reconsidered: demographic crises in western North America during the medieval climatic anomaly." *Current Anthropology* 40(2): 137-170.

Review of late Holocene paleoenvironmental and cultural sequences from four regions of western North America show striking correlations between drought and changes in subsistence, population, exchange, health, and interpersonal violence during the Medieval Climatic Anomaly (A.D. 800-1350). While ultimate causality is difficult to identify in the archaeological record, synchrony of the environmental and cultural changes and the negative character of many human responses--increased interpersonal violence, deterioration of long-distance exchange relationships, and regional abandonments--suggest widespread demographic crises caused by decreased environmental productivity. The medieval droughts occurred at a unique juncture in the demographic history of western North America when unusually large populations of both hunter-gathers and agriculturalists had evolved highly intensified economies that put them in unprecedented ecological jeopardy. Long-term patterns in the archaeological record are inconsistent with the predicted outcomes of simple adaptation or continuous economic intensification, suggesting that in this instance environmental dynamics played a major role in cultural transformations across a wide expanse of western North America among groups with diverse subsistence strategies. These events suggest that environment should not be overlooked as a potential cause of prehistoric culture change.

Jordan, A. (1994). "Paying the incremental costs of global environmental protection: the evolving role of GEF." *Environment* 36(6): 12-20,31-36.

The article assesses the role of the Global Environmental Facility, set up by the United Nations and the World Bank in 1991, pre- and post- UNCED 1992. In the pilot phase, the emphasis was on global warming, pollution of international waters, destruction of biodiversity, and depletion of stratospheric ozone. GEF was designed to generate global environmental benefits, rather than economic or environmental gains to the host nation. GEF is now the funding mechanism for the international conventions on ozone, biodiversity and climate change arising from the Rio conference, and thus a key player in environmental politics. Three

shifts in the international politics of the environment are highlighted: bureaucratic adaptation, i.e., redefinition of their roles by many of the major international organizations and agencies; common but differentiated responsibility (between donors); and institutional collaboration. Highlights of the pilot phase were donor domination; speed; additionality and incrementality; collaboration among stakeholders, and focus on global environmental problems. Issues for the post-pilot phase are: decision making; focus and objectives; and the scale of assistance. GEF should be viewed as a departure from traditional forms of international financial assistance. It is a post-UNCED test of how well governments can collaborate in pursuit of globally sustainable development. The transition to sustainable development and the restructuring of the GEF both require a complicated give and take between and within blocs of countries and across an array of complex issues. The agreement reached on GEF II in March 1994 marks the beginning of this new phase, with likely funding of \$2000 million.

Jung, T. Y., E. L. La Rovere, H. Gaj, P. R. Shukla, D. Zhou. (2000). "Structural Changes in Developing Countries and Their Implication for Energy-Related CO₂ Emissions." Technological Forecasting and Social Change **63**(2-3): 111-136.

The concept of "structural shifts" has various meanings. In this study, authors discuss structural shifts as they relate to the issue of climate change. The concept of "Sustainable Development" is emerging as one of the major challenges for economic development. Although the 20th century has generally been recognized as the era of "competition of ideologies," it is widely believed that the new international economic order of the 21st century will emerge under the paradigm of sustainable development. In this sense, structural shifts may be redefined for both developed and developing countries. To envisage shifts in the next century, several key-driving forces must be considered. First is the utilization of the natural endowments of a country, including climate and natural resources. Second is the size of land and population, population growth trends, and population composition. Patterns of urbanization, economic, and industrial structures, technological diffusion, and institutional and legal mechanisms are closely related to the patterns and strategies for economic development in each country as part of the new international economic order. Authors assess the dynamics of structural shifts through the interaction of all these driving forces. This paper examines historical development patterns and common features of developed countries to analyze both developed and developing countries' future adaptation processes to the new global concerns of climate change.

Juyal, N., L. S. Chamyal, S. Bhandari, D. M. Maurya, A. K. Singhvi. (2004). "Environmental changes during Late Pleistocene in the Orsang River Basin, western India." Journal of the Geological Society of India **64**(4): 471-479.

Chronometric and sedimentological data generated from the exposed Quaternary sequences of the Orsang River basin indicate close correspondence between the environmental changes and fluvial aggradation. The oldest and regionally extensive fine silty-clay occurring at the base of the successions is dated to >97 ka suggesting prevalence of high sinuosity suspended load fluvial regime. Its stratigraphic position suggests that the deposition occurred during the enhanced southwest monsoon corresponding to the Marine Isotopic Stage-5 (MIS-5). The gravel deposits that overlie provide an age of similar to 60 ka indicating dominance of braided system (MIS-4) during the reduced southwest monsoon. The pluvial interstadial (MIS-3) is represented by flood plain facies that was deposited under the persistent fluvial system strengthened by enhanced southwest monsoon and assigned ages ranging between 50 and 30 ka. An extensive aeolian sand sheet that blankets the topography, is luminescence dated to 21 ka suggesting the onset of Last Glacial Maximum in the Orsang River basin.

Kahn, M. E. (2003). "Two measures of progress in adapting to climate change." Global Environmental Change **13**(4): 307-312.

Adaptation will play a key role in determining the economic and social costs of climate change. One important measure of adaptation is reductions in deaths caused by climate events. This paper uses two new data sets to test the hypothesis that, in recent years, climate events cause less deaths than in the past. Using data on deaths caused by natural disasters and data on skin cancer death rates in warmer and cooler US states, this paper reports evidence in favor of the adaptation progress hypothesis.

Kajale, M. D. and B. C. Deotare. (1997). Late Quaternary environmental studies on salt lakes in western Rajasthan, India: a summarised view. Journal of Quaternary Science **12**(5): 405 – 412.

The paper reviews pollen analytical and palaeoenvironmental work carried out on saline lakes in western Rajasthan, northwest India. The saline lakes are salient geomorphological features within the arid and semi-arid landscapes to the west of the Aravalli mountain ranges. Preliminary palynological work was carried out on two profiles from a gypsum-rich lake depression around Thob (District of Barmer). The varied pollen data are indicative of a fluctuating vegetational assemblage, possibly in response to local hydrological conditions and not necessarily indicative of climatic change. Pollen of *Ephedra* sp. (a typical desert species) in the lower levels suggests episodes of relatively dry conditions during the early phase of lake sedimentation at the end of the Pleistocene. Other work at four lake sites, on the basis of pollen analysis has indicated shifts in climatic and vegetational belts during the early Holocene, especially during the period of Indus

Valley Culture. Later in the Holocene, between 5000 and 3500 yr BP, rainfall variations have been related to the dynamics of the monsoon. Pioneering geoarchaeological studies carried out at the palaeolithic site of 16 R and the adjacent Didwana lake have illustrated palaeoclimatic fluctuations and accompanying changes in cultural stages from the lower palaeolithic to mesolithic. These studies have been extended geochemically and sedimentologically through a detailed study documenting a history of salinity from 20000 to 13000 yr BP and freshwater conditions from 9000 to 6000 yr BP. Later studies have illustrated a sequence of changes reflecting summer and winter precipitation. These have indicated steppe vegetation during the last Glacial Maximum along with hypersaline lake conditions at Didwana, inferring a weakened summer monsoon and relatively high winter precipitation. The taxa indicative of both summer and winter precipitation in the mid-Holocene declined during the late Holocene, at the same time as falling lake levels around 4000 yr BP, a time when other lakes, at Sambhar, Lunkaransar and Pachpadra, also became ephemeral.

Kakade, B., K. Petare, G. Neelam, S. Pawar, A. Chaurasia. (2003). "Combating drought through a participatory watershed development approach: a case study from Gokulpura-Govardhanpura villages in Bundi district, Rajasthan, India." Natural Resource Management 6(2): 2-11.

Most of Rajasthan falls under the hot, semiarid agroclimatic zone. With 5.017 million ha of cultivable wasteland, the State of Rajasthan bears the highest share from a total of 13.879 million ha for India. The yield of food grains in the State is only 803 kg per hectare and is the lowest for any state in India (Kakade 2002). Droughts are ubiquitous to Rajasthan, with erratic rainfall and extreme temperatures being common features in many areas. This paper presents the approach implemented in the Bundi district by the Pune based non-government organization, BAIF. The implementation of the holistic watershed development approach has changed the whole socioeconomic and ecosystem scenario of the villages. The villages have overcome the subsequent droughts and now have ample water, enough food grains, fodder for livestock and many more benefits.

Kale, V. S., A. K. Singhvi, P. K. Mishra, D. Banerjee. (2000). "Sedimentary records and luminescence chronology of Late Holocene palaeofloods in the Luni River, Thar Desert, northwest India." CATENA 40(4): 337-358.

River Luni is the only well-integrated river system in the Thar Desert of India. This river catastrophically flooded due to unusually heavy rainfall in the catchment area during July 1979. In order to establish whether floods of this magnitude have occurred in the recent geological past, sedimentary records of palaeofloods occurring in the Sindari Gorge, in the lower Luni Basin were investigated. The

principal slackwater flood deposits were observed in a back-flooded tributary near Bhuka. Analysis of the slackwater flood deposits preserved in the back-flooded tributary and their luminescence dating suggests that the Luni River has experienced at least 17 extreme floods during the past millennium. Evidence from the Bhuka site also suggests that no floods comparable in magnitude to the July 1979 megaflood have occurred during this period. This observation is in conformity with the palaeoflood record of central India. Comparison of the long-term monsoon rainfall series for the Luni Basin and the Indian region reveals a clear link between the two, and indicates that the clustering of large floods in the last few decades and during the Medieval warming period is a regional phenomenon associated with wetter conditions. This correlates with a regionally extended episode of landscape stability denoted by stabilization of dunes in this region.

Kar, A., A. K. Singhvi, S. N. Rajaguru, N. Juyal, J. V. Thomas, D. Banerjee, R. P. Dhir. (2001) "Reconstruction of the late Quaternary environment of the lower Luni Plains, Thar Desert, India." *Journal of Quaternary Science* **16**(1): 61-68.

Geomorphological processes in the Thar Desert of India are largely climate driven. In the lower reaches of the River Luni (the only major drainage system in the Thar Desert) a fluvio-aeolian sequence was located at a site called Khudala. Sediments of this sequence represented a variety of depositional environments, namely aeolian, fluvially reworked aeolian, overbank deposits, gravels, and occasional evidence of pedogenesis. This provided a good opportunity to study aeolian-fluvial interaction in the region and for deducing climatic records. From the luminescence dating standpoint these sequences offered a good opportunity for a comparative study of thermoluminescence (TL), blue-green light stimulated luminescence (BGSL) and infrared light stimulated luminescence (IRSL) on different mineral separates of identical provenance but deposited under different environments. Broadly, within experimental errors, the TL ages agreed with BGSL and IRSL ages on aeolian sands, but differed substantially in the case of fluvially reworked and proximally deposited sands and silts. The sequence provided a record spanning more than 100 ka, with an aeolian phase at > 100 ka, a channel activation phase between 70 and 30 ka and a phase of climate instability between 13 and 8 ka. This appears consistent with the records of monsoon performance during this period, which includes the Younger Dryas. It is also inferred that during the Last Glacial epoch, geomorphological processes in the Thar (both aeolian and fluvial) were dormant largely on account of their relationship with the southwest monsoon.

Karl, T. R. and K. E. Trenberth (2003). "Modern Global Climate Change." *Science* **302**(5651): 1719-1723.

Modern climate change is dominated by human influences, which are now large enough to exceed the bounds of natural variability. The main source of global climate change is human-induced changes in atmospheric composition. These perturbations primarily result from emissions associated with energy use, but on local and regional scales, urbanization and land use changes are also important. Although there has been progress in monitoring and understanding climate change, there remain many scientific, technical, and institutional impediments to precisely planning for, adapting to, and mitigating the effects of climate change. There is still considerable uncertainty about the rates of change that can be expected, but it is clear that these changes will be increasingly manifested in important and tangible ways, such as changes in extremes of temperature and precipitation, decreases in seasonal and perennial snow and ice extent, and sea level rise. Anthropogenic climate change is now likely to continue for many centuries. We are venturing into the unknown with climate, and its associated impacts could be quite disruptive.

Kashyap, A. (2004). "Water governance: learning by developing adaptive capacity to incorporate climate variability and change." Water Science & Technology **49**(7): 141-6.

There is increasing evidence that global climate variability and change is affecting the quality and availability of water supplies. Integrated water resources development, use, and management strategies, represent an effective approach to achieve sustainable development of water resources in a changing environment with competing demands. It is also a key to achieving the Millennium Development Goals. It is critical that integrated water management strategies must incorporate the impacts of climate variability and change to reduce vulnerability of the poor, strengthen sustainable livelihoods and support national sustainable development. UNDP's strategy focuses on developing adaptation in the water governance sector as an entry point within the framework of poverty reduction and national sustainable development. This strategy aims to strengthen the capacity of governments and civil society organizations to have access to early warning systems, ability to assess the impact of climate variability and change on integrated water resources management, and developing adaptation intervention through hands-on learning by undertaking pilot activities.

Kates, R. W. (2000). "Cautionary tales: adaptation and the global poor." Climatic Change **45**(1): 5-17.

Many who study global change, particularly from industrialized countries, are optimistic about the capacity of agriculture to successfully adapt to climate change. This optimism is based on historic trends in yield increases, on the spread

of cropping systems far beyond their traditional agroecological boundaries, and the inherent flexibility of systems of international trade. Analysis of the success (or in rare cases, failure) of adaptation is by analogy - either to analogous socioeconomic or technological change or to short term environmental change. Such studies have been limited to industrialized countries. This paper uses five analogs from developing countries to examine potential adaptation to global climate change by poor people. Two are studies of comparative developing country responses to drought, flood, and tropical cyclone and to the Sahelian droughts of the 1970s and 1980s that illustrate adaptations to climate and weather events. Two address food production and rapid population growth in South Asia and Africa. Three types of adaptive social costs are considered: the direct costs of adaptation, the costs of adapting to the adaptations, and the costs of failing to adapt. A final analog reviews 30 village-level studies for the role that these social costs of adaptation play in perpetuating poverty and environmental degradation.

Kelly, P. M., W. N. Adger (2004) "Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation." *Climatic Change* 47 (4): 325-352.

Authors discuss approaches to the assessment of vulnerability to climate variability and change and attempt to clarify the relationship between the concepts of vulnerability and adaptation. In search of a robust, policy-relevant framework, we define vulnerability in terms of the capacity of individuals and social groups to respond to, that is, to cope with, recover from or adapt to, any external stress placed on their livelihoods and well-being. The approach that authors develop places the social and economic well-being of society at the centre of the analysis, focussing on the socio-economic and institutional constraints that limit the capacity to respond. From this perspective, the vulnerability or security of any group is determined by resource availability and by the entitlement of individuals and groups to call on these resources. Authors illustrate the application of this approach through the results of field research in coastal Vietnam, highlighting shifting patterns of vulnerability to tropical storm impacts at the household- and community-level in response to the current process of economic renovation and drawing conclusions concerning means of supporting the adaptive response to climate stress. Four priorities for action are identified that would improve the situation of the most exposed members of many communities: poverty reduction; risk-spreading through income diversification; respecting common property management rights; and promoting collective security. A sustainable response must also address the underlying causes of social vulnerability, including the inequitable distribution of resources.

Kennedy, G. and T. Mayer (2002). "Natural and constructed wetlands in Canada: an overview." *Water Quality Research Journal of Canada* 37(2): 295-325.

A review of freshwater wetland research in Canada was conducted to highlight the importance of these ecosystems and to identify wetland research needs. Both natural and constructed wetland systems are discussed. Natural wetlands are an important part of the Canadian landscape. They provide the habitat for a broad variety of flora and fauna and contribute significantly to the Canadian economy. It is estimated that the total value derived from consumptive and non-consumptive activities exceeds \$10 billion annually. The past decades have witnessed the continued loss and degradation of wetlands in Canada. In spite of recent protection, Canadian wetlands remain threatened by anthropogenic activities. This review shows that more research on fate and transport of pollutants from urban and agricultural sources in wetland systems is needed to better protect the health and to assure the sustainability of wetlands in Canada. Furthermore, improved knowledge of hydrology and hydrogeochemistry of wetlands will assure more effective management of these ecosystems. Lastly, better understanding of the effect of climate change on wetlands will result in better protection of these important ecosystems. Constructed wetlands are man-made wetlands used to treat non-point source pollution. The wetland treatment technology capitalizes on the intrinsic water quality amelioration function of wetlands and is emerging as a cost-effective, environmentally friendly method of treating a variety of waste waters. The use of wetland technology in Canada is, however, less common than in the USA. A number of research needs has to be addressed before the wetland treatment technology can gain widespread acceptance in Canada. This includes research pertaining to cold weather performance, including more monitoring, research on design adaptation and investigation of the effects of constructed wetlands on wildlife.

King, D. A. (2004). "Climate change science: Adapt, mitigate, or ignore?" *Science* **303**(5655): 176-177.

Global warming due to increased greenhouse gas emissions poses the most severe problem for governments today. A risk analysis forecasts increased flooding and coastline vulnerability in the United Kingdom and the world. The seriousness of economic damage depends on future global emission scenarios. The U.K. government is planning to reduce carbon dioxide emissions in the United Kingdom by 60% by 2050. Global agreement and sustained action to limit carbon dioxide emissions is needed.

Kirch, P. V., A. S. Hartshorn, O. A. Chadwick, P. M. Vitousek, D. R. Sherrod, J. Coil, L. Holm, and W. D. Sharp. (2004). "Environment, agriculture, and settlement patterns in a marginal Polynesian landscape." *PNAS* **101**: 9936-9941.

Understanding how the prehistoric Hawaiians sustained a permanent and sizeable human population in Kahikinui illuminates key aspects of the adaptability of preindustrial agrarian systems. Prehistoric Polynesian settlement on the arid, southern flank of Haleakala Volcano in Kahikinui district was concentrated between 400 and 600 m. This settlement zone, with a peak population density estimated by dated residential sites at 43-57 persons per km², depended on a dryland agricultural economy. Analysis of a suite of environmental variables strongly suggests that the distribution of human settlement was primarily determined by a few key parameters affecting the productivity of sweet potato and other dryland crops (Sweet potato is noted for its high degree of adaptability to soil and climate conditions). The rapid drop-off in settlement density <400 m elevation is directly related to the aridity and low water-holding capacity of the soil: this combination would have reduced soil moisture to levels below that required for sweet potato growth. The upper altitudinal boundary of the settlement zone is related to excess rainfall via a decline in soil nutrient availability. Above this, agricultural potential is limited by leaching. Indigenous Hawaiian agriculture was ritually controlled by an ideological system centered on the cults of Lono, god of dryland agriculture and sweet potato, and Kane, god of irrigation and taro. Rituals to ensure agricultural productivity were carried out in temples associated with these deities. In Kahikinui, authors have identified the stone platform and terraced foundations of 30 temples, whose orientations indicate associations with specific deities. These agricultural temples tend to concentrate at the interfaces between the hñaw flow (on which many temples were actually constructed) and the hkah and hkapa-1 substrates. Because these substrates were intensively cultivated, because of their optimum combination of workability and nutrient status, the temple sites presumably served as territorial markers for local groups using specific portions of these flows. Thus, the spatial distribution of Hawaiian agricultural temples exhibits a pattern linked to soil properties. In short, indigenous Hawaiian cultivators identified and adapted their agricultural system to an optimal zone for sweet potato cropping within a landscape that was on the marginal limits for tropical root crop production. The Kahikinui case is of particular interest in demonstrating the adaptability of Polynesian settlement systems to environmental constraints, which would have severely challenged indigenous agricultural production.

Komuscu, A. U., A. Erkan, S. Oz. (1998). "Possible impacts of climate change on soil moisture availability in the southeast Anatolia development project region (GAP): an analysis from an agricultural drought perspective." *Climatic Change* 40(3/4): 519-545.

This paper presents probable effects of climate change on soil moisture availability in the Southeast Anatolia Development Project (GAP) region of

Turkey. A series of hypothetical climate change scenarios and GCM [Global Climate Model]-generated IPCC [Intergovernmental Panel on Climate Change] Business-as-Usual scenario estimates of temperature and precipitation changes were used to examine implications of climate change for seasonal changes in actual evapotranspiration, soil moisture deficit, and soil moisture surplus in 13 subregions of the GAP. Of particular importance are predicted patterns of enhancement in summer soil moisture deficit that are consistent across the region in all scenarios. Least effect of the projected warming on the soil moisture deficit enhancement is observed with the IPCC estimates. The projected temperature changes would be responsible for a great portion of the enhancement in summer deficits in the GAP region. The increase in precipitation had less effect on depletion rate of soil moisture when the temperatures increase. Particularly southern and southeastern parts of the region will suffer severe moisture shortages during summer. Winter surplus decreased in scenarios with increased temperature and decreased precipitation in most cases. Even when precipitation was not changed, total annual surplus decreased by 4 to 43% for a 2 deg C warming and by 8-91% for a 4 deg C warming. These hydrological results may have significant implications for water availability in the GAP as the present project evaluations lack climate change analysis. Adaptation strategies - such as changes in crop varieties, applying more advanced dry farming methods, improved water management, developing more efficient irrigation systems, and changes in planting - will be important in limiting adverse effects and taking advantage of beneficial changes in climate.

König, U. (1998). "Climate change and tourism: investigation into the decision-making process of skiers in Australian ski fields." Pacific Tourism Review 2(1): 83-90.

This article presents the results of a skier and snowboarder survey that was carried out in the ski resorts of New South Wales, Australia in order to determine: how skiers and snowboarders think they would adapt if there were more winters ahead with little natural snow, what skiers and snowboarders would consider as important when choosing a ski resort if there were more future winters with little natural snow, and whether skiers and snowboarders perceive that climate change could threaten skiing in Australia. A survey was undertaken in three Australian ski resorts, Perisher Blue (595 respondents), Thredbo (282) and Charlotte Pass (49), during July-August 1996. The information provided by this article may be useful not only for the ski resorts when considering possible adaptation strategies to climate change but also for recreation planning in Australian alpine national parks.

Krankina, O. N., R. K. Dixon, A. P. Kirilenko, K. I. Kobak. (1997). "Global climate change adaptation: examples from Russian boreal forests." Climatic Change **36**(1/2): 197-215.

Russia contains approximately 20% of the world's timber resources and more than half of all boreal forests. These forests play a prominent role in environmental protection and economic development at global, national, and local levels, as well as providing commodities for indigenous people and habitats for a variety of plant and animal species. The response and feedbacks of Russian boreal forests to projected global climate change are expected to be profound. Large shifts in the distribution (up to 19% area reduction) and productivity of boreal forests are implied by the scenarios of General Circulation Models (GCMs). Uncertainty regarding the potential distribution and productivity of future boreal forests complicates the development of adaptation strategies for forest establishment, management, harvesting and wood processing. Although a low potential exists for rapid natural adaptation of long-lived, complex boreal forests, recent analyses suggest that Russian forest management and utilization strategies should be field tested to assess their potential to assist boreal forests in adaptation to a changing global environment. Current understanding of the vulnerability of Russian forest resources to projected climate change is discussed and examples of possible adaptation measures for Russian forests are presented, including: (1) artificial regeneration techniques that can be applied with the advent of failed natural regeneration and to facilitate forest migration northward; (2) silvicultural measures that can influence the species mix to maintain productivity under future climates; (3) identifying forests at risk and developing special management adaptation measures for them; (4) alternative processing and uses of wood and non-wood products from future forests; and (5) potential future infrastructure and transport systems that can be employed as boreal forests shift northward into melting permafrost zones. Current infrastructure and technology can be employed to help Russian boreal forests adapt to projected global environmental change. However, many current forest management practices may have to be modified. Application of this technical knowledge can help policymakers identify priorities for climate change adaptation.

Krishnan, A., Y. S. Rama Krishna, and G. G. S. N. Rao. 1980. "Is the incidence of droughts increasing in the arid zone of north-west India?" In, H. S. Mann, ed. Arid Zone Research and Development. Scientific Publishers, Jodhpur, pp. 47-51.

The occurrence of drought is studied through the determination of secular trends in the occurrence of deficit rainfall years, the available growing period, and moderate to severe drought periods as estimated by weekly water balances for the

rainy season. Daily rainfall data from different stations in western Rajasthan from 1901-1970 were used. Deficit rainfall years occurred more frequently during 1901-1920 and 1961-1970. The decreasing trend in the 1961-1970 decade is well marked in zones where rainfall is less than 300 mm annually. Rainfall deficit weeks for 1901-1970 do not show any specific trend. In the recent decade (1961-1970), there was a slight decrease in the growth period and increase in the severe drought periods from the values of the previous decade.

Kroeger, A. (1980). "Housing and health in the process of cultural adaptation: a case study among jungle and highland natives of Ecuador." The Journal of Tropical Medicine and Hygiene **83**(2): 53-69.

A household survey was undertaken among four Indian groups in Ecuador. Family housing conditions were related to dwelling development (from traditional to modern type) in data obtained from 727 family interviews. Measurements of the physical characteristics of the shelter completed the study. It is shown that: 1. The protection against the elements (temperature and humidity) is best in traditional houses and becomes worse with development; 2. The floor area per person is the highest in the traditional and the lowest in the modern houses; 3. Development does not mean improvement of domestic equipment; 4. New construction materials have many disadvantages when compared with traditional ones; 5. The more intensely a person is exposed to cross cultural influence the more likely he is to build a modern house. The findings are used to develop the argument that housing related health education should be adapted to the environment and the culture of the local population.

Kumar, K. K., K. R. Kumar, R. G. Ashrit, N. R. Deshpande, J. W. Hansen. (2004). "Climate impacts on Indian agriculture." International Journal of Climatology **24**(11): 1375-1393.

Agriculture (arguably the backbone of India's economy) is highly dependent on the spatial and temporal distribution of monsoon rainfall. This paper presents an analysis of crop-climate relationships for India, using historic production statistics for major crops (rice, wheat, sorghum, groundnut and sugarcane) and for aggregate food grain, cereal, pulses and oilseed production. Correlation analysis provides an indication of the influence of monsoon rainfall and some of its potential predictors (Pacific and Indian Ocean sea-surface temperatures, Darwin sea-level pressure) on crop production. All-India annual total production (except sorghum and sugarcane), and production in the monsoon (except sorghum) and post-monsoon seasons (except rice and sorghum) were significantly correlated to all-India summer monsoon rainfall. Monsoon season crops (except sorghum) were strongly associated with the three potential monsoon predictors. Results using

state-level crop production statistics and subdivisional monsoon rainfall were generally consistent with the all-India results, but demonstrated some surprising spatial variations. Whereas the impact of subdivisional monsoon rainfall is strong in most of the country, the influence of concurrent predictors related to El Niño-southern oscillation and the Indian Ocean sea-surface temperatures at a long lead time seem greatest in the western to central peninsula.

Kundzewicz, Z. W. (2002). "Non-structural flood protection and sustainability." Water International **27**(1): 3-13.

In this article, flood protection is considered in the context of sustainability. On the one hand, floods destroy human heritage and jeopardize sustainable development, which can be defined as "non-decreasing quality of life." On the other hand, following the most common interpretation of sustainable development, one should not choose flood protection policies that could be rated by future generations as inappropriate options of flood defense. This is how several large structural flood defenses are often viewed. Non-structural measures are in better agreement with the spirit of sustainable development, being more reversible, commonly acceptable, and environment-friendly. Among such measures are source control (watershed/landscape structure management), laws and regulations (including zoning), economic instruments, an efficient flood forecast-warning system, a system of flood risk assessment, awareness raising, flood-related databases, etc. As flood safety cannot be reached in most vulnerable areas with the help of structural means only, further flood risk reduction via non-structural measures is usually indispensable, and a site-specific mix of structural and non-structural measures seems to be a proper solution. Since sustainability requires thinking about the future generations, the climate change issue becomes important. Non-structural measures lend themselves well to application in climate change adaptation strategies. As uncertainty in the assessment of climate change impacts is high, flexibility of adaptation strategies is particularly advantageous.

Kundzewicz, Z. W. and L. Somlyódy (1997). "Climatic change impact on water resources in a systems perspective." Water Resources Management **11**(6): 407-435.

This paper is to analyse the climate change impact on water resources in a system's perspective, to discuss scientific gaps, and challenge scientific issues. The role of different scales and uncertainties, as well as the hydrological view of global circulation models are also discussed. Our preparedness for probable global (climate) change is reviewed in terms of assessment, planning, design and adaptation. Global climate change related to natural and anthropogenic processes has been the topic of concern and interest world wide. Despite ongoing research efforts, the climate predictions cannot be rated any better than speculative or

possible scenarios whose probability of occurrence is, at the present stage, impossible to assess. One of the most significant impacts of the 'greenhouse effect' is anticipated to be on water resources, including different elements of the hydrologic cycle, water supply and demand, regional vulnerability, and water quality. Thus, the impact of climate change appears to be an additional component on top of the large number of existing water-related problems. The existence of the greenhouse effect, the increase of greenhouse gas emissions, and the rise of corresponding concentrations are things that are certain. However, their impacts on hydrology and water management are highly uncertain. In the latter area, one needs information on much smaller spatial and temporal scales than those used in climate studies.

Labat, D., Y. Godderis, J. L. Probst, J. L. Guyot. (2004). "Evidence for global runoff increase related to climate warming." Advances in Water Resources **27**(6): 631-642.

Ongoing global climatic change initiated by the anthropogenic release of carbon dioxide is a matter of intense debate. Authors focus both on the impact of these climatic changes on the global hydrological cycle and on the amplitude of the increase of global and continental runoff over the last century, in relation to measured temperature increases. In this contribution, authors propose an original statistical wavelet-based method for the reconstruction of the monthly discharges of worldwide largest rivers. This method provides a data-based approximation of the evolution of the annual continental and global runoffs over the last century. A consistent correlation is highlighted between global annual temperature and runoff, suggesting a 4% global runoff increase by 1 degreesC global temperature rise. However, this global trend should be qualified at the regional scale where both increasing and decreasing trends are identified. North America runoffs appear to be the most sensitive to the recent climatic changes. Finally, this contribution provides the first experimental data-based evidence demonstrating the link between the global warming and the intensification of the global hydrological cycle. This corresponds to more intense evaporation over oceans coupled to continental precipitation increase or continental evaporation decrease. This process finally leads to an increase of the global continental runoff.

Ladefoged, T. N., M. W. Graves, M. D. McCoy. (2003). "Archaeological evidence for agricultural development in Kohala, Island of Hawai'i." Journal of Archaeological Science **30**(7): 923-940.

Measuring subsistence change, especially when it involves questions of resource intensification, requires special attention to issues of data quality and relevance. This is particularly so when, as in Remote Oceania, the archaeological

record is of relatively short duration and the nature of subsistence change was mostly quantitative, not qualitative. Agricultural development, particularly focused on the practice of dry land fixed field cultivation, is reviewed and a method developed for chronologically ordering the development of walls and trails constructed as the main structural features in three areas of the Kohala Dry Land Field System of Hawai'i Island. At least two different pathways to agricultural development are discernable, one of which documents intensification of effort over time and the other one shows the expansion of a relatively intensive system of dry land farming but little evidence of intensification. Differences in environment, geography, and the role of chiefs in underwriting agricultural development are likely factors that produce this pattern of dry land agriculture in Hawai'i.

Leach, G. and M. Leach (2004). "Carbonising forest landscapes? Linking climate change mitigation and rural livelihoods." IDS Bulletin **35**(3): 76-83.

Forestry-based carbon sinks are an important option for improving rural livelihoods, while also mitigating global climate change. Yet they are strongly opposed by major environmental organizations as an ineffective distraction that could hurt the poor. This article argues that insights into the social aspects of forestry can be used to design sink interventions that have the potential to bring huge benefits to rural livelihoods as well as to climate change mitigation. These benefits would be enhanced by various changes to the rules that apply to sinks under the Kyoto Protocol's Clean Development Mechanism.

Leichenko, R. M. and K. L. O'Brien (2002). "The dynamics of rural vulnerability to global change: the case of Southern Africa." Mitigation and Adaptation Strategies for Global Change **7**(1): 1-18.

Research on the agricultural impacts of global change frequently emphasizes the physical and socioeconomic impacts of climate change, yet global changes associated with the internationalization of economic activity may also have significant impacts on food systems. Together, climate change and globalization are exposing farmers to new and unfamiliar conditions. Although some farmers may be in a position to take advantage of these changes, many more are facing increased vulnerability, particularly in the developing world. This paper considers the dynamics of agricultural vulnerability to global change through the example of southern Africa. We demonstrate that the combination of global and national economic changes is altering the context under which southern African farmers cope with climate variability and adapt to long-term change. Authors find that farmers who formerly had difficulty adapting to climatic variability may become less vulnerable to drought-related food shortages as the result of trade

liberalization. At the same time, however, removal of national credit and subsidies may constrain or limit adaptation strategies of other farmers, leaving them more vulnerable to climate variability and change.

Leyden, B. W., M. Brenner, and B. H. Dahlin. (1998). "Cultural and climatic history of Coba, a Lowland Maya city in Quintana Roo, Mexico." Quaternary Research **49**: 111-122.

Lake Coba, within the archaeological site of Coba, provides evidence bearing on lowland Maya development. Palynological and geochemical data record multidecadal precipitation cycles from a 8.80-m, >8370-yr lake-sediment sequence terminating on bedrock. Late Classic sedimentation rates are rapid, but an anthropogenically derived colluvium layer is lacking. Initial vegetation was medium semi-deciduous and swamp forest. Forest clearance began 1650 B.C. (Early Preclassic) and maize first occurred at 850 B.C. (Middle Preclassic). Lakeside milpas existed until A.D. 720 (Late Classic) and then were moved from the city center as urbanization intensified and Lake Coba was diked as a reservoir. Coba was at most briefly vacated during the Classic Collapse and was abandoned after A.D. 1240, although some habitation persisted. The paleoecological record matches the archaeological history for Coba, but pervasive disturbance muted the climatic signal, as the Late Classic drought is barely evident. The question whether economic trees were maintained within the city is unresolved. Maize cultivation allowed the Maya to develop a complex society and support a large population, but dependence on maize was ultimately doomed by variable rainfall. Precipitation in extreme years was insufficient to support crops, while native vegetation was not directly affected by drought that devastated Maya agriculture.

Lim, B., E. Spanger-Siegfried, I. Burton, E. Malone, D. Huq. (eds.). (2005). Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures. Cambridge University Press, UK, 250 pp.

Climate change impacts can affect all sectors and levels of society. In the past few years, reducing vulnerability to climate change has become an urgent issue for the world's developing countries. Not only do these countries lack the means to cope with climate hazards, but their economies also tend to have greater dependence on climate-sensitive sectors, such as agriculture, water, and coastal zones. For these countries, climate change adaptation remains at the forefront of any sustainable development policy agenda.

Adaptation is a process by which individuals, communities and countries seek to cope with the consequences of climate change, including variability. The process of adaptation is not new; throughout history, people have been adapting to changing conditions, including natural long-term changes in climate. What is

innovative is the idea of incorporating future climate risk into policy-making. Although our understanding of climate change and its potential impacts has become clearer, the availability of practical guidance on adaptation to climate change has not kept pace.

The development of the Adaptation Policy Framework (APF) was motivated because the rapidly evolving process of adaptation policy making has lacked a clear roadmap. The APF seeks to address this gap by offering a flexible approach through which users can clarify their own priority issues and implement responsive adaptation strategies, policies and measures.

The APF is structured around four major principles that provide a basis from which actions to adapt to climate change can be developed. Embedded in these principles are features that distinguish the APF from previous guidance.

- *Adaptation to short-term climate variability and extreme events is included as a basis for reducing vulnerability to longer-term climate change.* As users seek to prepare for near-, medium- and longer-term adaptation, the APF helps them to firmly ground their decisions in the priorities of the present.

- *Adaptation policy and measures are assessed in a developmental context.* By making policy the centerpiece of adaptation, the APF shifts the focus away from individual adaptation projects as a response to climate change, and toward a fundamental integration of adaptation into key policy and planning processes.

- *Adaptation occurs at different levels in society, including the local level.* The APF combines national policymaking with a proactive “bottom-up” risk management approach. It enables the user to hone in on and respond to key adaptation priorities, whether at the national or village scale.

- *Both the strategy and the process by which adaptation is implemented are equally important.* The APF places a strong emphasis on the broad engagement of stakeholders. Stakeholders are seen as instrumental in driving each stage of the adaptation process.

The APF is comprised of five Components:

Component 1: Scoping and designing an adaptation project involves ensuring that a project – whatever its scale or scope – is well-integrated into the national policy planning and development process. This is the most vital stage of the APF process. The purpose is to put in place an effective project plan so that adaptation strategies, policies and measures can be implemented.

Component 2: Assessing current vulnerability involves responding to several questions, such as: Where does a society stand today with respect to vulnerability to climate risks? What factors determine a society's current vulnerability? How successful are the efforts to adapt to current climate risks?

Component 3: Assessing future climate risks focuses on the development of scenarios of future climate, vulnerability, and socio-economic and environmental trends as a basis for considering future climate risks.

Component 4: Formulating an adaptation strategy in response to current vulnerability and future climate risks involves the identification and selection of a set of adaptation policy options and measures, and the formulation of these options into a cohesive, integrated strategy.

Component 5: Continuing the adaptation process involves implementing, monitoring, evaluating, improving and sustaining the initiatives launched by the adaptation project.

These components are supplemented by two cross-cutting processes: 1) Engaging stakeholders in the adaptation process, and 2) Assessing and enhancing adaptive capacity.

Engaging stakeholders in the adaptation process is seen as essential to each APF component, and is ultimately crucial to the successful implementation of an adaptation strategy. Engaging stakeholders requires an active and sustained dialogue among affected individuals and groups.

Assessing and enhancing adaptive capacity involves catalyzing change management processes so that societies can better cope with climate change, including variability.

Users will approach the APF with a wide range of needs. For some, addressing all components of the APF process will be the most strategic, perhaps more resource-intensive route. Others may already have significant information on current vulnerability, but not on future climate risks, and may choose to fill gaps in information by investing heavily in only one or two of the components. The APF accommodates either of these approaches, and a wide range of other uses. Implementing the APF does not require an abundance of high quality data, or extensive expertise in computer-based models. Rather, it relies upon a thoughtful assessment and a robust stakeholder process. While not costless in terms of time and resources, the APF process is readily manageable if correctly applied.

Linder, M. (2000). "Developing adaptive forest management strategies to cope with climate change." *Tree Physiology* **20**(5_6): 299-307.

Numerous investigations have indicated that projected climate change will impact strongly on forest growth and composition. To adapt managed forests to changing environmental conditions it may be necessary to modify traditional forest management strategies. An extended version of a forest gap model was applied to a managed forest district in northeastern Germany. The model was initialized with forest inventory data and run using routines devised to simulate three management scenarios: (1) maximized timber production, (2) climatically well-adapted forest composition, and (3) maximized tree species diversity. The strategies were compared with a baseline scenario of traditional management without any response to climate change. The comparisons were based on simulated wood production and species composition after 110 years of development. The results underline the important influence that management strategies have on forest growth. Forest management may adopt a variety of strategies to respond to the expected changes in climate. Process-oriented forest gap models can aid in the assessment of these strategies.

Lockwood, J. G. (2001). "Abrupt and sudden climatic transitions and fluctuations: a review." *International Journal of Climatology* **21**(9): 1153-1179.

This review paper summarizes recent research work on abrupt climatic changes and oscillations. The climatic system is viewed as a dissipative, highly non-linear system, under non-equilibrium conditions, and, as such, should be expected to have some unusual properties. These unusual properties include bifurcation points with marked instability just before the point, magnification of semi-periodic oscillations around bifurcation points, and variations in the strength of teleconnections with distance from equilibrium. These properties are discussed and illustrated for the climatic system using both the historical, Holocene and glacial climatic records. It is found that there are abrupt climatic changes and oscillations on all time-scales. The amplitudes and frequencies of climate variability and teleconnections are found to vary between different time periods. A number of persistent oscillations exist, particularly one about 1500 years, but their amplitudes vary considerably between time periods. The Holocene appears to be no more climatically benign than the similar period in the Eemian. The importance of the North Atlantic thermohaline circulation for generating abrupt climatic changes in Europe, particularly in association with sudden pulses of fresh water, is illustrated. The concept of antiphase temperature changes between the North and South Atlantic is discussed. Externally generated abrupt climatic deteriorations owing to explosive volcanic eruptions and variations in solar irradiance are also discussed.

Loë, R. C. d. and R. D. Kreutzwiser (2000). "Climate variability, climate change and water resource management in the Great Lakes." Climatic Change **45**(1): 163-179.

Adaptation to climate change in water resource management will involve using the kinds of practices and activities currently being used. However, it remains unclear whether or not practices and activities designed with historical climate variability will be able to cope with future variability caused by atmospheric warming. The adaptation to climate change is examined in the context of Canadian water resources management, emphasizing issues in the context of the Great Lakes.

Machiwal, D., M. K. Jha, P. K. Singh, S. C. Mahnot, A. Gupta. (2004). "Planning and design of cost-effective water harvesting structures for efficient utilization of scarce water resources in semi-arid regions of Rajasthan, India." Water Resources Management **18**(3): 219-235.

Water-harvesting structures have the potential to increase the productivity of arable lands by enhancing crop yields and by reducing the risk of crop failure in arid and semi-arid regions, where water shortages are common because of scanty rainfall and its uneven distribution. In semi-arid regions of Rajasthan, India, existing practice of harvesting rainwater is through anicut and earthen embankments. Because of higher costs and higher technical skills involved in the construction of these structures, these structures have not been accepted by the resource-poor local people. Therefore, in the present paper, the detailed design of some low-cost water-harvesting structures using locally available materials and adaptable to the socio-economic conditions of the beneficiaries is discussed. Two types of cost-effective water-harvesting structures, which include dry stone masonry and upstream-wall cement masonry of heights 1, 2, and 2.5 m for catchments of less than 10, 10 to 20, and 20 to 30 ha, respectively are proposed and designed. The analysis of costs involved in constructing dry stone masonry and upstream-wall cement masonry water-harvesting structures, emergency spillway, anicuts and earthen embankments revealed that the earthen embankments have the least cost of construction whereas the anicuts have the highest construction costs for all the selected heights. However, based on the past experiences, earthen embankments are not suitable for the semi-arid regions of Rajasthan. The economic evaluation of the proposed structures indicated that the dry stone masonry structures are very cost-effective for the region with a benefit-cost ratio of 3.5:1 and the net present worth value of Rs. 102978. Although the economic indicators ranked the upstream-wall cement masonry structures lower than the dry stone masonry structures, the former has greater stability and strength compared to the latter. In practice, both the cost-effective water-harvesting

structures (i.e., dry stone masonry and upstream-wall cement masonry) are gaining wide acceptance and popularity in the region through some nongovernmental organizations, which have adopted the design presented in this paper.

Maciver, D. C. and F. Dallmeier. (2000). Adaptation to climate change and variability: Adaptive management. Environmental Monitoring and Assessment, **61**(1): 1-8.

This paper summarizes the recommendations from the Intergovernmental Panel on Climate Change (IPCC) Workshop on Adaptation to Climate Variability and Change convened in Costa Rica in 1998. Specifically, this paper also summarizes the adaptive management science issues and, in many cases, sectoral options. The Workshop, organized by Canada and Costa Rica, involved more than 200 experts and focused on adaptation science, adaptive management and adaptation options for climate variability and change.

Macklin, M. G., C. Bonsall, F. M. Davies, M. R. Robinson. (2000). "Human-environment interactions during the Holocene: new data and interpretations from the Oban area, Argyll, Scotland." Holocene **10**: 109-121.

Investigations of the archaeological, geochemical, microscopic charcoal and palynological records from 5 sites in the Oban area, along an altitudinal transect from coast to upland, provided new information on human-environment interactions during the Holocene. Some of the results were at variance with previous interpretations of Mesolithic human impacts and the timing of the transition to farming in Atlantic Scotland. High charcoal values and the occurrence of cereal-type pollen grains, which have commonly been used to infer human activity during the Mesolithic, appeared in the Oban area at least to be related to climate change. However, the greater frequency of woodland-decline episodes in inland and upland areas prior to 5000 BP was more easily explained in terms of human impact. Archaeological and palynological evidence indicates that the Mesolithic-Neolithic transition in the Oban area occurred at *c.* 5000 BP and, on evidence from elsewhere in northern Britain, coincided with a marked shift to drier climatic conditions. Up until *c.* 1000 BP agricultural communities had comparatively little impact on the environment. Thereafter, there was rapid and permanent deforestation possibly linked to the development of a distinctive land-use strategy and settlement pattern that survived until the nineteenth century AD.

Magadza, C. H. D. (2000). "Climate change impacts and human settlements in Africa: prospects for adaptation." Environmental Monitoring and Assessment **61**(1): 193-205.

Demographic processes and transmigration are creating human settlement conglomerates in Africa's vulnerable areas such as coastal zones, flood plains and areas of limited water resources. This paper discusses the possible impacts on these areas of climatic change with regard to: increased aridity in currently dry areas; changes in sea level (rising seas or coastal subsidence); population migration; response strategies (retreat, adapt, defend); flooding; energy needs; human health and comfort; sanitation; food security; and research and education needs.

Makadho, J. M. (1996). "Potential effects of climate change on corn production in Zimbabwe." Climate Research **6**(2): 147-151.

Global Circulation Models (GCMs) and the dynamic crop growth model CERES-Maize are used to assess the potential effects of climate change on maize in Zimbabwe. Maize is the most widely grown crop in Zimbabwe and is often under environmental stress due to high ambient temperature and low rainfall conditions. Global climate change scenarios suggest maize productivity in Zimbabwe will decrease dramatically under non-irrigated or irrigated conditions in some regions of agricultural production. The reductions in maize yields are primarily attributed to ambient temperature increases which shorten the crop growth period, particularly the grain-filling period. If climate effects occur farmers may find maize production an unacceptably risky activity. Adaptation options are available but financial costs may be prohibitive to communal area farmers.

Marcantonio, F., R. F. Anderson, S. Higgins, M. Q. Fleisher, M. Stute, and P. Schlosser. (2001). "Abrupt intensification of the SW Indian Ocean monsoon during the last deglaciation: constraints from Th, Pa, and He isotopes." Earth and Planetary Science Letters **184**(2): 505-514.

Sediments from western Arabian Sea core 74KL representing the last 23 ka were analyzed for helium, thorium, and protactinium isotopes. Assuming global average fluxes of extraterrestrial ^3He and ^{230}Th , the average ^3He -derived sediment mass accumulation rate (MAR) is a factor of 1.8 higher than the average ^{230}Th -derived MAR. ^3He - and ^{230}Th -derived MARs converge, however, during the Younger Dryas (YD) and during the peak of the early Holocene humid interval. These features, not seen anywhere else in the world, probably reflect a combination of climate-driven changes in the flux of ^{230}Th and ^3He . Ratios of $xs^{231}\text{Pa}/xs^{230}\text{Th}$, proxies of paleoproductivity, are lowest during the last glacial maximum (LGM), and increase abruptly during the Bolling-Allerod. Later, following a sudden decrease to near-LGM values during the YD, they rise abruptly to maximum values for the entire record in the early Holocene. Authors hypothesize that low $xs^{231}\text{Pa}/xs^{230}\text{Th}$ ratios reflect low productivity due to the decreased intensity of the SW monsoon, whereas the opposite is true for high

ratios. The correlation between Arabian Sea productivity and monsoonal upwelling, on the one hand, and North Atlantic climate variability, on the other, suggests a linkage between high- and low-latitude climates caused by changing patterns of atmospheric circulation.

Marean, C. W. (1997). "Hunter-Gatherer Foraging Strategies in Tropical Grasslands: Model Building and Testing in the East African Middle and Later Stone Age." *Journal of Anthropological Archaeology* **16**(3): 189-225.

Hunter-gatherer adaptations to moist tropical grasslands are not well known from either the ethnographic or the archaeological record. This is unfortunate as grassland adaptations are clearly significant to human biological and behavioral evolution. The most effective strategy for remedying this problem is to develop models for grassland exploitation based on strong understandings of the ecological similarities and differences between cold, temperate, and tropical grasslands. Cold, temperate, and tropical grasslands are similar in that water and raw materials are often scarce and the most abundant large mammals are gregarious and mobile. Tropical grasslands differ from cold and temperate grasslands by having a greater diversity and biomass of edible above-ground plants and plants with underground storage organs, making carbohydrate availability greater and less seasonal. Large mobile mammals and resident large mammals are more diverse and have greater biomass in tropical grasslands. Overall, tropical grasslands are a richer and less seasonally punctuated environment than either cold or temperate grasslands. A comparison of ethnographic data regarding variation in foraging strategies in different cold, temperate, and tropical settings lead to the construction of three models for hunter-gatherer exploitation of tropical grasslands: a Generalized Grassland Model (no specialized tactical hunting--considered the favored model given modern African grassland conditions), a Seasonal Grassland Model (only seasonal use of specialized tactical hunting techniques--considered unlikely for Africa), and a Specialized Grassland Model (regular use of specialized tactical hunting strategies--considered highly unlikely for Africa). A preliminary test of these models shows the Athi-Kapiti Plains Holocene archaeological evidence is most consistent with the Generalized Grassland Model. The Last Glacial Maximum is most consistent with the Seasonal Grassland Model. A single MSA occupation also suggests that specialized tactical hunting strategies were used. These differences in hunting strategies were probably due to the differences in ecological conditions between the Holocene and the Last Glacial Maximum.

Matondo, J. I. and K. M. Msibi (2001). "Estimation of the impact of climate change on hydrology and water resources in Swaziland." *Water International* **26**(3): 425-434.

The enhanced greenhouse gas effect is expected to cause high temperature increases globally (1 to 3.5 deg C), and this will lead to an increase in precipitation in some regions while other regions will experience reduced precipitation. Therefore, countries are engaged in the exercise of evaluating the impact of expected climate change on water resources using General Circulation Models (GCM) and hydrologic models. The WatBall model has been found appropriate for the evaluation of the impact of climate on water resources. The Usutu catchment was selected for the evaluation of the impact of climate change on water resources because it covers two thirds of Swaziland and traverses the four physiographic regions. Results of GCM models (precipitation, temperature, and potential evapotranspiration) have been used as input to the calibrated WatBall model to forecast stream flow for Usutu catchment for the wet, dry, and average annual conditions for the year 2075. Disregarding population increase and expanded agricultural activities, a comparison between observed and simulated stream flow reveals that all the GCM models are simulating low flows from June to September for the wet years and from May to September for the dry and normal years. The effect of population increase on water resources under climate change has revealed that all the GCM models simulate a water deficit for the winter months (May to September). It is concluded that stream flows will be low during the winter months and the population increase will cause water shortages during the winter months. Therefore, optimal water resources management will be crucial. Adaptation options have been suggested and range from modification of the existing infrastructure to water demand management.

Mátyás, C. (1996). "Climatic adaptation of trees: rediscovering provenance tests." Euphytica **92**(1/2): 45-54.

Common garden testing of populations of different origin started with forest trees more than two hundred years ago. Since then, so-called provenance tests have been established with most commercially important species. Beyond the strictly silvicultural goals, the tests offer excellent opportunities to study intraspecific genetic variation patterns and represent probably the most powerful available tool for testing hypotheses of climatic adaptation in trees. Analysis of adaptive traits (mostly juvenile height growth) in provenance experiments indicate the existence of very effective constraints on adaptedness. The performance of populations plotted against an ecological-climatic factor exhibits a characteristic pattern and can be described by response functions. The population average of a fitness-related trait for a locally adapted population is often significantly lower than that of populations from other environments; usually the ones from milder climate perform better. The phenomenon is interpreted as adaptation lag. Suboptimal adaptation is compensated by a high level of genetic diversity. Molecular genetic studies confirm the high level of allelic and individual genetic

diversity in forest trees. A consequence of individual homeostasis, phenotypic stability of populations is usually also high; the sensitivity to environmental changes is generally moderate. Phenotypically stable populations are valuable not only because of a wider range of potential cultivation but specifically because of a greater ability to adjust to unexpected changes. This trait should receive more attention in the future for obvious reasons. The maintenance of a high within-population genetic variance is favoured by the genetic system of the investigated species (effective gene flow, outbreeding, high genetic load, etc.). Random events and long-lasting biotic interactions are further effects impairing the efficiency of natural selection. In view of expected climate instability, genetic adaptability of forest trees causes serious concern due to their long lifespan compared to the rapidity of expected changes in environmental conditions. The potential of provenance tests to interpret long-term adaptational processes should be utilized to analyse, model and predict response of trees to climate change. Although seldomly appreciated, provenance research might be among the most important contributions of forestry to biological sciences.

Mátyás, C. (1997). "Effects of environmental change on the productivity of tree populations." IUFRO World Series **6**: 109-121.

Although much of climatic adaptation research has been initiated and studied on forest trees by provenance trials, results have failed to capture much attention outside the forestry community. The original goal of provenance experiments was to identify populations or areas of provenance which may provide reproduction material with the most desirable traits for a given region or country. Among other uses, provenance experiments also offer a direct opportunity to assess and forecast effects of environmental (climate) change. Instead of analysing genetic changes in subsequent generations in controlled environments, the observed variation in provenance tests may be interpreted as an adaptive response to changes in climate conditions. The necessary transfer of populations from the location of origin to the test site can be regarded as a simulation of environmental change and the response may be modelled. Spatial (geographic) variation patterns can therefore be interpreted as a simulation of responses to environmental change over time. When comparing the performance of populations across test locations, generalization of results is hindered by response changes modified by local site conditions. In order to enhance the flexibility of data evaluation and interpretation, the use of ecological distances (ecodistances) has been proposed. According to this concept, the quantitative response of populations at different test sites are related to environmental differences between the test site and the location of origin. This concept is examined using data on ponderosa pine (*Pinus ponderosa*) populations growing in the Sierra Nevada (California, USA). Results indicate that contrary to the general

perception of physiological reaction to environmental change, the response of adapted, local populations is asymmetric due to the manifold constraints of biological regulation. As a consequence, a temperature increase leads to instant growth and productivity loss, and selective mortality.

Mayewski, P. A., E. E. Rohling, J. C. Stager, W. Karlén, K. A. Maasch, L. D. Meeker, E. A. Meyerson, F. Gasse, S. van Kreveld, K. Holmgren, J. Lee-Thorp, G. Rosqvist, F. Rack, M. Staubwasser, R. R. Schneider, E. J. Steig. (2004). "Holocene climate variability." Quaternary Research **62**(3): 243-255.

The climate of the Holocene (11,500 cal yr B.P. to the present) has sustained the growth and development of modern society. Although the dramatic climate disruptions of the last glacial period have received considerable attention, relatively little has been directed toward climate variability in the Holocene. Examination of ~50 globally distributed paleoclimate records reveals as many as six periods of significant rapid climate change during the time periods 9000–8000, 6000–5000, 4200–3800, 3500–2500, 1200–1000, and 600–150 cal yr B.P. Most of the climate change events in these globally distributed records are characterized by polar cooling, tropical aridity, and major atmospheric circulation changes, although in the most recent interval (600–150 cal yr B.P.), polar cooling was accompanied by increased moisture in some parts of the tropics. Several intervals coincide with major disruptions of civilization, illustrating the human significance of Holocene climate variability.

Mbithi, P. M. and B. Wisner (1973). "Drought and famine in Kenya: magnitude and attempted solutions." Journal of Eastern African Research and Development **3**(2): 113-143.

The study reported in this article aimed at understanding the selection of farming technology as an adaptation response to marginal farming conditions, the latter characterized by frequent droughts, heavy, short-lived rainstorms, alkalinity, floods, crop and animal epidemics, poor marketing facilities, over-emphasis on family food supply, etc. The study examines: (1) the adoption process through which farmers select farming technology as an adaptation to marginal farming conditions; (2) the traditional technology, identifying taboos, and social practices compatible with modern dryland farming; (3) the major research recommended technological packages and the socio-economic and technical factors which influence their diffusion rate; (4) the role of occupational activity and crop diversification in increasing farmers' control over the environment; (5) famine relief, food supply and distribution problems; (6) nutritional implications of frequent food failures. Some of the major conclusions are: (a) lack of clear rural development policy for the marginal farming regions is leading to a very high rate

of population increase in some areas; (b) research to increase the lysine content of maize is constrained by poor extension/research contact, and lack of awareness of research workers of the need for a low cost solution; (c) regional and local famines are likely to increase; (d) famine relief needs to isolate welfare cases from occasional famine relief cases; (e) non-farm activities are available alternative to farming; (f) community feelings are subjected to unique social pressures; (g) these social pressures transcend all fields.

McCaffrey, S. C. (2003). "The need for flexibility in freshwater treaty regimes." Natural Resources Forum 27(2): 156-162.

Shrinking freshwater supplies pose particular threats in international drainage basins, which serve some 40% of the global population and account for approximately 60% of the world's river flows. The use and management of these basins are increasingly governed by treaties between the riparian states. While the rules of international law, properly understood, are sufficiently flexible to permit adaptation to changing conditions such as development, population growth and climate change, treaties are essentially rigid instruments that are modifiable only under certain limited conditions. Countries should take this fact into account in designing the regimes to govern their shared freshwater resources, including joint management institutions.

McCarthy, J. J. O. F. Canziani, N. A. Leary, D. J. Dokken, K. S. White. (eds.). (2001). Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, UK, 1042 pp.

McGregor, J. (1994). "Climate change and involuntary migration: implications for food security." Food Policy 19(2): 120-132.

This paper explores the nature of the relationships between environmental change and migration, and between migration and food security. It reviews the findings of studies on refugee livelihoods and on the economic and ecological transformations in refugee receiving areas, paying particular attention to situations where the reception of displaced populations has been of long-term benefit to hosting economies. The nature of interventions for displaced populations itself influences food security in hosting areas, and recent debates over refugee assistance have indicated some ways in which existing practice can be counterproductive. The recognition that environmental change can be associated with forced migration has made an important contribution to debates over who should be the legitimate beneficiaries of international relief, but the term 'environmental refugee' is misleading conceptually and is legally and institutionally

unfounded. As the group of potential recipients of assistance expands, some of the mainstays of refugee protection are being undermined.

McMichael, A. J. and R. S. Kovats (2000). "Climate change and climate variability: adaptations to reduce adverse health impacts." Environmental Monitoring and Assessment **61**(1): 49-64.

Global climate change has a range of consequences for human health as a result of disturbance or weakening of the biosphere's natural or human managed life support systems. The full range of potential human health impacts of global climate change is diverse and would be distributed differentially spatially and over time. Changes in the mortality toll of heatwaves and changes in the distribution of vector-borne infectious diseases may occur early. The public health consequences of sea level rise and of regional changes in agricultural productivity may not occur (or become apparent) for several decades. Vulnerability is a measure of both sensitivity to climate change and the ability to adapt in anticipation of, or in response to, its impacts. The basic modes of adaptation to climate-induced health hazards are biological, behavioural and social. Adaptation can be undertaken at the individual, community and whole-population levels. Adaptive strategies should not introduce new health hazards. Enhancement of the acknowledged public health infrastructure and intervention programmes is essential to reduce vulnerability to the health impacts of climate change. In the longer-term, fundamental improvements in the social and material conditions of life and in the reduction of inequalities within and between populations are required for sustained reduction in vulnerability to environmental health hazards.

Meltzer, D. J. (1999). "Human responses to middle Holocene (Altithermal) climates on the North American Great Plains." Quaternary Research **52**: 404-416.

The climate of the Great Plains during the middle Holocene varied considerably, but overall it was marked by a north-south gradient of increasingly warmer and drier conditions, with a reduction in effective moisture, surface water, and resource abundance, and an increase in resource patchiness, sediment weathering, erosion, and aeolian activity. Pronounced drought conditions were most evident on the Southern High Plains. Understanding the human responses to middle Holocene climates is complicated by a lack of archaeological data, which is partly a result of geomorphic processes that removed or deeply buried sites of this age, and by the varying adaptive responses of hunter-gatherers during this period. On the Southern High Plains, where drought was most severe, surface and groundwater sources dried and bison populations were diminished, prompting substantial adaptive changes, including local abandonment, well-digging to tap underground water, and a widening of the diet breadth to incorporate higher-cost,

lower-return seed and plant resources. Sites of this age on the Central and Northern Plains also show a possible increase in diet breadth (with the incorporation of plant foods in the diet), and perhaps changes in settlement mobility (including possible shift into higher elevation areas, or mapping-on to extant rivers and springs). But linking those changes to middle Holocene drought is less straightforward.

Mendelsohn, R. and A. Dinar (1999). "Climate change, agriculture, and developing countries: does adaptation matter?" World Bank Research Observer **14**(2): 277-293.

Because most developing countries depend heavily on agriculture, the effects of global warming on productive croplands are likely to threaten both the welfare of the population and the economic development of the countries. Tropical regions in the developing world are particularly vulnerable to potential damage from environmental changes because the poor soils that cover large areas of these regions already have made much of the land unusable for agriculture. Although agronomic simulation models predict that higher temperatures will reduce grain yields as the cool wheat-growing areas get warmer, they have not examined the possibility that farmers will adapt by making production decisions that are in their own best interests. A recent set of models examines cross-sectional evidence from India and Brazil and finds that even though the agricultural sector is sensitive to climate, individual farmers do take local climates into account, and their ability to do so will help mitigate the impacts of global warming.

Mendelsohn R. (2000). Efficient adaptation to climate change. Climatic Change **45**(3-4): 583-600.

Firms and individuals will likely engage in substantial private adaptation with respect to climate change in such sectors as farming, energy, timber, and recreation because it is in their interest to do so. The shared benefit nature of joint adaptation, however, will cause individuals to underprovide joint adaptation in such areas as water control, sea walls, and ecological management. Governments need to start thinking about joint adaptation, being careful to design efficient responses which treat climate change problems as they arise.

Menne, B., N. Kunzli, R. Bertollini. (2002). "The health impacts of climate change and variability in developing countries." International Journal of Global Environmental Issues **2**(3/4): 181-205.

Health is a focus reflecting the combined impacts of climate change on the physical environment, ecosystems, the economic environment and society. Long-

term changes in the world's climate may affect many requisites of good health - sufficient food, safe and adequate drinking water, and secure dwelling. The current large-scale social and environmental changes mean that we must assign a much higher priority to population health in the policy debate on climate change. Climate change will affect human health and wellbeing through a variety of mechanisms. Climate change can adversely impact on the availability of fresh water supply and the efficiency of local sewerage systems. It is also likely to affect food security. Cereal yields are expected to increase at high and mid latitudes but decrease at lower latitudes. Changes in food production are likely to significantly affect health in Africa. In addition, the distribution and seasonal transmission of several vector-borne infectious diseases (such as malaria and dengue) may be affected by climate change. Altered distribution of some vector species may be among the early signals of climate change. A change in the world climate could increase the frequency and severity of extreme weather events. The impacts on health of natural disasters are considerable - the number of people killed, injured or made homeless from such causes is increasingly alarming. The vulnerability of people living in risk-prone areas is an important contributor to disaster casualties and damage. An increase in heatwaves (and possibly air pollution) will be a problem in urban areas, where excess mortality and morbidity is currently observed during hot weather episodes. We can assume that climate change will affect the most vulnerable in developing countries. These might be socioeconomic deprived populations, people who lack access to a health care system, technology and communication, as well as immunocompromised persons. The health community has, however, difficulties in clearly attributing changes in ranges of diseases or mortality to climatic changes. The main reasons are the gradual process of climate change, the multiple causes of diseases, the many factors that permit human population health to adapt, and the lack of retrospective and prospective studies from developing countries. Adaptation is a key response strategy to minimize potential impacts of climate change. A primary objective of adaptation is the reduction, with the least cost, of death, disease, disability and human suffering. The ability to adapt to climate change impacts, and specifically of health, will depend on many factors including existing infrastructure, resources, technology, information and the level of equity in different countries and regions.

Messerli, B., M. Grosjean, T. Hofer, L. Nunez, C. Pfister. (2000). "From nature-dominated to human-dominated environmental changes." Quaternary Science Reviews **19**(1-5): 459-479.

To what extent is it realistic and useful to view human history as a sequence of changes from highly vulnerable societies of hunters and gatherers through periods with less vulnerable, well buffered and highly productive agrarian-urban societies to a world with regions of extreme overpopulation and overuse of life

support systems, so that vulnerability to climatic-environmental changes and extreme events is again increasing? This question cannot be fully answered in our present state of knowledge, but at least we can try to illustrate, with three case studies from different continents, time periods and ecosystems, some fundamental changes in the relationship between natural processes and human activities that occur, as we pass from a nature-dominated to a human dominated environment.

1. Early-mid Holocene: Nature dominated environment — human adaptation, mitigation, and migration. In the central Andes, the Holocene climate changed from humid (10,800–8000 BP) to extreme arid (8000–3600 BP) conditions. Over the same period, prehistoric hunting communities adopted a more sedentary pattern of resource use by settling close to the few perennial water bodies, where they began the process of domesticating camelids around 5000 BP and irrigation from about 3100 BP.

2. Historical period: An agrarian society in transition from an "enduring" to an innovative human response. Detailed documentary evidence from Western Europe may be used to reconstruct quite precisely the impacts of climatic variations on agrarian societies. The period considered spans a major transition from an apparently passive response to the vagaries of the environment during the 16th century to an active and innovative attitude from the onset of the agrarian revolution in the late 18th century through to the present day. The associated changes in technology and in agricultural practices helped to create a society better able to survive the impact of climatic extremes.

3. The present day: A human dominated environment with increasing vulnerability of societies and economies to extreme events and natural variability. The third example, dealing with the history and impact of floods in Bangladesh, shows the increasing vulnerability of an over-exploited and human-dominated ecosystem. Measurements exist for a short time only (decades), historical data allow a prolongation of the record into the last century, and paleo-research provides the long-term record of processes operating over millennia. The long-term paleo-perspective is essential for a better understanding of future potential impacts on an increasingly human-dominated environment. Understanding today's global change processes calls for several new perspectives and synergisms:

- the integration of biophysically oriented climate change research with research about the increasingly dominant processes of human forcing,
- a focus on overexploited or limited natural resources and on vulnerable and critical regions,

- fuller use of our understanding of variability on a range of different timescales: "The present without a past has no future".

Me-Bar, Y., F. Valdez. (2003). "Droughts as random events in the Maya lowlands." Journal of Archaeological Science **30**(12): 1599-1606.

Because the values of most of the parameters controlling the occurrence and severity of a drought in a given location are unknown, and no periodicity has been observed, droughts can be considered random events. Running a random number generator within the limits of the annual rainfall variability relevant to the Maya lowlands, and defining a "Lean Year", it is observed that strings of lean years occur quite frequently. Defining "Severe Drought", "Disaster", and "Catastrophe" based on the length of these strings, it is observed that a severe drought occurs on average every 32 years, a disaster occurs on average every 130 years, and a catastrophe on average every 500 years. These values fit the measured variability of the Yucatan climate, as observed in lake core sediments and in the post conquest written records. It also fits the average occurrence of "megadroughts" in the US Great Plains.

Kane, S. and Gary Yohe. Eds.) (2000) Societal Adaptation to Climate Variability and Change. Kluwer Academic Publishers, Dordrecht, 2000, 278 pp.

Masika, R. (2002). Gender, development and climate change. Oxford UK, Oxfam Publishing, 112 pp.

This book considers the gendered dimensions of climate change. It shows how gender analysis has been widely overlooked in debates about climate change and its interactions with poverty, and demonstrates its importance for those seeking to understand the impacts of global environmental change on human communities. Ranging in scope from high-level global climate change negotiations to an analysis of disaster responses and mitigation policies at local level, the contributors examine the potential impacts of environmental degradation and change on vulnerable groups. They highlight the different vulnerabilities, risks, and coping strategies for poor women and men in the face of environmental degradation and increased livelihood insecurity.

McNeely, J. A. (2004). "Nature vs. nurture: managing relationships between forests, agroforestry and wild biodiversity." Agroforestry Systems **61-62**(1): 155-165.

Many agroforestry systems are found in places that otherwise would be appropriate for natural forests, and often have replaced them. Humans have had a profound influence on forests virtually everywhere they both are found. Thus

'natural' defined as 'without human influence' is a hypothetical construct, though one that has assumed mythological value among many conservationists. Biodiversity is a forest value that does not carry a market price. It is the foundation, however, upon which productive systems depend. The relationship between agroforestry and the wild biodiversity contained in more natural forests is a complicated one, depending on the composition of the agroforestry system itself and the way it is managed. Complex forest gardens are more supportive of biodiversity than monocrop systems, shade coffee more than sun coffee, and systems using native plants tend to be more biologically diverse. Nonnative plants, especially potentially invasive alien species, threaten biodiversity and need to be avoided. The relationship between forests, agroforestry and wild biodiversity can be made most productive through applying adaptive management approaches that incorporate ongoing research and monitoring in order to feed information back into the management system. Maintaining diversity in approaches to management of agroforestry systems will provide humanity with the widest range of options for adapting to changing conditions. Clear government policy frameworks are needed that support alliances among the many interest groups involved in forest biodiversity.

McNeill, J. R. and V. Winiwarter. (2004). "Breaking the sod: Humankind, history, and soil." *Science* **304**: 1627-1629.

For most of history, few things have mattered more to human communities than their relations with soil, because soil provided most of their food and nutrients. Accordingly, some of the earliest written documents were agricultural manuals intended to organize, preserve, and impart soil knowledge. Indeed, ancient civilizations often worshipped the soil as the foundry of life itself. For the past century or two, nothing has mattered more for soils than their relations with human communities, because human action inadvertently ratcheted up rates of soil erosion and, both intentionally and unintentionally, rerouted nutrient flows.

Miller, K. A., S. L. Rhodes, L. J. MacDonnell. (1997). "Water allocation in a changing climate: institutions and adaptation." *Climatic Change* **35**(2): 157-177.

The effects of water allocation institutions on society's adaptability to prospective climate change were examined. Such institutions included basic systems of water law, specific statutes, systems of administration and enforcement, and social norms regarding acceptable water-use practices. Both climate and the changing nature of demands on the resource have affected the development and evolution of water allocation institutions in the USA. Water laws and administrative arrangements, for example, have adapted to changing circumstances, but the process of adaptation can be costly and subject to conflict.

Analysis of past and ongoing institutional change was used to identify factors that may have a bearing on the costliness of adaptation to the uncertain impacts of global warming on water availability and water demands. Several elements were identified that should be incorporated in the design of future water policies to reduce the potential for disputes and resource degradation that might otherwise result if climate change alters regional hydrology.

Mirza, M. M. Q. (2003). "Climate change and extreme weather events: can developing countries adapt?" Climate Policy **3**(3): 233-248.

Developing countries are vulnerable to extremes of normal climatic variability, and climate change is likely to increase the frequency and magnitude of some extreme weather events and disasters. Adaptation to climate change is dependent on current adaptive capacity and the development models that are being pursued by developing countries. Various frameworks are available for vulnerability and adaptation (V&A) assessments, and they have both advantages and limitations. Investments in developing countries are more focused on recovery from a disaster than on the creation of adaptive capacity. Extreme climatic events create a spiral of debt burden on developing countries. Increased capacity to manage extreme weather events can reduce the magnitude of economic, social and human damage and eventually, investments, in terms of borrowing money from the lending agencies. Vulnerability to extreme weather events, disaster management and adaptation must be part of long-term sustainable development planning in developing countries. Lending agencies and donors need to reform their investment policies in developing countries to focus more on capacity building instead of just investing in recovery operations and infrastructure development.

Mirza, M. M. Q., R. A. Warrick, N. J. Ericksen. (2003). "The implications of climate change on floods of the Ganges, Brahmaputra and Meghna rivers in Bangladesh." Climatic Change **57**(3): 287-318.

Climate change in the future would have implications for river discharges in Bangladesh. In this article, possible changes in the magnitude, extent and depth of floods of the Ganges, Brahmaputra and Meghna (GBM) rivers in Bangladesh were assessed using a sequence of empirical models and the MIKE11-GIS hydrodynamic model. Climate change scenarios were constructed from the results of four General Circulation Models (GCMs) - CSIRO9, UKTR, GFDL and LLNL, which demonstrate a range of uncertainties. Changes in magnitude, depth and extent of flood discharge vary considerably between the GCMs. Future changes in the peak discharge of the Ganges River are expected to be higher than those for the Brahmaputra River. Peak discharge of the Meghna River may also

increase considerably. As a result, significant changes in the spatial extent and depths of inundation in Bangladesh may occur. Faster changes in inundation are expected at low temperature increases than of higher temperature changes. Changes in land inundation categories may introduce substantial changes in rice agriculture and cropping patterns in Bangladesh. Reduction of increased flood hazard due to climate change requires strengthening of flood management policies and adaptation measures in Bangladesh.

Mishra, C., H. H. T. Prins, S. E. Van Wieren (2003). "Diversity, risk mediation, and change in a Trans-Himalayan agropastoral system." Human Ecology **31**(4): 595-609.

Authors describe the diversity and dynamism of social, agricultural, and livestock husbandry practices in a traditional mountain production system in the Indian Trans-Himalaya. These are interpreted in the context of their role in mediating environmental risk. The production system is a little known Buddhist agropastoral system in the high altitude Spiti Valley (agriculture up to 4450 m, livestock grazing 4900 m, total area ca. 12,000 km²) in the Himalayan state of Himachal Pradesh. The local population (ca. 10,000) belongs to one of the three Buddhist sects *Gelukpa*, *Shakyapa*, or *Ningmapa*, is related by blood, and shares a common Tibetan dialect. Family is the basic unit of production, though families are highly dependent upon the community to meet production goals. A village council appointed on rotation and functioning democratically is responsible for village administration, and is the arbiter of all decision-making pertaining to collective work and settling disputes. The council ensures equal access of families to common resources, as well as equitable distribution of responsibilities among them. Systems of primogeniture, celibacy, and polygamy seem to have prevented the fragmentation of land holdings and limited population growth. The diversity of practices in the agropastoral system seems adapted to the risk-prone mountainous environment, the risks being climatic, geological, and those posed by wildlife. The system seems to aim at maximizing production while mediating environmental risk. The production system comes forth as highly dynamic, characterized by continuous innovation and experimentation. Recent changes in the production system are in response to both changes in local conditions as well as increasing integration of the local economy with regional markets, though many aspects of the traditional lifestyle continue to be maintained.

Mithen, S. (2004). After the Ice: A Global Human History, 20,000-5000 BC. Weidenfeld and Nicolson, London, 636 pp. Also Harvard University Press; and Phoenix, London, 2004.

Drawing on recent findings from archaeology, genetics, and the environmental sciences, the author provides a region-by-region account of the transformations of human populations in the 15 millennia following the Last Glacial Maximum. Twenty thousand years ago Earth was in the midst of an ice age. Then global warming arrived, leading to massive floods, the spread of forests and the retreat of the deserts. By 5,000 BC a radically different human world had appeared. In place of hunters and gatherers there were farmers; in place of transient campsites there were towns. The foundations of our modern world had been laid and nothing that came after - the Industrial Revolution, the atomic age, the internet - have ever matched the significance of those events. Book tells the story of climate change's impact during this momentous period - one that also saw the colonisation of the Americas and mass extinctions of animals throughout the world... [20,000 B.C., the peak of the last ice age--the atmosphere is heavy with dust, deserts, and glaciers span vast regions, and people, if they survive at all, exist in small, mobile groups, facing the threat of extinction. But these people live on the brink of seismic change--10,000 years of climate shifts culminating in abrupt global warming that will usher in a fundamentally changed human world. *After the Ice* is the story of this momentous period--one in which a seemingly minor alteration in temperature could presage anything from the spread of lush woodland to the coming of apocalyptic floods--and one in which we find the origins of civilization itself. Drawing on the latest research in archaeology, human genetics, and environmental science, *After the Ice* takes the reader on a sweeping tour of 15,000 years of human history. Steven Mithen brings this world to life through the eyes of an imaginary modern traveler--John Lubbock, namesake of the great Victorian polymath and author of *Prehistoric Times*. With Lubbock, readers visit and observe communities and landscapes, experiencing prehistoric life--from aboriginal hunting parties in Tasmania, to the corralling of wild sheep in the central Sahara, to the efforts of the Guila Naqitz people in Oaxaca to combat drought with agricultural innovations. Part history, part science, part time travel, *After the Ice* offers an evocative and uniquely compelling portrayal of diverse cultures, lives, and landscapes that laid the foundations of the modern world].

Molua, E. L. (2002). "Climate variability, vulnerability and effectiveness of farm-level adaptation options: the challenges and implications for food security in Southwestern Cameroon." *Environment and Development Economics* 7(3): 529-545.

The risks associated with increasing climate variability pose technological and economic challenges to societies which are dependent on agriculture for their livelihood. In southwestern Cameroon, the natural variability of rainfall and temperatures contribute to variability in agricultural production and food insecurity. This paper explores the impact of climate variability in southwestern

Cameroon on food availability. It examines farm household's vulnerability to food availability relating to climate, and reviews the interplay of climate, agriculture, and prospects for food security in the region. An econometric function directly relates farm income and precipitation, in order to statistically estimate the significance of farm-level adaptation methods. The results reveal that precipitation during growing and adaptation methods through changes in soil tillage and crop rotation practices have significant effects on farm returns. An essential precondition for food security and overall agricultural development in southwestern Cameroon is a dynamic agricultural sector brought about both by steady increase in agricultural production and by greater efforts in farmer support. It enables farm households to take advantage of the opportunities and to minimize the negative impacts of climate variation on agriculture.

Moos, R. H. (2002). "The mystery of human context and coping: an unraveling of clues." *American Journal Of Community Psychology* **30**(1): 67-88.

Community and clinical psychology share a fundamental focus: to understand the interplay between human contexts, coping, and adaptation. To highlight recent progress in this area, article offers a guiding conceptual framework and discuss 8 propositions about environment and coping. The propositions consider such issues as patterns of social climate and coping and their links to personal development and dysfunction, the connections between ongoing life circumstances and intervention programs, the role of personal characteristics in matching individuals and environments, and the value of placing specific settings in an ecological context. Author then focuses on 8 enigmas, such as how to identify conceptually unifying dimensions of diverse social contexts, how to model the processes involved in person-environment transactions, how to understand the link between adversity and personal growth, how to examine the generality of models across ethnic and cultural groups, and how to enhance positive carryover from intervention programs to ongoing life contexts. Author concludes by addressing some implications of these issues for a vision of a dynamic community psychology.

Morrill, C., J. T. Overpeck, J. E. Cole. (2003). "A synthesis of abrupt changes in the Asian summer monsoon since the last deglaciation." *The Holocene* **13**(4): 465-476.

Authors have compiled 36 previously published palaeoclimate records to determine the timing and spatial pattern of century-scale abrupt changes in Asian monsoon precipitation since the last deglaciation. They identify abrupt events from (1) the interpretations of the authors of these records and (2) the more objective moving t-test calculation. These results indicate that abrupt climatic

changes occurred at similar to 11.5 cal. ka, similar to 4.5-5.0 cal. ka and ad 1300. At the start of the Holocene (similar to 11.5 cal. ka), Asian monsoon precipitation increased dramatically. This climatic change is synchronous with an abrupt warming in the North Atlantic. During the middle Holocene, there was a time of preferred and widespread weakening in monsoon strength (similar to 4.5-5.0 cal. ka). This result contradicts previous notions of either a gradual trend towards drier conditions or a series of abrupt events that occurred in an unorganized fashion across space and time. The middle-Holocene abrupt event could have been synchronous with an abrupt cooling event in the North Atlantic, as well as a warming and intensification of interannual variability in the tropical Pacific. In contrast to previous periods, precipitation changes at ad 1300 have a heterogeneous spatial pattern. Authors find no conclusive evidence for a change in the Asian monsoon at similar to 8.2 cal. ka, as suggested by several previous studies. More high-resolution data may be needed to observe this short-lived event. Overall, these results attest to the potential for rapid and major shifts in Asian monsoon precipitation that may be triggered by variations in other components of the climatic system.

Mortimore, M. J. and W. M. Adams (2001). "Farmer adaptation, change and 'crisis' in the Sahel." Global Environmental Change **11**(1): 49-57.

Perceptions of a continuing crisis in managing Sahelian resources are rooted in five dimensions of the Sahel Drought of 1972-1974 as it was understood at the time: crises in rainfall (drought), food supply, livestock management, environmental degradation, and household coping capabilities. A closer examination of household livelihood and farming systems shows that adaptive strategies have been evolved in response to each of these imperatives. Illustrations are provided from recent research in north-east Nigeria. A systematic understanding of indigenous adaptive capabilities can provide a basis for policies enabling a reduction of dependency on aid assistance in the Sahel.

Mount, T. D. (1994). "Climate change and agriculture: a perspective on priorities for economic policy." Climatic Change **27**(1): 121-138.

Research on the effects of climate change on US agriculture and world grain markets suggests that adaptation will occur with relatively small effects on total production. Additional research shows that reducing emission of greenhouse gases from US agricultural production is relatively expensive compared to encouraging reforestation as an offset to emissions of carbon dioxide. Nevertheless, continued population growth and the increasing inequality of income across countries are likely to exacerbate the adverse effects of climate change. Concepts of sustainability should be expanded to cover industrial as well

as agricultural production, and promote the efficient use of fossil fuels in general. Dealing with climate change effectively will require international cooperation and a willingness to address population growth and the divergence of incomes between rich and poor countries.

Moy, C. M., G. O. Seltzer, D. T. Rodbell, and D. M. Anderson. (2002). "Variability of El Niño/Southern Oscillation activity at millennial timescales during the Holocene epoch." *Nature* **420**: 162-165.

The variability of El Niño/Southern Oscillation (ENSO) during the Holocene epoch, in particular on millennial timescales, is poorly understood. Palaeoclimate studies have documented ENSO variability for selected intervals in the Holocene, but most records are either too short or insufficiently resolved to investigate variability on millennial scales. Here authors present a record of sedimentation in Laguna Pallcacocha, southern Ecuador, which is strongly influenced by ENSO variability, and covers the past 12,000 years continuously. Authors find that changes on a timescale of 2–8 years, which authors attribute to warm ENSO events, become more frequent over the Holocene until about 1,200 years ago, and then decline towards the present. Periods of relatively high and low ENSO activity, alternating at a timescale of about 2,000 years, are superimposed on this long-term trend. Authors attribute the long-term trend to orbitally induced changes in insolation, and suggest internal ENSO dynamics as a possible cause of the millennial variability. However, the millennial oscillation will need to be confirmed in other ENSO proxy records.

Munasinghe, M. (2001). "Exploring the linkages between climate change and sustainable development: A challenge for transdisciplinary research." *Conservation Ecology* **5**(1): 14. [online] URL: <http://www.consecol.org/vol5/iss1/art14>

In recent years, both sustainable development and climate change have become well known worldwide, and the work of the Intergovernmental Panel on Climate Change (IPCC) has also focused on the nexus of these two key topics. The IPCC third assessment report confirms that global mean temperatures will rise 1.5-6 degrees Celsius during the next century. Furthermore, climate change will significantly affect the economic, social, and environmental dimensions of sustainable development, as well as key issues like poverty and equity. Therefore, the IPCC is seeking answers to important questions: how future development patterns will affect climate change; how climate change impacts, adaptation, and mitigation will affect future sustainable development prospects; and how climate change responses might be better integrated into emerging sustainable development strategies. Some key lessons have emerged from these efforts. The IPCC intellectual community has already proved to be quite cohesive and resilient

in the face of determined attacks by powerful and well-financed “anti-climate change” lobbies. While addressing sustainable development issues, adaptation and learning within the IPCC have further strengthened the network. First, fresh ideas have been brought in to catalyze change. Transdisciplinary approaches are essential to deal with large-scale, long-term, complex, and interlinked issues like sustainable development and climate change. Second, the disciplinary mix has continued to evolve to meet the challenge. However, crossing disciplinary and cultural boundaries requires sound knowledge of one’s own discipline (especially its limitations), open-mindedness, great patience, and sincere effort on all sides. Third, IPCC internal processes have adjusted to facilitate beneficial changes, while limiting harmful dissension. E-mail has proved to be a powerful, but potentially risky tool. How something is said could be as important as what is said, to ensure effective communication. Despite some difficult moments, fair-mindedness and good will have prevailed. The IPCC has been able to accommodate different ways of thinking about the problem, as well as new modes of communication, while reinforcing desirable codes of conduct and behavioral norms.

Murdiyarso, D. (2000). "Adaptation to climatic variability and change: Asian perspectives on agriculture and food security." Environmental Monitoring and Assessment **61**(1): 123-131.

The impacts of climate change on potential rice production in Asia are reviewed in the light of the adaptation to climatic variability and change. Collaborative studies carried out by IRRI and US-EPA reported that using process-based crop simulation models, increasing temperature may decrease rice potential yield up to 7.4% per degree increment of temperature. When climate scenarios predicted by GCMs were applied it was demonstrated that rice production in Asia may decline by 3.8% under the climates of the next century. Moreover, changes in rainfall pattern and distribution were also found suggesting the possible shift of agricultural lands in the region. The studies however have not taken the impacts of climatic variability into account, which often produce extreme events like that caused by monsoons and *El Niño*. Shifts in rice-growing areas are likely to be constrained by land-use changes occurring for other developmental reasons, which may force greater cultivation of marginal lands and further deforestation. This should be taken into account and lead to more integrated assessment, especially in developing countries where land-use change is more a top-down policy rather than farmers' decision. A key question is: To what extent will improving the ability of societies to cope with current climatic variability through changing design of agricultural systems and practices help the same societies cope with the likely changes in climate?

Neff, U., S. J. Burns, A. Mangini, M. Mudelsee, D. Fleitmann, and A. Matter. 2001. Strong coherence between solar variability and the monsoon in Oman between 9 and 6 kyr ago. *Nature* **411**: 290-293.

Variations in the amount of solar radiation reaching the Earth are thought to influence climate, but the extent of this influence on timescales of millennia to decades is unclear. A number of climate records show correlations between solar cycles and climate, but the absolute changes in solar intensity over the range of decades to millennia are small and the influence of solar flux on climate is not well established. The formation of stalagmites in northern Oman has recorded past northward shifts of the intertropical convergence zone, whose northward migration stops near the southern shoreline of Arabia in the present climate. Here authors present a high-resolution record of oxygen isotope variations, for the period from 9.6 to 6.1 kyr before present, in a Th–U-dated stalagmite from Oman. The $\delta^{18}\text{O}$ record from the stalagmite, which serves as a proxy for variations in the tropical circulation and monsoon rainfall, allows us to make a direct comparison of the $\delta^{18}\text{O}$ record with the $\Delta^{14}\text{C}$ record from tree rings, which largely reflects changes in solar activity. The excellent correlation between the two records suggests that one of the primary controls on centennial- to decadal-scale changes in tropical rainfall and monsoon intensity during this time are variations in solar radiation.

Nelson, V., K. Meadows, T. Cannon, J. Morton, A. Martin. (2002). "Uncertain predictions, invisible impacts, and the need to mainstream gender in climate change adaptations." *Gender and Development* **10**(2): 51-59.

Authors outline climate change predictions, and explore the effects of long-term climate change on agriculture, ecological systems, and gender relations. They identify predicted changes in natural hazard frequency and intensity as a result of climate change, and explore the gendered effects of natural hazards. Paper also highlights the urgent need to integrate gender analyses into public policy making, and in adaptation responses to climate change.

Nicholls, R. J. and J. A. Lowe (2004). "Benefits of mitigation of climate change for coastal areas." *Global Environmental Change* **14**(3): 229-244.

This paper considers the possible benefits of mitigation of climate change for coastal areas with a strong emphasis on sea-level rise, as this is one of the most certain consequences of human-induced global warming. There is a long-term 'commitment to sea-level rise' due to the long thermal lags of the ocean system and hence the response of sea-level rise to mitigation is slower than for other climate factors. Therefore, while climate stabilisation reduces coastal impacts during the 21st century, compared to unmitigated emissions, the largest benefits

may occur in the 22nd century (and beyond). The results of the analysis suggest that a mixture of adaptation and mitigation policies need to be considered for coastal areas, as this will provide a more robust response to human-induced climate change than either policy in isolation. This requires the joint evaluation of mitigation and adaptation in coastal areas, ideally using a probabilistic risk-based methodology, which would be a departure from existing analyses. Because of the long time constants involved such assessments need to continue beyond 2100 to provide the full implications of the different policy choices.

Nguyen, H. P. and J. R. Anderson (1991). "Local adaptation, varietal diversity and the skewness of regional crop yields." Agricultural Systems **36**(2): 159-171.

On grounds of theory, anecdote and intuition, it is argued that crop varieties that are well adapted to local conditions will tend to have negatively skewed yield distributions. Conversely, when varieties are widely adopted that do not feature close local adaptation, and varietal diversity is substantially reduced, yields may tend to be other than negatively skewed. These arguments are supported by data on yields of different crops in different environments around the world. Analogous arguments concerning the degree of optimality of the crop-growing environment and the state of technological achievements of an agriculture are also similarly addressed. As the degree of control in an environment increases, yields again tend to be negatively skewed in contrast to those environments which are regulated but sub-optimal, where positive skewness tends to be encountered.

Noble, I. R. and R. Dirzo. (1997). "Forests as human-dominated ecosystems." Science **277**: 522-525.

Forests are human-dominated ecosystems. Many of the seemingly lightly managed or unmanaged forests are actually in use for agroforestry or for hunting and gathering. Agroforestry does reduce biodiversity, but it can also act as an effective buffer to forest clearance and conversion to other land uses, which present the greatest threat to forested ecosystems. In forests used for logging, whole-landscape management is crucial. Here, emphasis is placed on areas of intensive use interspersed with areas for conservation and catchment purposes. Management strategies for sustainable forestry are being developed, but there is a need for further interaction among foresters, ecologists, community representatives, social scientists, and economists.

Noss, R. F. (2001). "Beyond Kyoto: forest management in a time of rapid climate change." Conservation Biology **15**(3): 578-590.

Policies to reduce global warming by offering credits for carbon sequestration have neglected the effects of forest management on biodiversity.

Author reviews properties of forest ecosystems and management options for enhancing the resistance and resilience of forests to climate change. Although forests, as a class, have proved resilient to past changes in climate, today's fragmented and degraded forests are more vulnerable. Adaptation of species to climate change can occur through phenotypic plasticity, evolution, or migration to suitable sites, with the latter probably the most common response in the past. Among the land use and management practices likely to maintain forest biodiversity and ecological functions during climate change are: (1) representing forest types across environmental gradients in reserves; (2) protecting climatic refugia at multiple scales; (3) protecting primary forests; (4) avoiding fragmentation and providing connectivity, especially parallel to climatic gradients; (5) providing buffer zones for adjustment of reserve boundaries; (6) practicing low-intensity forestry and preventing conversion of natural forests to plantations; (7) maintaining natural fire regimes; (8) maintaining diverse gene pools; and (9) identifying and protecting functional groups and keystone species. Good forest management in a time of rapidly changing climate differs little from good forest management under more static conditions, but there is increased emphasis on protecting climatic refugia and providing connectivity.

Núñez, L., M. Grosjean, I. Cartajena. (2002). "Human Occupations and Climate Change in the Puna de Atacama, Chile." *Science* **298**(5594): 821-824.

Widespread evidence for human occupation of the Atacama Desert, 20° to 25°S in northern Chile, has been found from 13,000 calibrated 14C years before the present (cal yr B.P.) to 9500 cal yr B.P., and again after 4500 cal yr B.P. Initial human occupation coincided with a change from very dry environments to humid environments. More than 39 open early Archaic campsites at elevations above 3600 meters show that hunters lived around late glacial/early Holocene paleolakes on the Altiplano. Cessation of the use of the sites between 9500 and 4500 cal yr B.P. is associated with drying of the lakes. The mid-Holocene collapse of human occupation is also recorded in cave deposits. One cave contained Pleistocene fauna associated with human artifacts. Faunal diversity was highest during the humid early Holocene... Paleoeological data show that this area changed dramatically from very arid environments at the Last Glacial Maximum (LGM) to relatively humid conditions during late glacial and early Holocene times. In northern Chile, this change began around 14,000 cal yr B.P. and culminated between 13,000 and 9500 cal yr B.P. Grass cover was extensive, and vascular plant diversity was high, particularly between 11,800 and 10,500 cal yr B.P. The shorelines of late glacial paleolakes were up to 70 m above those of the current salt lakes and provided excellent habitats for mobile groups of hunters.

O'Brien, K., R. Leichenko, U. Kelkar, H. Venema, G. Aandahl, H. Tompkins, A. Javed, S. Bhadwal, S. Barg, L. Nygaard, J. West. (2004). "Mapping vulnerability to multiple stressors: climate change and globalization in India." Global Environmental Change Part A **14**(4): 303-313.

There is growing recognition in the human dimensions research community that climate change impact studies must take into account the effects of other ongoing global changes. Yet there has been no systematic methodology to study climate change vulnerability in the context of multiple stressors. Using the example of Indian agriculture, this paper presents a methodology for investigating regional vulnerability to climate change in combination with other global stressors. This method, which relies on both vulnerability mapping and local-level case studies, may be used to assess differential vulnerability for any particular sector within a nation or region, and it can serve as a basis for targeting policy interventions.

Among India's population of more than one billion people, about 68% are directly or indirectly involved in the agricultural sector. This sector is particularly vulnerable to present-day climate variability, including multiple years of low and erratic rainfall. Climate sensitivity for India in the period 1961–1990 is: The areas with high to very high climate sensitivity for agriculture are located in the semiarid regions of the country, including major parts of the states of Rajasthan, Gujarat, Punjab, Haryana, Madhya Pradesh, and Uttar Pradesh.

Based on the biophysical, social, and technological indicators adaptive capacity in 1991 across India's 466 districts has been identified. There is a higher degrees of adaptive capacity in districts located along the Indo-Gangetic Plains (except Bihar) and lower adaptive capacity in the interior portions of the country, particularly in the states of Bihar, Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, and Karnataka.

The globalization vulnerability profile was constructed by combining for each district the values of the adaptive capacity and import sensitivity indices. High vulnerability is visible in most of Rajasthan and Karnataka, as well as in substantial portions of Bihar, Madhya Pradesh, Maharashtra, Gujarat, and Assam. Notable areas of low vulnerability occur along the Indo-Gangetic plains, a highly productive region that is commonly referred to as the breadbasket of India.

Vulnerability to climate change and globalization: The most vulnerable concentrated in Rajasthan, Gujarat, Madhya Pradesh, as well as in southern Bihar and western Maharashtra. These may be interpreted as areas of "double exposure," where globalization and climate change are likely to pose simultaneous challenges to the agricultural sector.

Jhalawar district in Rajasthan is located in a semi-arid area that receives an average of 943mm of rainfall annually. In addition to high degrees of climate sensitivity, it also ranks among the lowest of the state's districts in terms of its adaptive capacity. Over the past 10 years, many farmers in Jhalawar have shifted from traditional crops, such as sorghum and pearl millet, to production of soybeans, which receive higher market prices. However, because soybean prices also fluctuate according to world market prices, the shift toward soybean production has left farmers in Jhalawar vulnerable to external market price shocks. Farmers in Jhalawar are also found to be highly vulnerable to climatic variability. At present, Jhalawar is experiencing its fourth consecutive year of drought, and crop yields have been substantially reduced, particularly for the majority of farmers who lack access to irrigation. To cope with successive years of drought, many small farmers report family members migrating to the neighboring state of Gujarat in search of wage labor. Institutional credit for agriculture in Rajasthan has become less available after structural adjustment, and more farmers now obtain loans from private moneylenders at interest rates of about 36%. Paying back these loans has become difficult when both yields and market prices have been low. What the case study shows, which was not visible through the national profiles, is the effect that institutional barriers or support systems have on local level vulnerability. In the cases of Jhalawar institutional barriers leave farmers who are "double exposed" poorly equipped to adapt to either of the stressors, let alone both simultaneously.

Why are these "double exposed" districts, such as Jhalawar in Rajasthan, a concern? They are likely to be areas where farmers are adapting to a variable and changing climate under conditions of economic stress. Reacting to two processes of change simultaneously will, of course, present challenges throughout India, but these districts are likely to feel disproportionately more stress, particularly if there is a mismatch between climate-compatible crops and market-driven demand for those crops. It is in these areas of double exposure where policy changes and other interventions may be most needed in order to help farmers to negotiate changing contexts for agricultural production.

One of the limitations of the approach is that it did not entail detailed investigation of factors that constrain or enable adaptive capacity at the local level. While case studies suggested that institutions play a critical role in both constraining and enabling farmer adaptation, further study of the role of institutions in influencing vulnerability is needed.

O'Connor, T. G. and G. A. Kiker (2004). "Collapse of the Mapungubwe society: Vulnerability of pastoralism to increasing aridity." *Climatic Change* 66(1-2): 49-66.

The Mapungubwe agro-pastoral society in the Limpopo valley, South Africa, persisted for 300 yrs before disappearing in about 1290 as a result of a decrease in mean annual rainfall (MAR) from about 500 mm to the current 340 mm. The influence of rainfall changes and competition from wildlife on cattle and small stock populations was investigated (agriculture was not) using the SAVANNA model. Six scenarios were compared for a 350 km² area (Venetia–Limpopo Nature Reserve) for a 280 yrs simulation period: livestock only, wildlife only, and wildlife plus livestock, for a climate of ‘low’ (MAR 340 mm) versus ‘high’ (MAR 480 mm) rainfall. High inter-annual variability in rainfall resulted in highly variable grass production, but production of woody plants was more stable. Extreme drought events of one or more years duration resulted in marked population declines of the grazers, cattle and zebra. Populations of mixed feeders or browsers, including kudu, small stock and impala, were comparatively stable, the latter two mentioned were in part stabilised by offtake. Cattle populations persisted under a high rainfall climate irrespective of wildlife, but became extinct within 120 yrs under a low rainfall climate when competing with wildlife, in particular zebra. The size of the persisting populations of cattle or small stock under low rainfall was about half that for the corresponding high rainfall scenario. Pastoralism based on cattle was apparently unviable once climate started changing, and small stock were probably insufficient for meeting societal needs. Although crop failure is a sufficient explanation for the disappearance of the Mapungubwe settlement, destabilization of pastoralism would have compounded food security. The recorded rapid onset of a dry climate is of portent for current-day pastoral societies in marginal environments.

Ohtsuka, R., T. Inaoka, M. Umezaki, N. Nakada, T. Abe. (1995). “Long-term subsistence adaptation to the diversified Papua New Guinea environment: Human ecological assessments and prospects.” Global Environmental Change 5(4): 347-353.

Adaptive diversity of Papua New Guinea peoples, represented by population densities varying from less than 1 person to more than 100 persons/km², is mostly attributable to their agricultural systems in accordance with the natural and sociocultural environment. Comparison of long-term adaptation among several populations selected for highland/lowland status and degree of modernization is expected to clarify the causal relationships and to predict future potential. This article discusses relationships between productivity and sustainability of agriculture and population dynamics in the agrodiversified environment in Papua New Guinea.

Olsson, P., C. Folke, F. Berkes. (2004). “Adaptive comanagement for building resilience in social-ecological systems.” Environmental Management 34(1): 75-90.

Ecosystems are complex adaptive systems that require flexible governance with the ability to respond to environmental feedback. Authors present, through examples from Sweden and Canada, the development of adaptive comanagement systems, showing how local groups self-organize, learn, and actively adapt to and shape change with social networks that connect institutions and organizations across levels and scales and that facilitate information flows. The development took place through a sequence of responses to environmental events that widened the scope of local management from a particular issue or resource to a broad set of issues related to ecosystem processes across scales and from individual actors, to group of actors to multiple-actor processes. The results suggest that the institutional and organizational landscapes should be approached as carefully as the ecological in order to clarify features that contribute to the resilience of social-ecological systems. These include the following: vision, leadership, and trust; enabling legislation that creates social space for ecosystem management; funds for responding to environmental change and for remedial action; capacity for monitoring and responding to environmental feedback; information flow through social networks; the combination of various sources of information and knowledge; and sense-making and arenas of collaborative learning for ecosystem management. Authors propose that the self-organizing process of adaptive comanagement development, facilitated by rules and incentives of higher levels, has the potential to expand desirable stability domains of a region and make social-ecological systems more robust to change.

O'Riordan, T. and A. Jordan (1999). "Institutions, climate change and cultural theory: towards a common analytical framework." Global Environmental Change 9(2): 81-93.

Institutions are the multitude of means for holding society together, for giving it a sense of purpose and for enabling it to adapt. Institutions help to define climate change both as a problem and a context, through such socialised devices as the use of scientific knowledge, culturally defined interpretation of scientific findings, and politically tolerable adaptation strategies. This paper briefly reviews the origins and current status of the 'new' institutional theories that have recently developed within the social sciences. The conclusion is that they are based on such contradictory interpretations of human behaviour that, although appealing, a complete synthesis will never be possible. In effect, there is a fundamental institutional 'failure' over the interpretation and resolution of climate change. Cultural theory helps to explain why this is the case by throwing light on the inherent contradictions that beset us all when confronted with global warming.

Orlando, B., D. Baldock, S. Canger, J. Mackensen, S. Maginnis, M. S. Manguiat, S. Rietbergen, C. Robledo, and N. Schneider (eds.). (2002). Carbon, forests and

people: towards the integrated management of carbon sequestration, the environment and sustainable livelihoods. IUCN-The World Conservation Union, Gland, Switzerland.

This book reviews the environmental and social impacts of forestry and land use activities relating to increased carbon sequestration and describes approaches to address these impacts. It assesses the potential impacts of these activities. It also considers the opportunities and challenges for forest projects. Finally, it gives strategies, methods and approaches available to address the synergies and trade-offs that may arise between climate change, environment and livelihood objectives.

Ortloff, C. R., and A. L. Kolata. (1993). "Climate and collapse: Agro-ecological perspectives on the decline of the Tiwanaku State." Journal of Archaeological Science **20**: 195-221.

After approximately 700 years of growth and colonial expansion, the Tiwanaku state disintegrated as a regional political force in the south-central Andes between c. AD 1000-1100. This paper examines the collapse of the state of Tiwanaku through the lens of its agricultural history. Proximate cause of Tiwanaku's decline as a politically integrated, expansive state society was the deterioration and ultimate abandonment of its regional-scale agricultural systems, both in its core area in the Andean altiplano and in its economic colonies in the lower-altitude yungas zones. The collapse of Tiwanaku intensive agriculture was triggered by regional change in climatic conditions recorded in highly-resolved palaeoenvironmental data derived from the Quelccaya ice cap of southern Peru and in sediment cores from Lake Titicaca. The analysis of the Quelccaya data documents a radical climate change in the south-central Andes during the post-AD 1000 era in the form of a statistically significant decrease in mean precipitation level that persisted until c. AD 1400. By defining vulnerability classes for various agricultural technologies used in different regions of the Tiwanaku state, authors then relate this palaeoclimatic data to performance of specific core area and colonial Tiwanaku agricultural systems. They demonstrate that chronic drought conditions led to sequential collapse of these distinct agricultural systems: irrigation-based agriculture in Tiwanaku colonies at lower altitude failed first, followed by groundwater-dependent raised-field systems in the altiplano. Agricultural and settlement pattern changes in the post-AD 1000 period are correlated with the palaeoenvironmental data to present an integrated view of the coupling of climate and cultural process. The full implications of the agro-ecological collapse model presented here reach well beyond an explanation for the decline of Tiwanaku alone.

Ososkova, T., N. Gorelkin, V. Chub. (2000). "Water resources of Central Asia and adaptation measures for climate change." Environmental Monitoring and Assessment **61**(1): 161-166.

A large part of the Central Asian region is located within the inner flow of the Aral Sea basin. The water resources are formed from renewed superficial and underground waters of natural origin, and also with returnable waters. The intensive increase of water intake, that took place in the second half of the twentieth century caused practically complete assimilation of the river inflow. That was the main reason for the Aral Sea crisis. On the basis of the analysis of long periodical rows of observation by meteorological and hydrological stations, the estimation of regional water resources and calculations of changes of some components of the hydrological cycle due to the expected climate changes are presented. Measures for adaptation in the southern part of the Aral Sea region are considered.

Overpeck, J., D Anderson, S. Trumbore, W. Prell. (1996). "The southwest Indian Monsoon over the last 18,000 years." Climate Dynamics **12**(3): 213 – 225.

Previously published results suggest that the strength of the SW Indian Monsoon can vary significantly on century- to millenium time scales, an observation that has important implications for assessments of future climate and hydrologic change over densely populated portions of Asia. Authors present new, well-dated, multi-proxy records of past monsoon variation from three separate Arabian Sea sediment cores that span the last glacial maximum to late-Holocene. To a large extent, these records confirm earlier published suggestions that the monsoon strengthened in a series of abrupt events over the last deglaciation. However, our data provide a somewhat refined picture of when these events took place, and suggest the primacy of two abrupt increases in monsoon intensity, one between 13 and 12.5 ka, and the other between 10 and 9.5 ka. This conclusion is supported by the comparisons between our new marine data and published paleoclimatic records throughout the African-Asian monsoon region. The comparison of data sets further supports the assertion that maximum monsoon intensity lagged peak insolation forcing by about 3000 years, and extended from about 9.5 to 5.5 ka. The episodes of rapid monsoon intensification coincided with major shifts in North Atlantic-European surface temperatures and ice-sheet extent. This coincidence, coupled with new climate model experiments, suggests that the large land-sea thermal gradient needed to drive strong monsoons developed only after glacial conditions upstream of, and on, the Tibetan Plateau receded (cold North Atlantic sea-surface temperatures, European ice-sheets, and extensive Asian snow cover). It is likely that abrupt changes in seasonal soil hydrology were as important to past monsoon forcing as were abrupt snow-

related changes in regional albedo. Our analysis suggests that the monsoon responded more linearly to insolation forcing after the disappearance of glacial boundary conditions, decreasing gradually after about 6 ka. Our data also support the possibility that significant century-scale decreases in monsoon intensity took place during the early to mid-Holocene period of enhanced monsoon strength, further highlighting the need to understand paleomonsoon dynamics before accurate assessments of future monsoon strength can be made.

Pachauri, R. K. (2004). "Climate change and its implications for development: the role of IPCC assessments." *IDS Bulletin* **35**(3): 11-14.

The Intergovernmental Panel on Climate Change (IPCC) Reports show that climate change is likely to have significant developmental consequences for all, but developing countries and the poor persons within all countries will be disproportionately affected by impacts on agriculture, health and water. As the largest source of employment in most developing countries, impacts on agriculture and on food security are especially critical. Altered precipitation rates will also result in more frequent droughts and floods in large parts of Asia and could impact adversely on the achievements of the Millennium Development Goals (MDGs) on water and sanitation, which are linked to other MDGs. Vulnerability of agriculture and options for adaptation have only recently been studied in India in detail. These indicate serious problems for India, as there are limited opportunities for changes in crops, compounded by other factors such as unfavourable global trading regimes.

Pandey, D. N. (2001). "A bountiful harvest of rainwater." *Science* **293**(5536): 1763.

Over thousands of years, societies have developed a diversity of local water harvesting and management regimes that continue to survive in South Asia, Africa, and other parts of the world. Such systems are often integrated with agroforestry and local forest management practices. In their Policy Forum "Managing water for people and nature" (*Science's Compass*, 11 May, p. 1071), Nels Johnson and co-authors discuss several market mechanisms for sustainable water management, including taxing users to pay commensurate costs of supply and distribution and costs of integrated watershed management, and charging polluters for effluent treatment. Although such measures are indeed essential, Authors argues that they are insufficient: They should be complemented with policy innovations to promote rainwater harvesting. Revival of local practices of rainwater harvesting could provide substantial amounts of water. For example, a hectare of land in Barmer, one of India's driest places, with 100 millimeters of rainfall annually, could yield 1 million liters of water per year from harvesting

rainwater. Even with simple technology such as ponds and earthen embankments called tanks, at least half a million liters a year can be harvested from rain falling over 1 hectare of land, as is being done in the Thar Desert, making it the most densely populated desert in the world. Indeed, there are 1.5 million village tanks in use and sustaining everyday life in the 660,000 villages in India. In the Negev Desert, decentralized harvesting of water in microcatchments from rain falling over a 1-hectare watershed yielded 95,000 liters of water per hectare per year, whereas collection efforts from a single large unit from a 345-hectare watershed yielded only 24,000 liters per hectare per year. Thus, 75% of the collectible water was lost as a result of the longer distance of runoff. Indeed, this is consistent with local knowledge distilled in an Indian proverb, "Capture rain where it rains." In the cities, rainwater could be harvested from building rooftops for residential use, and any surplus could be channeled through bore wells to replenish the groundwater, avoiding loss to runoff. However, if tanks and other rain harvesting technology are to be used to their full potential, policy innovations must include institutional changes so that such common-pool resources are effectively managed. Also, all forms of government subsidies need to be removed to allow market mechanisms, such as the ones Johnson et al. discuss, to run their course. Users would then find it prudent not only to make efficient use of priced water, but they would also have the incentive to collect the gift that Mother Nature has to offer in the form of rain.

Pandey, D. N. (2002). "Carbon sequestration in agroforestry systems." *Climate Policy* 2(4): 367-377.

Management of trees in agroecosystems such as agroforestry, ethnoforests, and trees outside forests can mitigate green house gas (GHG) emissions under the Kyoto Protocol. Agroforestry systems are a better climate change mitigation option than oceanic, and other terrestrial options because of the secondary environmental benefits such as helping to attain food security and secure land tenure in developing countries, increasing farm income, restoring and maintaining above-ground and below-ground biodiversity, corridors between protected forests, as CH₄ sinks, maintaining watershed hydrology, and soil conservation. Agroforestry also mitigates the demand for wood and reduces pressure on natural forests. Promoting woodcarving industry facilitates long-term locking-up of carbon in carved wood and new sequestration through intensified tree growing. By making use of local knowledge, equity, livelihood security, trade and industry, can be supported. There is need to support development of suitable policies, assisted by robust country-wide scientific studies aimed at better understanding the potential of agroforestry and ethnoforestry for climate change mitigation and human well-being.

Pandey, D. N., A. K. Gupta, D. M. Anderson. (2003). "Rainwater harvesting as an adaptation to climate change." *Current Science* **85**(1): 46-59.

Extreme climate events such as aridity, drought, flood, cyclone and stormy rainfall are expected to leave an impact on human society. They are also expected to generate widespread response to adapt and mitigate the sufferings associated with these extremes. Societal and cultural responses to prolonged drought include population dislocation, cultural separation, habitation abandonment, and societal collapse. A typical response to local aridity is the human migration to safer and productive areas. However, climate and culture can interact in numerous ways. Authors hypothesize that people may resort to modify dwelling environments by adapting new strategies to optimize the utility of available water by harvesting rain rather than migrating to newer areas. Authors review recent palaeoclimatological evidence for climate change during the Holocene in India, and match those data with archaeological and historical records to test our climate change-rainwater harvest hypothesis. Article finds a correlation between heightened historical human efforts for construction of rainwater harvesting structures across regions in response to abrupt climate fluctuations, like aridity and drought. Historical societal adaptations to climate fluctuations may provide insights on potential responses of modern societies to future climate change that has a bearing on water resources, food production and management of natural systems.

Pandey, N. 2002. Gender economics of the Kyoto Protocol. *Conservation Ecology* **6**(1): r14. [online] URL: <http://www.consecol.org/vol6/iss1/resp14>

Global climate change is threatening the social, economic, and ecological systems of our world. Cost effectiveness of the Kyoto Protocol presents a compelling argument for its implementation. Missing from the climate-change debate, however, is the differential impact of climate change on women, and how implementation of the Kyoto Protocol could specifically benefit economically disadvantaged women in developing countries. The argument favoring implementation of the Kyoto Protocol would be strengthened if it included a recognition of gender economics. Any fruitful discussion on the economics of climate change must consider: the additional work burden of women and female children; the differences, according to gender, in access to resources and consumption patterns; and the comparative vulnerability of women to climate change. Men and women have differential knowledge of local resources and climate issues. Women can play a crucial role in climate-change mitigation through adaptive management of local resources, thereby saving ecosystems from catastrophic shifts. Women should be active and equal partners in the decision-making process on the Clean Development Mechanism, as well as in capacity building, technology transfer, vulnerability studies, and projects concerning

climate-change mitigation and adaptation. Scientific and policy efforts on climate-change mitigation and sustainable development should, therefore, also pay attention to the profound influence that gender economics has in any collective attempt to build a sustainable society.

Pareek, O. P., B. B. Vashishtha, D. K. Samadia. (1999). "Genetic diversity in drought hardy cucurbits from hot arid zone of India." IPGRI Newsletter for Asia, the Pacific and Oceania(No. 28): 22-23.

A total of 842 open-pollinated semi-cultivated landraces of matura (*Citrullus lanatus*), kachari (*Cucumis callosus*), snap melon (*Cucumis melo*) were collected in the north-western parts of Rajasthan in 1995 and evaluated. Some accessions with economic and nutritional potential for cultivation in the arid regions of India as an adaptation were identified.

Payet, R. and D. Obura (2004). "The negative impacts of human activities in the eastern African region: an international waters perspective." Ambio **33**(1-2): 24-33.

The complex interactions between human activities and the environment at the interface of land and water is analyzed with a focus on the Somali Current (East Africa), and Indian Ocean Island States, subregions of the Global International Waters Assessment (GIWA). These 2 subregions contain some of the world's richest ecosystems, including the high biodiversity forests of Madagascar and the diverse coastal habitats of the eastern African coast. These ecosystems support local communities and national and regional economies. Current and future degradation of these systems, from water basins to continental shelves, affects the livelihoods and sustainability of the countries in the region, and long-term efforts to reduce poverty. The assessments determined that pollution and climate change are the primary environmental and social concerns in the Islands of the Indian Ocean, while freshwater shortage and unsustainable exploitation of fisheries and other living resources are the primary environmental and social concerns in East Africa. The GIWA approach, through assessing root causes of environmental concerns, enables the development of policy approaches for mitigating environmental degradation. This paper explores policy frameworks for mitigating the impacts, and reducing the drivers, of 3 environmental concerns--freshwater shortage; solid waste pollution; and climate change--addressing social and institutional causes and effects, and linking the subregions to broad international frameworks. The common theme in all 3 case studies is the need to develop integrated ecosystem and international waters policies, and mechanisms to manage conflicting interests and to limit threats to natural processes.

Perrings, C. (2003). "The economics of abrupt climate change." Philosophical Transactions. Series A, Mathematical, Physical, And Engineering Sciences **361**(1810): 2043-2057.

The US National Research Council defines abrupt climate change as a change of state that is sufficiently rapid and sufficiently widespread in its effects that economies are unprepared or incapable of adapting. This may be too restrictive a definition, but abrupt climate change does have implications for the choice between the main response options: mitigation (which reduces the risks of climate change) and adaptation (which reduces the costs of climate change). The paper argues that by (i) increasing the costs of change and the potential growth of consumption, and (ii) reducing the time to change, abrupt climate change favours mitigation over adaptation. Furthermore, because the implications of change are fundamentally uncertain and potentially very high, it favours a precautionary approach in which mitigation buys time for learning. Adaptation-oriented decision tools, such as scenario planning, are inappropriate in these circumstances. Hence learning implies the use of probabilistic models that include socioeconomic feedbacks.

Phadtare, N. R. (2000). "Sharp Decrease in Summer Monsoon Strength 4000-3500 cal yr B.P. in the Central Higher Himalaya of India Based on Pollen Evidence from Alpine Peat." Quaternary Research **53**(1): 122-129.

Age-constrained pollen data and magnetic susceptibility of an alpine peat profile from the Garhwal Higher Himalaya display a continuous record of climate and monsoon trends for the past 7800 yr. About 7800 cal yr B.P., dominance of evergreen oak (*Quercus semecarpifolia*), alder (*Alnus*), and grasses in the pollen record reflect a cold, wet climate with moderate monsoon precipitation. From 7800 to 5000 cal yr B.P., vegetation was progressively dominated by conifers, indicating ameliorated climate with a stronger monsoon. A warm, humid climate, with highest monsoon intensity, from 6000-4500 cal yr B.P. represents the mid-Holocene climatic optimum. Between 4000 and 3500 cal yr B.P., the abundance of conifers sharply decreased, with the greatest increase in evergreen oak. This trend suggests progressive cooling, with a decrease in the monsoon to its minimum about 3500 cal yr B.P. Two relatively minor cold/dry events at ca. 3000 and 2000 cal yr B.P. marked step-wise strengthening of the monsoon until ca. 1000 cal yr B.P. After a cold/dry episode that culminated ca. 800 cal yr B.P., the monsoon again strengthened and continued until today. A sharp decrease in temperature and rainfall at 4000-3500 cal yr B.P. represents the weakest monsoon event of the Holocene record. This cold/dry event correlates with proxy data from other localities of the Indian subcontinent, Arabian Sea, and western Tibet.

Pielke, R. A., Jr. (1998). "Rethinking the role of adaptation in climate policy." Global Environmental Change **8**(2): 159-170.

Since the late 1980s, scientists and policy makers have devoted considerable attention and resources to the issue of global climate change. Domestic and International policies in response focus primarily on prevention of future climate impacts on society through the mitigation of carbon dioxide emissions. Academic and political attention is also largely focused on issues of mitigation. Adaptation refers to adjustments in individual, group, and institutional behavior to reduce society's vulnerabilities to climate, and thus reduce its impacts. In 1996, the Intergovernmental Panel on Climate Change (IPCC) wrote that adaptation offers a 'very powerful option' for responding to climate change and ought to be viewed as a 'complement' to mitigation efforts. Yet, the IPCC also wrote that 'little attention has been paid to any possible tradeoff between both types of options'. This paper discusses the limitations of mitigation responses and the need for adaptation to occupy a larger role in climate policy.

Piperno, D. R. and K. E. Stothert. (2003). "Phytolith Evidence for Early Holocene Cucurbita Domestication in Southwest Ecuador." Science **299**: 1054-1057.

Cucurbita (squash and gourd) phytoliths recovered from two early Holocene archaeological sites in southwestern Ecuador and directly dated to 10,130 to 9320 carbon-14 years before the present (about 12,000 to 10,000 calendar years ago) are identified as derived from domesticated plants because they are considerably larger than those from modern wild taxa. The beginnings of plant husbandry appear to have been preceded by the exploitation of a wild species of Cucurbita during the terminal Pleistocene. These data provide evidence for an independent emergence of plant food production in lowland South America that was contemporaneous with or slightly before that in highland Mesoamerica.

Polsky, C. and I. Easterling, William E. (2001). "Adaptation to climate variability and change in the US Great Plains: A multi-scale analysis of Ricardian climate sensitivities." Agriculture, Ecosystems & Environment **85**(1-3): 133-144.

The Ricardian approach to estimating climate change impacts is an important technique for incorporating how adaptations modulate the overall effect. Past Ricardian work expresses climate sensitivities in terms of local effects only, ignoring the influence on adaptation of broader-scale social, environmental and economic factors. This paper extends the Ricardian approach to account for influences at multiple spatial scales. Results from multi-level modeling support the hypothesis that a county's Ricardian climate sensitivity is influenced not only by its climate but also by social factors associated with the climate of the agro-climatic

zone in which it is located. The model estimates a non-linear, hill-shaped relationship between July maximum temperatures and agricultural land values, with initial increases beneficial in all counties but more beneficial in districts of high interannual temperature variability. Farmers and institutions in districts of high variability have therefore adapted to be more resilient to variability than farmers in areas of comparatively stable climate. However, the underlying reasons for this lessened vulnerability are unclear and may be associated with unsustainable land-use practices. Future research should investigate the precise form of these local and extra-local adaptations to determine if implementing the adaptations elsewhere would compromise agricultural system sustainability.

Polyak, V. J and Asmerom, Y. (2001). "Late Holocene climate and cultural changes in the Southwestern United States." *Science* **294**: 148-151.

Columnar stalagmites in caves of the Guadalupe Mountains during the late Holocene record a 4000-year annually resolved climate history for the southwestern United States. Annual banding, hiatuses, and high-precision uranium-series dating show a present day-like climate from 4000 to 3000 years ago, following a drier middle Holocene. A distinctly wetter and cooler period from 3000 to 800 years ago was followed by a period of present day-like conditions, with the exception of a slightly wetter interval from 440 to 290 years before the present. The stalagmite record correlates well with the archaeological record of changes in cultural activities of indigenous people. Such climate change may help to explain evidence of dwelling abandonment and population redistribution.

Potdar, M. B., S. S. Pokharna, V. N. Sridhar. (1993). "Response of vegetation in the Thar Desert to monsoon rainfall: an investigation using NOAA AVHRR and meteorological data." *Journal of Arid Environments* **25**(1): 19-26.

The study of dependence of vigor and senescence of desert vegetation on monsoon rainfall is important in understanding the desert ecosystem. In the study reported here the response of vegetation in the Thar Desert to the monsoon rainfall is investigated using multitemporal NOAA AVHRR data of post-monsoon period and meteorological data of 1990 monsoon period for the nine core districts of western Rajasthan. The temporal profiles show three distinct characteristics and these have been interpreted in terms of cumulative soil-moisture budget during monsoon. The results show that the vigour and the senescence of desert vegetation are strongly correlated with the root zone cumulative soil moisture and somewhat weakly correlated with the cumulative soil moisture at the deeper layers. The plot of normalized difference vegetation index (a surrogate measure of vigour of vegetation) at the end of the monsoon vs. average annual rainfall shows the existence of three ecological zones.

Powell, J. M. (2002). "Environment and institutions: three episodes in Australian water management, 1880-2000." Journal of Historical Geography **28**(1): 100-114.

The under-researched history of water management experience in Australia has been deeply implicated in a protracted coming-to-terms with a prodigiously demanding national territory. While providing new insights into a chronicle of human occupation extending over scores of thousands of years, the story of that experience may also illuminate the tensions between developmentalism and conservationism during the modern era and promote a more secure anchoring for debates on sustainability and national identity. Three sample studies demonstrate that {{environmental adaptations}} were distinctively balanced and confused by economic, political and social considerations, and by the evolution of scientific and technological ideas. Selected themes, periods and areas are as follows: modes of organization--centralization and decentralization in Victoria, 1880-1914; the formation of irrigation policy--Queensland, 1920-1936; and institutional change and the bioregional alternative--the Murray-Darling Basin, 1975-2000. The resultant emphasis indicates an expanding potential for the insertion of supplementary forms of applied scholarship.

Prasad, S., S. Kusumgar, S. K. Gupta. (1997). A mid to late Holocene record of palaeoclimatic changes from Nal Sarovar: a palaeodesert margin lake in western India. Journal of Quaternary Science **12**(2): 153-159.

With a view to obtain palaeoclimatic data from a climatically sensitive region authors have studied core samples from Nal Sarovar, a large shallow lake lying within the palaeodesert margin of Thar in western India. A combination of C/N ratios and $\delta^{13}\text{C}$ on a radiocarbon-dated core section have been used as climatic proxies. A high-resolution record extending back to ca. 6.6 ka BP has been reconstructed. The data indicate that, in the past, climate has varied from drier to wetter than present on time-scales of few hundreds to few thousands of years. There are, however, significant differences on the timing of these wet and dry periods, when compared with the available data from lakes farther north, in Rajasthan. Further, it looks unlikely that during the 6.6 ka the catchment areas of Nal Sarovar experienced such a significant increase in rainfall as has been suggested for the Rajasthan lakes. Interestingly, drier periods in Nal Sarovar data appear to correlate well with periods of glacier expansion in Eurasia indicating that the palaeoclimatic variations recorded in Nal Sarovar are a regional feature.

Prasad, R., R. S. Mertia, P. Narain. (2004). "Khadin cultivation: a traditional runoff farming system in Indian Desert needs sustainable management." Journal of Arid Environments **58**(1): 87-96.

Khadin cultivation is a typical land use system of runoff farming followed since 15th century in 100-200 mm rainfall zone in Jaisalmer district of western Rajasthan. The soils in khadins are fertile due to regular settlement of fine sediments brought down by the runoff water and their potential for producing food grain is well recognized for securing a dependable harvest. However, the productivity from khadin cultivation remains low due to many factors. Some of the thrust areas and strategies for better management of khadins with higher productivity on sustainable basis include designing of new khadins with provision of spillway, recycling of excess stored water for either growing of crops in down reaches or for life saving irrigation in upper reaches and adjoining land, conservation measures to ensure availability of soil moisture to crops over a period of their duration, standardization of fertilizer requirement of different crops and adoption of multi-production systems such as agroforestry, fisheries, etc. To predict the crop productivity from khadin cultivation on sustainable basis; there is a need to generate data on productivity in relation to rainfall, catchment area, ponding depth, status of conserved moisture, and soil fertility for different crops over a period of time for low, normal and above-normal monsoon. Future research has to be directed to develop short-duration varieties whose water requirement matches with the availability of conserved moisture in khadins. Emphasis has to be given on integration of multipurpose woody perennials like *Acacia nilotica* (Linn.) Del sub sp. indica, *Prosopis cineraria* (Linn.) Druice, *Zizyphus mauritiana* Lamk. etc., and fruit bearing plant species such as *Cordia myxa* Linn. and *Phoenix dactylifera* Linn. for enhancing productivity from khadin cultivation.

Quine, C. and B. Gardiner (2002). Climate change impacts: storms. Forestry Commission Bulletin, Edinburgh, UK.

This chapter reviews the current impact of strong winds on forests, and then considers predicted changes in the incidence of storms. Strong winds cause a variety of effects to trees and forests, including mortality of young plants through desiccation or toppling, restriction of growth, effects upon tree form (through branch and leader loss), and mortality through windthrow and wind snap. The emphasis here is on how climate change may influence the last two of these impacts. Key findings are the following. (1) The UK has a severe wind climate, with the potential for afforestation often limited by wind; current forest management, particularly in the uplands is, therefore, adapted to extremes of wind climate. (2) Since 1945, there has been notable damage to some forests in the UK, on average, every other year. (3) Current predictions suggest a modest increase in mean wind speed, while the frequency of gales may increase; the predictions of both are tentative and generally within the magnitude of current inter-annual variability. (4) Although the predictions suggest little impact in terms of the wind

climate, uncertainty over the frequency of extremes, and the sensitivity of the damage threshold to methods of forest management, indicates no room for complacency. (5) Climate change could have indirect consequences for wind risk management, including: changes to the frequency and duration of waterlogging; increased frequency of wet snow leading to more snow damage; larger leaf area resulting in increased wind resistance and thus vulnerability. (6) No major adaptation to current management practice is recommended at this stage, but continuation of 'best practice' is appropriate, with review as climate predictions are refined. A number of key points should be considered for site-specific estimates of risk. (i) There are dangers in applying solutions from elsewhere without a careful appraisal of the similarity of the two situations. (ii) For stands at high risk the potential options will tend to be limited, while for stands at low risk the options will be wide and goals other than risk-minimizing will take precedence; it is those sites at moderate risk where the greatest potential exists to either exacerbate the risk by poor decision making, or to reduce it through careful management; existing wind-risk models provide guidance. (iii) Careful appraisal of future scenarios will be required, to reassess the strategy of continued wind risk-sensitive management and to identify whether more substantial changes in practice are warranted.

QunYing, L. and E. Lin (1999). "Agricultural vulnerability and adaptation in developing countries: the Asia-Pacific region." *Climatic Change* **43**(4): 729-743.

During the last decades, a large number of climate change impact studies on agriculture have been conducted qualitatively and quantitatively in many regions of the Asia-Pacific. Changes in average climate conditions and climate variability will have a significant consequence on crop yields in many parts of the Asia-Pacific. Crop yield and productivity changes will vary considerably across the region. Vulnerability to climate change depends not only on physical and biological response but also on socioeconomic characteristics. Adaptation strategies that consider changes in crop varieties or in the timing of agricultural activities imply low costs and, if readily undertaken, can compensate for some of the yield loss simulated with the climate change scenarios. The studies suggest that the regions of Tropical Asia appear to be among the more vulnerable, some areas of Temperate Asia also appear to be vulnerable.

Ramakrishnan, P. S. (1998). "Sustainable development, climate change and tropical rain forest landscape." *Climatic Change* **39**(2/3): 583-600.

A potential impact of climate change in the South Asian context in general and in the Indian subcontinent in particular is an increase in rainfall, in some areas up to 50%. Using an extensive information base available on the dynamics of

landscape structure and function of the northeastern hill areas of India, scenarios on landscape changes, as an adaptation to climate change, have been constructed. Climate change would impose a variety of stresses on sustainable livelihood of the inhabitants of the rain-forested areas through stresses on ecosystem function. It is concluded that appropriate management strategies for natural forests and plantation forestry should go hand in hand with a comprehensive rural ecosystem rehabilitation plan.

Ramesh, R. (2001). "High resolution Holocene monsoon records from different proxies: An assessment of their consistency." *Current Science* **81**(11): 1432-1436.

Available high resolution quantitative monsoon reconstructions for the Holocene period in the Indian region are compared to assess for consistency among the proxy records. There is a good concordance among three different monsoon proxies from western India: (a) Pollen-based reconstruction of annual rainfall in Rajasthan from a sediment core in lake Lunkaransar, (b) stable carbon isotope variations in organic carbon from another core from the same lake, and (c) stable oxygen isotopic variations in surface-dwelling foraminifera from a sediment core in the coastal eastern Arabian Sea. While this is reassuring, the degree of concordance diminishes when records from widely separated sites in the Indian region are compared. Possible causes for this inconsistency are discussed, perhaps the most important among them being the large spatial variations in monsoon rainfall over the Indian region, apparent in modern instrumental records. There is a need to assess the temporal variance of this geographical variability before multiproxy quantitative monsoon rainfall reconstructions can be integrated as a single time series (somewhat akin to the modern All India Summer Monsoon Rainfall time series compiled by the India Meteorological Department). Such an effort can serve to test and improve palaeoclimate/palaeomonsoon models.

Ramesh, R., R. A. Jani, R. Bhushan. (1993). "Stable isotopic evidence for the origin of salt lakes in the Thar Desert." *Journal of Arid Environments* **25**(1): 117-123.

There are a number of salt lakes in and around the Thar Desert, India. A few major ones are Sambhar, Kuchaman, Didwana in Rajasthan and Kharaghoda in Gujarat. There have been a number of hypotheses concerning the origin of these salt lakes. One of them is that these lakes are relicts of the Tethys Sea that existed in this region before the collision of the Indian and Eurasian plates around 70 Ma ago. Authors have tested this hypothesis by collecting more than 50 brine and fresh water samples from in and around these lakes and measuring their stable isotope ratios of oxygen ($\delta^{18}\text{O}$) and hydrogen ($\delta^2\text{H}$). Our results show no evidence for the above hypothesis of marine origin for these lakes. On the

contrary, the isotopic data are consistent with the hypothesis that the water in these lakes are of meteoric origin and the salt is locally derived by the weathering of rocks in this region. A simple model calculation shows that these lakes behave as terminal lakes; they receive water during the short monsoon season (June–September) and evaporate during the rest of the year (there is no outflow and evaporation is equal to inflow). The model calculated saturation $\delta^{18}\text{O}$ value for these lakes is in good agreement with the mean measured value indicating that these lakes are formed by accumulation and evaporation cycles fed by local precipitation.

Ragab, R. and C. Prudhomme (2002). "Climate Change and Water Resources Management in Arid and Semi-arid Regions: Prospective and Challenges for the 21st Century." *Biosystems Engineering* **81**(1): 3-34.

The overgrowing population and the recent droughts are putting water resources under pressure and calling for new approaches for water planning and management if escalating conflicts are to be avoided and environmental degradation is to be reversed. As countries are using their water resources with growing intensity, poor rainfall increasingly leads to national water crises as water tables fall and reservoirs, wetlands and rivers empty. Global warming could cause further changes, further variability and further uncertainty. The UK Hadley Centre's global climate model was run at a spatial scale of 2.5° by 3.75° (latitude and longitude) grid squares to simulate the global climate according to scenarios of greenhouse gas concentration emission. Runs of the model assuming the emission scenario proposed by the Intergovernmental Panel on Climate Change in 1995 are analysed here for the 2050s time horizon. Outputs provide estimations of climate variables, such as precipitation and temperature, at a monthly time step. Those results, assumed representative of future climatic conditions, are compared to mean monthly values representative of the current climate and expressed in terms of percentage change. The results show that, for the dry season (April–September), by the 2050s, North Africa and some parts of Egypt, Saudi Arabia, Iran, Syria, Jordan and Israel, are expected to have reduced rainfall amounts of 20–25% less than the present mean values. This decrease in rainfall is accompanied by a temperature rise in those areas of between 2 and 2.75°C . For the same period, the temperature in the coastal areas of the Mediterranean countries will rise by about 1.5°C . In wintertime, the rainfall will decrease by about 10–15% but would increase over the Sahara by about 25%. Given the low rainfall rate over the Sahara, the increase by 25% will not bring any significant amount of rain to the region. In wintertime, the temperature in the coastal areas will also increase but by only 1.5°C on average, while inside the region it will increase by 1.75 – 2.5°C .

In southern Africa (Angola, Namibia, Mozambique, Zimbabwe, Zambia, Botswana and South Africa), results suggest an increase of the annual average temperature ranging between 1.5 and 2.5°C in the south to between 2.5 and 3°C in the north. The summer range is between 1.75 and 2.25°C in the south, and increases towards the north to between 2.75 and 3.0°C while the winter range is between 1.25 and 2°C in the south, and increases towards the north to between 2.5 and 2.75°C. On the other hand, the annual average will decrease by 10–15% in the south and by 5–10% in the north. The annual average decrease is 10%. However, some places will have an increase i.e. by 5–20% in South Africa in wintertime. In the Taklimakan region (Tarim Basin) west of China, the annual average temperature is shown to increase by 1.75–2.5°C. Annual average rainfall should increase by 5–25% in most of the region but decrease by 5–10% in some small parts. In summer, an increase by 5–15% is indicated in most of the region, and an increase by up to 25% or more during the wintertime.

In the Thar Desert (India–Pakistan–Afghanistan), estimations suggest that the annual average increase in temperature ranges from 1.75 to 2.5°C, ranging from 1.5 to 2.25°C in winter and from 2 to 2.5°C in summer. Annual average precipitation is shown to decrease by 5–25% in the region. The winter will have values closer to the annual average but the summer will have more decrease and most of the region will see a decrease closer to 25%.

In the Aral Sea basin (Kazakhstan, Turkmenistan and Uzbekistan), estimates suggest an annual average increase in temperature ranging from 1.75 to 2.25°C, higher in summer (between 2 and 2.75°C) than in winter (between 1.5 and 2°C). Rainfall should increase by 5–20% annually, in summer increasing by 5–10% in the north but decreasing by up to 5% in the south, while in wintertime, both south and north should undergo increases of 5–10% and 20–25%, respectively.

In Australia, results indicate an increase in the annual average temperature ranges of 1–1.5°C in the south to 2.5–2.75°C in the north, slightly higher during the summer than in the winter. The summer range is between 1 and 2°C in the south and increases towards the north to 2.5–3.0°C while the winter range is between 1 and 1.5°C in the south, and increases towards the north to between 2 and 2.25°C. Rainfall annual average is shown to decrease by 20–25% in the south and by 5–10% in the north.

Given the above-mentioned facts, in order to meet the water demands in the next century, some dams and water infrastructure will be built in some countries and a new paradigm by rethinking the water use with the aim of increasing the productive use of water will have to be adopted. Two approaches are needed: increasing the efficiency with which current needs are met and increasing the

efficiency with which water is allocated among different uses. In addition, non-conventional sources of water supply such as reclaimed, recycled water and desalinated brackish water or seawater is expected to play an important role.

Rajesh (2000). "Rajasthan: drought, debt and poverty." Economic and Political Weekly **35**(25): 2101-2104.

A discussion is presented of the lack of water conservation in Rajasthan, India, and the situation that this has led to. It is noted that dependence on tube wells has grown over the years, and groundwater levels have fallen. Relief is inadequate and corruption eats into even the little help that is available.

Randhir, T. O. and T. W. Hertel (2000). "Trade liberalization as a vehicle for adapting to global warming." Agricultural and Resource Economics Review **29**(2): 159-172.

This study assesses the potential interaction between climate change and agricultural trade policies. It distinguishes between two dimensions of agricultural trade policy: market insulation and subsidy levels. Building on the previous work of Tsigas, Frisvold and Kuhn (1997) it is found that, in the presence of current levels of agricultural subsidies, increased price transmission - as called for under the Uruguay Round Agreement on Agriculture - reduces global welfare in the wake of climate change. This is due to the positive correlation between productivity changes and current levels of agricultural support. Increases in subsidized output under climate change tend to exacerbate inefficiencies in the global agricultural economy in the absence of market insulation. However, once agricultural subsidies have also been eliminated, price transmission via the global trading system contributes positively to economic adaptation under climate change.

Rasid, H. and A. Mallik. (1995). "Flood adaptations in Bangladesh: Is the compartmentalization scheme compatible with indigenous adjustments of rice cropping to flood regimes?" Applied Geography **15**(1): 3-17.

Compatibility of the proposed compartmentalization scheme with indigenous adjustments of rice cropping to flood regimes in Bangladesh is assessed in the context of the floodplain farmers' preferences for regulated flood levels. A systematic sample survey among the residents of 23 villages in five major floodplains of Bangladesh—the upper and lower Brahmaputra, the Ganges, the Meghna and the Dhaleswari—provided data on indigenous practices of rice cropping and respondents' preferences for regulated flood levels. The results of the questionnaire survey indicated that, irrespective of significant spatial variations in preferences for specific ranges of flood levels, an overwhelming majority of

respondents preferred regulated levels that coincided with the overall range of the normal flood regimes, to which different varieties of monsoon season rice crops have been adjusted. Despite such coincidence of respondents' preference with the objective of compartmentalization to regulate flood levels, the scheme is considered incompatible with indigenous practices of rice cropping because of its operational constraints and problems with the construction and maintenance of flood control compartments and their potential environmental impacts.

Ravallion, M. and G. Datt (2002). "Why has economic growth been more pro-poor in some states of India than others?" *Journal of Development Economics* **68**(2): 381-400.

Authors use 20 household surveys for India's 15 major states spanning 1960-1994 to study how the sectoral composition of economic growth and initial conditions interact to influence how much growth reduced consumption poverty. The elasticities of measured poverty to farm yields and development spending did not differ significantly across states. But the elasticities of poverty to (urban and rural) non-farm output varied appreciably, and the differences were quantitatively important to the overall rate of poverty reduction. States with higher elasticities did not experience higher rates of non-farm growth. The non-farm growth process was more pro-poor in states with initially higher literacy, higher farm productivity, higher rural living standards (relative to urban areas), lower landlessness and lower infant mortality.

Ravindranath, N. H. and R. Sukumar (1998). "Climate change and tropical forests in India." *Climatic Change* **39**(2/3): 563-581.

India has 64 Mha under forests, of which 72% are tropical moist deciduous, dry deciduous, and wet evergreen forest. Projected changes in temperature, rainfall, and soil moisture are considered at regional level for India under two scenarios, the first involving greenhouse gas forcing, and the second, greenhouse gas forcing and sulfate aerosols. The projections use available predictive models. Under the former scenario a general increase in temperature and rainfall in all regions is indicated. This could potentially result in increased productivity, and change forest type boundaries along altitudinal and rainfall gradients, with species migrating from lower to higher altitudes and the drier forest types being transformed to moister types. The aerosol scenario, however, indicates a more modest increase in temperature and a decrease in precipitation in central and northern India, which would considerably stress the forests in these regions. Although India seems to have stabilized the area under forest since 1980, anthropogenic stresses such as livestock pressure, biomass demand for fuelwood and timber, and the fragmented nature of forests will all affect forest response to

changing climate. Thus, forest area is unlikely to expand even if climatically suitable, and will probably decrease in parts of northeast India due to extensive shifting cultivation and deforestation. A number of general adaptation measures to climate change are listed (forest protection and conservation, reforestation and biomass conservation).

Reilly, J., N. Hohmann, S. Kane, R. S. Chen. (1994). "Climate change and agricultural trade. Who benefits, who loses?" Global Environmental Change 4(1): 24-36.

To examine the central role of trade, the balance between the gains and losses of agricultural producers and consumers, and the implications for agricultural policy, a model of world food markets under conditions of simulated climate change and crop yields is developed. The scenarios show that the impacts differ significantly among the scenarios and among countries. The direct impact of climate change on yield, the global effect on commodity prices, and the export import status of a country are shown to determine the economic winners and losers. The trade effects and the high degree of uncertainty should be critical considerations in adaptation policies. Several modest changes that existing national and international institutions might make to better prepare the agricultural system to respond to uncertain climate change are reviewed. For the most part, these suggestions support existing efforts to redirect agricultural systems, notably, reduced barriers on international trade in agricultural commodities as have been pursued under the GATT, and farming system evaluation (as opposed to a narrow focus on yield) as necessitated by the need to evaluate sustainable agricultural systems. Populations that are vulnerable to hunger are likely to benefit from greater integration into food markets combined with improved education and skill development that can provide these people with the means to purchase food, should changing climate degrade their ability to produce food themselves.

Reilly, J. and D. Schimmelpfennig (2000). "Irreversibility, uncertainty, and learning: portraits of adaptation to long-term climate change." Climatic Change 45(1): 253-278.

The usefulness of adaptation strategies to changing climate depends on the characteristics of the system that must adapt. Divergent views on whether climate change will seriously affect society and what society can do about it can be traced, in part, to divergent views on these characteristics of systems. Issues of scale and how impacts are measured are also important. The paper identifies a set of fundamental characteristics of natural systems and social systems that help to make underlying assumptions in climate change adaptation studies explicit. These are: short-run autonomous flexibility; short-run non-autonomous flexibility;

knowledge and capacity to undertake short-run actions; long-run autonomous flexibility; long-run non-autonomous flexibility; and knowledge and capacity to plan for and undertake adaptations that require changes in long-lived assets. Applications to crop agriculture and ecosystems illustrate how these portraits can be used. It is found that if empirical research is to resolve questions of adaptability, more careful specification of the exact measure of impact and far richer models of the process of adaptation, able to test implicit assumptions in much of the existing empirical research, are needed.

Reilly, J. M. and D. Schimmelpfennig (1999). "Agricultural impact assessment, vulnerability, and the scope for adaptation." *Climatic Change* **43**(4): 745-788.

Climate change assessments which have considered climate impacts of a 2 x CO₂ climate, using models of the global agricultural system, have found small impacts on overall production, but larger regional changes. Production shifts among regions can be considered one mechanism for adaptation. Adaptation at the farm level, through changes in crops, cultivars, and production practices, is another adaptation mechanism. Existing studies differ in how important these mechanisms will be. Studies that have considered yield effects at specific sites have found very wide ranges of impacts. A useful way to evaluate the impacts of climate change, given the uncertainty about future impacts, is to consider vulnerability. Studies have defined vulnerability in terms of yield, farm profitability, regional economy, and hunger. Vulnerability and climate impacts, particularly in terms of higher order effects on profitability and sustainability, will depend on how society and the economy develop. Lower income populations and marginal agricultural regions, particularly arid or flood prone areas, are most vulnerable to climate change.

Richerson, P. F., R. Boyd, R. L. Bettinger, R. L. (2001). "Was agriculture impossible during the Pleistocene but mandatory during the Holocene? A climate change hypothesis." *American Antiquity* **66**: 387-412.

Several independent trajectories of subsistence intensification, often leading to agriculture, began during the Holocene. No plant-rich intensifications are known from the Pleistocene, even from the late Pleistocene when human populations were otherwise quite sophisticated. Recent data from ice and ocean-core climate proxies show that last glacial climates were extremely hostile to agriculture-dry, low in atmospheric CO₂, and extremely variable on quite short time scales. Authors hypothesize that agriculture, was impossible under last-glacial conditions. The quite abrupt final amelioration of the climate was followed immediately by the beginnings of plant-intensive resource-use strategies in some areas, although the turn to plants was much later elsewhere. Almost all trajectories

of subsistence intensification in the Holocene are progressive, and eventually agriculture became the dominant strategy in all but marginal environments. Authors hypothesize that, in the Holocene, agriculture was, in the long run, compulsory. They use a mathematical analysis to argue that the rate-limiting process for intensification trajectories must generally be the rate of innovation of subsistence technology or subsistence-related social organization. At the observed rates of innovation, population growth will always be rapid enough to sustain a high level of population pressure. Several processes appear to retard rates of cultural evolution below the maxima observed in the most favorable cases.

Riebsame, W. R. (1991). "Drought: opportunities for impact mitigation." Episodes **14**(1): 62-65.

It is difficult to mark the start and end of drought because the moisture deficit develops slowly over weeks, months, or years. Atmospheric scientists can neither forecast nor control drought. Drought mitigation must focus on reducing the underlying physical and social vulnerability. Short-term adjustments do not yield a lasting adaptation to drought. Some argue that repetitive food aid may worsen long-term food-production problems and land degradation by deferring more fundamental adjustments. Decisionmakers need better information and a broader range of adjustment options in order to reduce drought vulnerability. A linking of global warming/climate change studies with drought studies can yield insights into how societies might deal with climate change and help define the potential for future drought. These issues are discussed.

Rigsby, C. A., P. A. Baker, M. S. Aldenderfer. (2003). "Fluvial history of the Rio Ilave valley, Peru, and its relationship to climate and human history." Palaeogeography, Palaeoclimatology, Palaeoecology **194**(1-3): 165-185.

Fluvial strata and landforms in the Rio Ilave valley (Peru) document a history of Holocene aggradation and downcutting that is correlative with regional climatic events and provides an environmental context for human occupation of the river valley. Periods of aggradation correspond to periods of high (or rising) level in Lake Titicaca and elsewhere on the Altiplano, and increased sediment accumulation in the Rio Ilave valley. Downcutting episodes correspond to periods of low level in Lake Titicaca and low or rapidly decreasing sedimentation rates in the Ilave delta. There are five terrace tracts (T1 through T5) present in this southwestern Lake Titicaca tributary. These tracts occur as both paired and unpaired terraces and have average heights from 1.4 to 24.3 m above the valley floor. The major part of the fluvial sequence was deposited during the time period from prior to the Last Glacial Maximum until about 8300 calendar years Before Present (cal BP) – a period of generally high (but variable) precipitation on the

Altiplano and high water level in Lake Titicaca. Initial deposition (aggradation) was followed by successive downcutting to the T4 and T3 terrace surfaces. Initial downcutting began immediately after precipitation, runoff, and sediment load decreased while base level dropped. It was followed by a period of episodic equilibrium and minor downcutting that included a prolonged period of soil formation between ~8350 and 6780 cal BP. The major pulses of downcutting likely occurred between ~6000 and 4500 cal BP and were coincident with periods of decreased precipitation on the Altiplano and decreasing levels of Lake Titicaca. Two final periods of infilling, resulting in deposition of the T2 and T1 terrace sediments at ~4000 to 2500 cal BP and ~2000 to 1600 cal BP (during periods of rising water level in Lake Titicaca, lacustrine sedimentation in the Rio Desaguadero valley, and increased sedimentation offshore the Ilave delta), were separated by brief equilibrium stages and a brief downcutting event. This fluvial history, when coupled with regional paleoclimatic data, relates to the region's preceramic through Tiwanaku-period archeological records. Archeological evidence indicates that humans occupied the Ilave valley as early as 10000 cal BP. The higher terraces (T3, T4 and T5) were occupied for at least 5000 years, but humans did not utilize the lower terraces (T1 and T2) until after ~4400–3700 cal BP. Our results confirm that these lower terraces would not have been available for either occupation or agriculture until after ~4000 cal BP.

Ringrose, S., A. Chipanshi, W. Matheson, R. Chanda, L. Motoma, I. Magole, A. Jellema. (2002). "Climate- and human-induced woody vegetation changes in Botswana and their implications for human adaptation." Environmental Management **30**(1): 98-109.

For purposes of suggesting adaptive and policy options regarding the sustained use of forestry resources in Botswana, an analysis of the whole countrywide satellite data (showing the mean present distribution of vegetation in terms of species abundance and over all density) and the projection of vegetation cover changes using a simulation approach under different climatic scenarios were undertaken. The analysis revealed that changes in vegetation cover types due to human and natural causes have taken place since the first vegetation map was produced in 1971. In the southwest, the changes appear to be more towards an increasing prevalence of thorn trees; in the eastern part of the country where widespread bush encroachment is taking place, the higher population density suggests more human induced (agrarian-degradation) effects, while in the sparsely settled central Kalahari region, changes from tree savanna to shrubs may be indicative of the possible influence of climate with the associated effects of fires and local adaptations. Projection of future vegetation changes to about 2050 indicates degeneration of the major vegetation types due to the expected drying. Based on the projected changes in vegetation, current adaptive and policy

arrangements are not adequate and as such a shift from the traditional adaptive approaches to community-based types is suggested. Defining forestry management units and adopting different management plans for the main vegetation stands that are found in Botswana are the major policy options.

Robbins, P. (1998). "Nomadization in Rajasthan, India: migration, institutions, and economy." Human Ecology **26**(1): 87-112.

Amidst a global trend toward settlement, the incidence of pastoral nomadism is increasing in the Marwar region of western Rajasthan, India, with a regional livestock population increasingly on the move, sometimes turning to year-round nomadism in order to meet the demands of seasonal pasturage. The notion that common property grazing resources have disappeared amid unprecedented growth of the regional herd cannot explain the observed trends. Rather, changing institutional and economic patterns are creating new contexts for strategic movement. The transition into migratory strategies has developed from the decline of key village social institutions which manage pasture and forest land, the profits earned from intensification in an increasingly capitalized market, and the benefits of migration in the form of the herd's increased reproductive capacity. Producers in this population increase their access to markets and the reproductive rate of their herd through long, annual migration. Nomadism in this setting is therefore a general adaptation to changes in the socioeconomic conditions of the region, although differential resource endowments account for the range of strategies.

Robledo, C., M. Fischler, A. Patiño. (2004). "Increasing the resilience of hillside communities in Bolivia: has vulnerability to climate change been reduced as a result of previous sustainable development cooperation?" Mountain Research and Development **24**(1): 14-18.

Climate change scenarios predict impacts in Bolivia that include longer dry seasons and more frequent storms. Can the local population cope with these changes? How resilient are the social systems and local ecosystems? A case study prepared by Intercooperation (IC) for 'Vulnerable Communities and Adaptation,' an IC/IISD/IUCN/SEI project on climate change, investigated how Swiss development cooperation has helped reduce vulnerability to climate change in a community in the Altiplano of Bolivia. Regardless of considerations of climate change during planning and implementation of the project, one collateral benefit has been improvement in the resilience profile of the Khuluyo community.

Roncoli, C., K. Ingram, P. Kirshen. (2001). "The costs and risks of coping with drought: livelihood impacts and farmers' responses in Burkina Faso." Climate Research **19**(2): 119-132.

This paper analyzes the responses enacted by families of the Central Plateau in Burkina Faso during the year that followed a severe drought in 1997. Authors illustrate the agro-ecological and socio-economic contexts that shape livelihood options and constraints in an area characterized by high levels of climatic risk and low natural resource endowment. A description of farmers' perceptions and official accounts identifies key criteria whereby farmers formulate evaluations and predictions of a season. Authors document how food procurement and management practices are shaped by household resource access profiles and livelihood portfolios. Livelihood diversification, encompassing migration, non-farm work and social support networks, in addition to livestock production, is shown to be a critical dimension of adaptation. Livelihood and production adjustments result in risks for most, but also gains for those who have the resources needed to take advantage of distress sales and high prices of agricultural commodities. Household livelihood and risk management increasingly hinge on efforts by household members who traditionally have had marginal access to resources, especially women. The research points to the need for closer integration of drought preparedness efforts, farmers' understanding of climate-crop interactions and interventions that bolster the capacity of resource-limited households to respond. Affordable grain, locally adapted seed varieties, labour saving technology and flexible credit are among the most needed inputs.

Rounsevell, M. D. A., S. P. Evans, P. Bullock. (1999). "Climate change and agricultural soils: impacts and adaptation." *Climatic Change* **43**(4): 683-709.

The response of soils to climate change, and the implications such changes have for agriculture, are reviewed. The review highlights the importance of understanding the dynamics of soil processes when addressing climate change impacts on agriculture. Rapid soil responses to climate change (e.g. soil water, organic carbon and erodibility) have been widely investigated and reported in the literature. However, it is important that longer-term processes (e.g. pedogenesis) are not ignored by the research community because these have potentially important implications for long-term agricultural land use and are often irreversible. The use of good land management practices, as currently understood, provides the best strategy for adaptation to the impact of climate change on soils. However, it appears likely that farmers will need to carefully reconsider their management options, and land use change is likely to result from different crop selections that are more appropriate to the changing conditions. Perhaps the greatest impact of climate change on soils will arise from climate-induced changes in land use and management.

Roy, M. and H. D. Venema (2002). "Reducing risk and vulnerability to climate change in India: the capabilities approach." Gender and Development **10**(2): 78-83.

This paper argues that the ability of women to adapt to climate change pressures will be enhanced by using the 'capabilities approach' to direct development efforts. By using this approach, women will improve their wellbeing, and act more readily as agents of change within their communities. This argument is supported by previous research on gender and livelihoods, and a study conducted in rural India. Examples are based on the experiences of poor, rural women in India, who are particularly vulnerable to climate change impacts. Their survival is dependent on their being able to obtain many essential resources from their immediate environment. However, these women lack many of the requirements for wellbeing, such as access to health care, literacy, and control over their own lives. Gaining these would reduce their vulnerability to their changing environmental circumstances.

Ryan, W. and W. Pitman. (1998). Noah's Flood: The New Scientific Discoveries about the Event that Changed History. New York: Simon and Schuster, pp. 319.

Saint, K. (1988). "Drought in the Aravallis." Social Action (New Delhi) **38**(2): 129-137.

The visible effects of drought in the Aravallis mountains, Rajasthan, are not different from the way Colonel Brooke had described them a century ago. However the coping mechanisms of the tribals have been weakened by deforestation and the destruction of their life support system. A long-term solution has to be worked out, not a short-term relief plan, which can be used as a mode of building up community assets to strengthen the weaker sections. In other words, what is needed is not drought relief but drought proofing.

Salinger, M. J., C. J. Stigter, H. P. Das. (2000). "Agrometeorological adaptation strategies to increasing climate variability and climate change." Agricultural and Forest Meteorology **103**(1/2): 167-184.

The indications for climate change in the most recent WMO global climate system reviews are summarized. There are indications for increasing climate variability in certain areas. Some of the principal causes of increasing climate variability and climate change (ICV & CC) are a mixture of external and internal factors to the climate system. Of changes over the past century, increases in greenhouse gases have probably been the most important cause of climate change. Continued warming of global climate is expected to occur if atmospheric greenhouse gases keep increasing, with global climate models projecting an

increase in mean temperature by 1-3 deg C by 2100 A.D. Upon these general background trends interannual climate variability has operated. Volcanic eruptions that inject significant amounts of sulphate aerosols into the stratosphere cause a cooling of global climate in the order of 0.5 deg C for a period of 12-24 months. The ENSO (El Niño/Southern Oscillation) is the major cause of climate variability on seasonal to interannual time scales. Since 1976 El Niño episodes of the Southern Oscillation have increased in frequency, and become more extreme. There has yet been little analysis of short-term extreme events, such as high intensity rainfall, tropical storms, tornadoes, high winds, extreme temperatures and droughts to show if the frequency and intensity of these have changed. However, for some of these events in some areas an increase is occurring while in other areas no changes have currently occurred. Changes in extremes cause significant impacts on agriculture. Strategies to fight slower variations have already been widely proposed and require application. Agrometeorologists can assist the agricultural community in developing strategies to adapt to ICV & CC that should be validated on-farm for improved extension advisories, together with farmers. To enhance adaptation and promote sustainable development, strategic planning studies for assessment of natural resources, technological change and innovation are required to increase productivity, with sustainable economic growth that preserves finite natural resources. The ten most essential agricultural umbrella projects with agrometeorological priority components in the literature that either modify the consequences of ICV & CC and/or mitigate their causes have been selected. The Commission for Agricultural Meteorology has pledged to guide the implementation of projects that assist adaptation strategies to ICV & CC within the WMO Agrometeorological Programme.

Samuel, T. J. (1984). "Economic adaptation of refugees in Canada: experience of a quarter century." International Migration **22**(1): 45-55.

This paper examines the economic adaptation, in terms of employment and income, for 400,000 refugees, mainly displaced persons, Hungarians, Czechoslovaks, Ugandan Asians, Chileans, and Indochinese, in Canada during the last 25 years. The author looks at 1) ease in obtaining a first job, 2) unemployment, 3) wives' employment, 4) job search techniques, and 5) occupation. Economic climate largely determines the time needed to find a first job. 55% of Hungarian refugees in 1957-58 found a job within a month; only 30% of Czechoslovak refugees in 1968-69 found a job within a month. Refugees and regular immigrants have higher unemployment than native Canadians; but the rate drops dramatically within a few years. Employment and unemployment for refugees is influenced by 1) prevailing labor market conditions, 2) English and/or French language proficiency, 3) sympathy by the population for the refugees, 4) support by people of the same ethnic group, and 5) the refugees' own adaptability. Survey results

show that more refugee wives are employed than Canadian born wives; over 69% of Chilean refugee women worked in 1975-76. Most refugees use the Canada Employment Center, and informal channels such as "word of mouth" and friends and relatives to find jobs. Lack of qualifications and experience, and lack of language proficiency hinder many refugees in finding jobs for which they have trained. Income is an indicator of the success of refugee economic adaptation. Refugees, like regular immigrants, have lower than average income levels in their first years in Canada; however, they often earn more than the Canadian born after the difficult first years. Family incomes, because of female labor force participation, may widen the differences even more. Although many refugees are not working in their intended professions, most refugee groups have adjusted well economically in Canada.

Sanchez, P. A. (2000). "Linking climate change research with food security and poverty reduction in the tropics." *Agriculture, Ecosystems & Environment* **82**(1/3): 371-383.

A Consultative Group on International Agricultural Research (CGIAR) intercentre working group on climate change identified joint opportunities that take advantage of the comparative advantages of the CGIAR and the International Geosphere-Biosphere Programme. CGIAR centres will focus on adaptation and mitigation research in Developing Countries. A natural resource management approach is suggested, which consists of six steps: (1) identifying and quantifying the extent of food insecurity, rural poverty and resource degradation; (2) conducting technological and policy research; (3) optimizing the trade-offs between global environmental benefits and private farmer benefits; (4) extrapolating and disseminating results, including research on policy implementation; (5) assessing impact and (6) providing feedback. Two examples of current CGIAR research illustrate this approach. Agroforestry alternatives to slash and burn agriculture at tropical forest margins were identified and the trade-offs between carbon sequestration and farmer profitability provided options to policy makers. Land tenure problems were resolved with participatory policy research. Agroforestry practices sequester an additional 57 Mg C per ha. Soil nutrient capital is being replenished in subhumid tropical Africa, helping farmers to attain food security. Afterwards when farmers shift to high-value tree or vegetable crop production, poverty is reduced. The transformation of low productivity croplands to sequential agroforestry is estimated to triple system carbon stocks in 20 years.

Sandweiss, D. H., K. A. Maasch, D. G. Anderson. (1999). "Climate and culture: Transitions in the Mid-Holocene." *Science* **283**: 499-500.

Between about 8000 and 3000 years ago, climate worldwide underwent substantial changes. At the same time, human cultures experienced a period of substantial progress toward more complex societies, as exemplified by the first temple mounds in South America, the Egyptian pyramids, and the rise and fall of civilizations in East Asia. Archeologists and paleoclimatologists alike are now investigating possible causal connections between these simultaneous developments and are finding a complex pattern of cultural responses to climatic change.

Sandweiss, D. H., H. McInnis, R. L. Burger, A. Cano, B. Ojeda, R. Paredes, M. de C. Sandweiss, M. D. Glascock. (1998). "Quebrada Jaguay: Early south American maritime adaptations. *Science* **281**: 1830-1832.

Excavations at Quebrada Jaguay 280 (QJ-280) (16°30'S) in south coastal Peru demonstrated that Paleoindian-age people of the Terminal Pleistocene (about 11,100 to 10,000 carbon-14 years before the present or about 13,000 to 11,000 calibrated years before the present) in South America relied on marine resources while resident on the coast, which extends the South American record of maritime exploitation by a millennium. This site supports recent evidence that Paleoindian-age people had diverse subsistence systems. The presence of obsidian at QJ-280 shows that the inhabitants had contact with the adjacent Andean highlands during the Terminal Pleistocene. The absence of any other Terminal Pleistocene sites in the region, the location of QJ-280 on the banks of a quebrada offering an easy travel route to the highlands, the seasonal nature of local waterflow, and the presence of highland obsidian in the Terminal Pleistocene component all support this hypothesis. By the early Holocene, coastal occupation may have become year-round, as suggested by the near absence of obsidian, the more substantial structures, and the explosion of local sites dating to this time. Thus, building on the achievements of their Terminal Pleistocene predecessors, the Early Holocene inhabitants of southern Peru seem to have developed a fully maritime adaptation.

Sandweiss, D. H., K. A. Maasch, R. L. Burger, J. B. Richardson III, H. B. Rollins, A. Clement. (2001). "Variation in Holocene El Niño frequencies: Climate records and cultural consequences in ancient Peru." *Geology* **29**(7): 603–606.

Analysis of mollusks from archaeological sites on the north and central coasts of Peru indicates that between ca. 5800 and 3200–2800 cal yr B.P., El Niño events were less frequent than today, with modern, rapid recurrence intervals achieved only after that time. For several millennia prior to 5.8 ka, El Niño events had been absent or very different from today. The phenomena called El Niño have had severe consequences for the modern and colonial (historically recorded)

inhabitants of Peru, and El Niño events also influenced prehistoric cultural development: the onset of El Niño events at 5.8 ka correlates temporally with the beginning of monumental temple construction on the Peruvian coast, and the increase in El Niño frequency after 3.2–2.8 ka correlates with the abandonment of monumental temples in the same region. People who lived on the coast of northern Peru began building large temple complexes about 5,800 years ago even before the pyramids in Egypt. The Peruvians continued building the complexes for nearly 3,000 years. Around 2800 B.C., the sites were abandoned.

Sarkar, A., R. Ramesh, B. L. K. Somayajulu, R. Agnihotri, A. J. T. Jull, and G. S. Burr. (2000). "High resolution Holocene monsoon record from the eastern Arabian Sea." *Earth and Planetary Science Letters* **177**(3-4): 209-218.

Through stable oxygen and carbon analyses of rapidly accumulating sediment cores from the eastern Arabian Sea, authors show that the excess of evaporation over precipitation (E-P) steadily appears to have decreased during the last ~10000 to ~2000 years, most probably due to an increasing trend in the summer monsoon rainfall, contrary to the land-based paleoclimatic data from this region, which indicate onset of aridity around 4000 years ago. These results are consistent with the hypothesis that significant spatial variability in the monsoon rainfall observed today was persistent during most of the Holocene. Alternatively, the trend can be seen as an adjustment between two phases, one between ~10000 and ~6000 years ago of increasing precipitation and another between 3500 and 2000 years ago after the arid episode. Authors also report a significant ~700 year periodicity, similar to that reported recently from the South China Sea, indicating that the centennial/millennial scale response of the Indian and Chinese monsoons to high latitude forcing may be alike.

Savory, A. (1991). "Holistic resource management: a conceptual framework for ecologically sound economic modeling." *Ecological Economics*, **3**(3): 181-191.

Economic modelling that enables us to make better decisions and plans is complex because of the multi-dimensional relationships involved. Underlying the need for workable models lies the foundation of how people make decisions in managing their resources. There is an underlying subconscious model which has been used by mankind for thousands of years and which has become the mainstream scientific management model. This is illustrated with the reasons why this model cannot reverse desertification. Desertification has led to the downfall of some 26 civilizations, no matter how they measured their wealth or managed their money. A new holistic model under development is described. This model is proving successful in that desertification is being reversed even in drought years and people are experiencing more prosperity through improved decision-making.

This model is enabling us to analyse major resource management policies simply and with a high degree of confidence. Both at a farm level and at a national level authors are able to detect major economic mistakes which were undetectable with the mainstream scientific model subconsciously used by economists. This holistic model is seen as a possible foundation on which to build successful economic models. Others are invited to become involved in its expanded development.

Scheraga, J. D. and A. E. Grambsch (1998) "Risks, opportunities, and adaptation to climate Change". Climate Research 10: 85–95.

Adaptation is an important approach for protecting human health, ecosystems, and economic systems from the risks posed by climate variability and change, and for exploiting beneficial opportunities provided by a changing climate. This paper presents 9 fundamental principles that should be considered when designing adaptation policy, for example, a sound understanding of the potential regional effects of climate on human and ecological systems is required to target appropriate investment in adaptive responses. The distribution of potential impacts across different populations and the mechanisms by which these impacts occur are also key to effective adaptation measures. Options for coping with climatic changes must be considered in the context of multiple stressors. Further, adaptation is likely to exhibit varying levels of effectiveness as demonstrated by current efforts to deal with climate variability. Potential adverse side effects of adaptive strategies must also be accounted for to avoid solutions that are worse than the problem. These issues and others are presented in this paper, with examples from various impacts studies to illustrate key points. The nine principles are: (1) The effects of climate change vary by region. (2) The effects of climate change may vary across demographic groups. (3) Climate change poses risks and opportunities. (4) The effects of climate change must be considered in the context of multiple stressors and factors, which may be as important to the design of adaptive responses as the sensitivity to change. (5) Adaptation comes at a cost. (6) Adaptive responses vary in effectiveness, as demonstrated by current efforts to cope with climate variability. (7) The systemic nature of climate impacts complicates the development of adaptation policy. (8) Maladaptation can result in negative effects that are as serious as the climate-induced effects being avoided. (9) Many opportunities for adaptation make sense whether or not the effects of climate change are realized.

Schuldenrein, J., R. P. Wright, M. R. Mughal, M. A. Khan. (2004). "Landscapes, soils, and mound histories of the Upper Indus Valley, Pakistan: new insights on the Holocene environments near ancient Harappa." Journal of Archaeological Science 31(6): 777-797.

The site of Harappa in central Pakistan has been the primary source of information on Indus Valley cultural and natural landscapes in the Upper Indus Basin. While the site has been excavated for over 100 years, little was known of the pre-occupation history and environments responsible for the culture's emergence in the third millennium BC. Recent geoarcheological investigations of sites sharing the same landform as Harappa-the Bari Doab-along the ancient Beas River have synthesized sediment, soil, and cultural stratigraphics that place Harappa in the context of a regional landscape history. Two key sites-Lahoma Lal Tibba and Chak Purbane Syal-illustrate that larger floodplains of the Indus system stabilized sometime in the early Holocene, when soil development exceeded rates of alluviation. The site of Harappa was revisited to procure radiocarbon dates beneath initial occupation horizons. The stratigraphy and dates established the Pleistocene/Holocene interface and confirmed coeval trends of diminished Early Holocene floodplain accretion and sustained soil formation. Pedogenesis continued at least to the beginning of the fifth millennium BP when occupation began to intensify along the Beas and elsewhere in the Upper Indus. Site formation sequences at Lahoma Lal Tibba and Chak Purbane Syal mirror those of Harappa proper, albeit on a smaller scale.

Schimmelmann, A, C. B. Lange, B. J. Meggers. (2003) Palaeoclimatic and archaeological evidence for a similar to 200-yr recurrence of floods and droughts linking California, Mesoamerica and South America over the past 2000 years. The Holocene **13**(5): 763-778.

Conspicuous grey, clay-rich flood deposits in the predominantly olive, varved sediment in the central Santa Barbara Basin, California, were dated via varve-counting to c. AD 212, 440, 603, 1029, 1418 and 1605. The similar to 200-yr quasi-periodicity and the timing of individual floods match time periods of known supraregional climatic changes and the documented similar to 200-yr periodicity in palaeoclimate records elsewhere. The floods of c. ad 440 and ad 1418 occurred during global reorganizations of atmospheric circulation. Cold spells seem to have accompanied the floods of c. AD 1029 and ad 1605. California floods and other palaeoclimate records suggest that expressions of regional climates are modulated by solar variability with a similar to 200-yr periodicity. Our compilation of palaeoclimatic and Mesoamerican and South American archaeological records provides evidence that palaeoenvironmental and cultural changes were often coincident within their respective dating uncertainties and occurred in similar to 200-yr steps. The matching pattern supports the hypothesis that manifestations of changing climates, such as drought or flooding, served as destabilizing cofactors in transitions of precolumbian cultures. Extrapolation of the similar to 200-yr recurrence pattern of Santa Barbara flooding suggests that catastrophic flooding in southern California may be expected for the early part of this century.

Sharma, S. (1995). "Drought, mortality and social structure." Environmental Education and Information **14**(1): 85-94.

The social aspects of drought-induced morbidity and mortality in India are analyzed in this study. Mortality trends in Rajasthan State in India in the 1980s were analysed to correlate the increased death rate with the drought of 1987. It is demonstrated that drought-induced malnutrition is the root cause of death. Sociologically, populations are divided into three sections--fragile, resilient and potent--which are differently affected by droughts, the fragile section suffering worst.

Sharma, S., M. Joachimski, M. Sharma, H. J. Tobschall, I. B. Singh, C. Sharma, M. S. Chauhan, G. Morgenroth. (2004). "Lategracial and Holocene environmental changes in Ganga plain Northern India." Quaternary Science Review **23**(1-2): 145-159.

Stable isotope, elemental geochemistry and pollen analysis of a sediment profile from Sanai lake, Central Ganga Plain, were used to document climatic oscillations during the last similar to 15,000 yr in Indian subcontinent. Micaceous sandy sediments at the base of the profile indicate an active channel and humid conditions before similar to 15,000 C-14 yr BP. The channel was abandoned during comparatively and conditions (15,000-13,000 C-14 yr BP) and converted into a swamp. Enhanced humidity around 13,000 C-14 yr BP led to submergence of marshes and establishment of a large lake. A dry phase is also identified around an estimated age of 11,500-10,500 C-14 yr BP which might correspond to the Younger Dryas event witnessed globally. The Early to Mid-Holocene climatic optimum (similar to 10,000-5800 C-14 yr BP) is characterised by a lake environment. Occurrence of warmth loving aquatic plants, lower $\delta^{18}O$ values of gastropod aragonite, heavier $\delta^{13}C$ (org) values indicate a sensitive response of the lake ecology to the climatic warming and increased rainfall. This is followed by an event during 5000-2000 C-14 yr BP and from similar to 1700 C-14 yr BP there is evidence of climatic amelioration. The sequence and magnitude of the millenium-scale climatic oscillations documented along the lake profile correlate well with records from other parts of the Indian subcontinent indicating that the recorded changes are an expression of broad scale, probably global and climatic change.

Shimada, I., C. B. Schaaf, L. G. Thompson, E. Mosley-Thompson. (1991). "Cultural impacts of severe droughts in the prehistoric Andes: application of a 1,500-year ice core precipitation record." World Archaeology **22**(3):248-70.

The Peruvian coast is currently very arid and is reliant on irrigation to support agriculture. However, the Mochica (Moche IV) established urban centres

and controlled the entire northern Peruvian coastline south of the Sechura desert from about 300 A.D. This community is known for its metallurgy and large adobe structures, such as the Huaca del Sol. These cities and surrounds were abandoned abruptly about 600 A.D. with irrigation channels becoming overrun by sand dunes. Between 600 and 750 AD, the culture was re-established (Moche V) further inland where highland rivers drain onto the Andean foothills. This example shows a shift in both the ecological system (agricultural productivity) and the social system (human occupation). A number of serious environmental disturbances occurred in the area around the time of abandonment (Shimada et al. 1991). Firstly, a flood extensively damaged the base of the Huaca del Sol and stripped away several metres of soil from the surrounding area. This flood destroyed the capital city, swept away fields and irrigation systems and resulted in widespread famine (Weiss and Bradley, 2001). Shortly after this, a 30-year period of drought (563 to 594 A.D.) forced abandonment of the region. The landscape became more arid, evidenced by levels of dust in ice-cores (deMenocal, 2001). The population migration took place to inland valleys that provided easy access to water where irrigation channels could be re-established (Shimada et al. 1991).

Sidle, R. C., D. Taylor, X. X. Lu, W. N. Adger, D. J. Lowe, W. P. de Lange, R. M. Newnham, J. R. Dodson. (2004) Interactions of natural hazards and society in Austral-Asia: evidence in past and recent records. *Quaternary International* **118-19**: 181-203.

Interactions of some of the principal historical natural hazards with human populations in the Austral-Asian region are discussed both from the perspective of the impact of the hazard on humans as well as the effects of human activities and climate change on hazard magnitude and frequency. Basically, the former type of interaction is evident for most hazards, while the latter interaction is primarily confined to terrestrial and coastal flooding, erosion, landslides, sea level rise, drought, and fire. Social Vulnerability to natural hazards is related to the resources available to cope with the hazard, level of economic development, the ability to predict the occurrence of a hazard and to adjust and adapt to conditions posed by the hazard, and planning measures embraced by societies. Historical chronologies are presented for a range of hazards. Problems in reconstructing historical records of natural hazards include: interpretations of oral records; lack of supporting artifacts; obliteration of evidence of chronic hazards by higher magnitude events; and the inability to distinguish between the effects of different hazards in sediment records. Nevertheless, useful examples illustrate the effects and awareness of volcanic activity and associated hazards, Such as tsunamis, by early Maori and subsequent development of avoidance strategies; the effects of widespread land use changes and increases in population on the occurrence of

floods, landslides and gullies in China and New Zealand; and the effects of forest conversion and drought on fire hazards in Indonesia.

Singh, R. S., K. D. Sharma, Faroda, A. S. (1999). "Climate change and its impact on drought and floods in Luni river basin of north-west arid India." Journal of Agrometeorology **1**(2): 99-111.

To quantify possible climatic changes in the Luni Basin, long-term fluctuations and trends in rainfall within and in the adjoining areas were analysed for the period 1901-96 using weather data obtained from 12 stations including monthly and annual air temperatures of Jodhpur and Pali, Rajasthan, India. A significant rising trend in annual mean air temperature of 0.015 deg C year⁻¹ in Jodhpur and 0.008 deg C year⁻¹ in Pali was observed. Increasing (warming) trends were observed in the minimum air temperatures in Jodhpur during May, June and August. The annual precipitation ranged from 300 (in the northwest) to 600 mm (in the southeast) of the basin, more than 85% of which occurred from June to September. An increasing linear trend for the rainfall at 8 locations (with the highest (1.6 mm year⁻¹) in Ajmer) was observed during the study period. The impact of these climatic changes on the intensity and frequency of droughts and floods is discussed.

Singh, A. K., J. Sing, K. K. Reddy, R. Singh. (2003). "Drought proofing mechanism in Mahi command area through linear programming model - a case study." Indian Journal of Agricultural Research **37**(3): 187-192.

A linear programming model was developed to formulate an optimal cropping pattern during drought years in the command area of the Mahi Bajaj Sagar irrigation project in Banswara district, Rajasthan, India. The study revealed that by judiciously using a minimum quantity (58.7% of normal usage) of irrigation water during drought years, feeding 58% of the cropping area with minimum investment (less by 40.9%), it would be possible to achieve food security. At the same time, cooperative societies and local credit institutions should be strengthened for better results.

Singh, H. S. (2003). "Vulnerability and adaptability of tidal forests in response to climate change in India." Indian Forester **129**(6): 749-756.

The climate change indicators reveal that the Earth's climate has demonstrably changed and may further change at higher rate in the 21st century. As a result, ecological productivity and biodiversity will be altered and marine ecosystems, especially mangroves will be disrupted significantly. Large area of mangroves (4871 km²) in India is expected to go under major transformation, depending on the rate of climate change and anthropogenic activities. The

responses of mangroves to sea level rise have been assessed and projected that the diversity in mangrove communities may improve at higher latitudes in some areas under low to medium level of sea level rise. The latitudinal range extension may occur at the expense of salt marsh communities; adaptation and survival chance of mangroves in deltaic region like Sundarbans will be higher than other areas; adaptation of mangroves on islands like Andaman and Nicobar will be low in response to moderate to high rate of sea level rise. It is expected that change in climatic condition may lead to an increase in species migration pole wards. It is likely that some species in tropical region, especially on Andaman and Nicobar Islands may not be successful to compete and may lose in favour of other species. Extensive hyper saline mudflats between mangroves and coast in subtropical regions like the Gulf of Kachchh will work as barrier against sea level rise and will provide opportunity to adaptation of mangroves with landward movement, depending on rate of sea level rise and precipitation. Strict protection; preparation of action plan for each mangrove area in this context; enhance level of regeneration in potential inter-tidal zone; plantation of species which fail to adapt to sea level rise; providing adequate space for backward movement of mangroves and reintroducing suitable threatened species in mangrove areas in higher latitude can be some management options to improve the adaptability. Major parts of the mangroves are in Marine Protected Areas where protection measures and scientific intervention in response to expected climate change will certainly contribute to the conservation of vulnerable areas and threatened species of the tidal forests.

Sinha, A. and D. F. Ruggles. (2004). "The Yamuna riverfront, India: A comparative study of Islamic and Hindu traditions in cultural landscapes. Landscape Journal 23(2): 141-152.

Cultural traditions encompass specific modes of visibility. Islamic and Hindu ways of seeing are described in terms of their inscription upon the cultural landscape of India. The historic Yamuna riverfront at Agra, one-time capital of the Mughal empire, is compared with the riverfront at Braj, sacred to the Hindus for its association with the god Krishna. The land-water interface at Braj is marked by steps that allow access to the river for bathing, shrines and temples for worship, and a porous architecture that facilitates vision and movement in the public realm. In contrast, at historic Agra, the interface was marked by walls enclosing royal gardens, palaces, and tombs, creating private enclaves and permitting the common residents only interstitial access to the river, if any at all. Pavilions on riverfront terraces with gardens below framed views of the landscape, implying a separation between the viewer and the designated object. Although the river was the prime object of vision in both traditions, the Islamic mode of visibility was phenomenal presentation while the Hindu mode is iconic

representation. [This article can also be interpreted as the evolution of tradition which is although influenced by culture but has the similar motive and similar outcome via different adaptive strategies].

Sinha, R., D. Stueben, Z. Berner. (2004). "Palaeohydrology of the Sambhar Playa, Thar Desert, India, using geomorphological and sedimentological evidences." Journal of the Geological Society of India **64**(4): 419-430.

The Sambhar Playa in western Rajasthan, India has been studied to understand its tectono-geomorphologic evolution and palaeohydrological reconstruction. The playa basin originated due to tectonic movements during the Quaternary, and was deepened by large scale deflation during and periods. A dense network of relict drainage reflects abundant supply of water and sediments during wetter phases. A deep core (similar to 23 m) raised from the center of the playa indicates an alternation of clastic and evaporitic sediments. Mineralogical assemblages and the geochemical characteristics have been used to decipher the palaeohydrological conditions in the region for a period extending over 25 ka. Evaporite mineralogy shows a major change in brine chemistry at similar to 5 m depth, the lower part being rich in gypsum and the upper part completely devoid in gypsum. The vertical profile shows a correlation between Na/Al ratio, $\delta(18)O$ values of carbonates, $MgO/(MgO+CaO)$ ratio of insoluble fraction and dolomite content. Authors interpret these trends as changes in evaporation/inflow ratio which in turn would reflect low/high stands of the lake.

Sivakumar, S. and E. Kerbart (2004). "Drought, sustenance and livelihoods: 'akal' survey in Rajasthan." Economic and Political Weekly **39**(3): 285-294.

This article presents findings from a survey conducted in Rajasthan, India in March-April 2003, when the 'maha akal', the drought, was at its peak over large parts of rural Rajasthan and the government-initiated relief works were yet to make an impact. Covering 122 hamlets in 56 panchayats across nine districts, the report examines the manifestations of drought in people's everyday lives, specifically the ways food and water shortages impact men, women and children. It also examines the long-run impact of drought on people's assets (particularly livestock) and livelihoods and the coping strategies they adopt. It is concluded that drought may be a one-time occurrence but the effects are far-reaching and deep. In Rajasthan, it has reached a point where livelihood means are becoming persistently elusive. It is also apparent that relief programmes can at best bring some 'patchwork' respite, posing as a temporary cure.

Sloan, A. W. (1975). "Adaptation and failure of adaptation to extreme natural environments." Forensic Science **5**(1): 81-89.

Although the environmental stresses to which man is subjected on the ground are less than those commonly encountered in aviation or under water, they may still exceed an individual's powers of adaptation. Extremes of temperature, commonly encountered in the Arctic or the tropics, may occur in regions of normally temperate climate and lead to failure of temperature regulation, resulting in hypothermia, frostbite, heat exhaustion, or heat stroke. High mountains impose additional hazards due to high winds and lack of oxygen, and deep mines are dangerous work-places because of high temperature and humidity. Some physiological acclimatization occurs in extreme natural environments and the dangers may be reduced by appropriate clothing, diet and behaviour.

Smit, B., I. Burton, R.J.T. Klein, R. Street (1999) The science of adaptation: A framework for assessment." Mitigation and Adaptation Strategies for Global Change 4(3-4): 325-352.

This paper outlines what is meant by "adaptation" to climate change, and how it might be addressed in the IPCC Assessments. Two roles of adaptation in the climate change field are identified: adaptation as part of impact assessment (where the key question is: what adaptations are likely?), and adaptation as part of the policy response (where the central question is: what adaptations are recommended?). The concept of adaptation has been adopted in several fields including climate impact assessment and policy development, risk management, and natural hazards research. A framework for systematically defining adaptations is based on three questions: (i) adaptation to what? (ii) who or what adapts? and (iii) how does adaptation occur? The paper demonstrates that, for adaptation purposes, climate extremes and variability are integral parts of climate change, along with shifts in mean conditions. Attributes for differentiating adaptations include purposefulness, timing, temporal and spatial scope, effects, form and performance. The framework provides a guide for the treatment of adaptation in the IPCC assessments, both in the assessment of impacts and in the evaluation of adaptive policy options.

Smit, B. and M. W. Skinner (2002). "Adaptation options in agriculture to climate change: a typology." Mitigation and Adaptation Strategies for Global Change 7(1): 85-114.

Adaptation in agriculture to climate change is important for impact and vulnerability assessment and for the development of climate change policy. A wide variety of adaptation options has been proposed as having the potential to reduce vulnerability of agricultural systems to risks related to climate change, often in an *ad hoc* fashion. This paper develops a typology of adaptation to systematically classify and characterize agricultural adaptation options to climate change, drawing

primarily on the Canadian situation. In particular, it differentiates adaptation options in agriculture according to the involvement of different agents (producers, industries, governments); the intent, timing and duration of employment of the adaptation; the form and type of the adaptive measure; and the relationship to processes already in place to cope with risks associated with climate stresses. A synthesis of research on adaptation options in Canadian agriculture identifies four main categories: (i) technological developments, (ii) government programs and insurance, (iii) farm production practices, and (iv) farm financial management. In addition to these 'direct adaptations', there are options, particularly information provision, that may stimulate adaptation initiatives. The results reveal that most adaptation options are modifications to on-going farm practices and public policy decision-making processes with respect to a suite of changing climatic (including variability and extremes) and non-climatic conditions (political, economic and social). For progress on implementing adaptations to climate change in agriculture there is a need to better understand the relationship between potential adaptation options and existing farm-level and government decision-making processes and risk management frameworks.

Smith, J., K. Mulongoy, R. Persson, J. Sayer. (2000). "Harnessing carbon markets for tropical forest conservation: Towards a more realistic assessment." Environmental Conservation 27(3): 300-311.

The proposed Clean Development Mechanism (CDM) of the Kyoto Protocol paves the way for financial and technological transfers to support forestry projects that sequester carbon or protect carbon stocks. From its inception, the concept has been highly controversial. It has been enthusiastically supported by those who believe that conservation of tropical forests will be difficult unless forest owners and managers are compensated for the environmental services of their forests. Others believe that financial transfers supporting 'carbon farming' would ignore social concerns and the full range of goods and services of forests. This paper examines the implications of CDM for forest conservation and sustainable use, by drawing on recent literature and the results of a policy dialogue with CDM stakeholders. Authors conclude that initial estimates of the contribution tropical forestry could make to both climate change mitigation and to forest conservation need to be scaled down. CDM payments for tropical forestry are likely to be received in a far more limited area than initially expected. The cost-effectiveness of forestry projects relative to projects in the energy sector may have been overestimated. In particular few estimates have adequately accounted for the likelihood that the duration of CDM forestry projects is unlikely to be as long as the residency time of carbon in the atmosphere. Also political realities and investor priorities may not have been sufficiently understood. CDM funding for forestry may also decline in future as

economically viable clean technologies are increasingly developed in the energy sector. Tropical forests are likely to be an intermediate climate change mitigation strategy for buying time, until more permanent options become available. The most important justification for including forests in CDM may lie in the contribution CDM could potentially make to forest conservation and sustainable use. An analysis of the implications of CDM for forests reveals the importance of involving forest stakeholders more closely in the CDM debate. To prevent perverse outcomes and reduce the risk of 'leakage' of emission reduction to areas outside project boundaries, CDM projects may need to be limited to niches which meet certain political and institutional preconditions and where sufficient understanding of local decision-making and the broader context is available, CDM may be more effective if used to remove non-economic impediments to forestry activities that are economically viable and meet local needs. Lessons from the forestry sector in relation to plantations, natural forest management, forest conservation and non-timber forest products are discussed to illustrate the dangers of misusing CDM and also to give examples of how CDM could be harnessed for better use of forests. CDM should be seen as one more tool for enhancing the effectiveness of more conventional ways of promoting forest conservation and sustainable use.

Smith, J. and G. Applegate (2004). "Could payments for forest carbon contribute to improved tropical forest management?" *Forest Policy and Economics* 6(2): 153-167.

Under the Kyoto Protocol, industrialized countries will be able to meet carbon emission reduction commitments by financing forestry projects that sequester carbon in developing countries. While this mechanism would compensate for missing markets in forest environmental services, it could also enable industrialized countries to avoid reducing energy use. This paper assesses whether such projects could contribute to improved logging practices in the tropics. Results from studies primarily in Asia and Latin America are analysed in the context of the modalities of the Kyoto Protocol. Results showed that the opportunity cost of shifting from conventional logging to improved practices may have been underestimated. At the same time, the long-term carbon and biodiversity benefits of improved forest management may have been underestimated. These results follow primarily from the fact that most previous studies assume that a permanent forest estate is maintained under conventional logging and that cutting cycles are as long as 30-60 years. A more realistic scenario, however, consists of repeated harvesting at short intervals during the first few decades, resulting in the degradation of the forest into shrub and grassland. The implications of these results are that forest management projects may be less cost-effective than previously assumed. Therefore, expectations about their potential

contribution to improved management should be scaled down. At the same time, the extent to which such projects will enable industrialized countries to avoid reducing industrial pollution is also unlikely to be significant. Cost-effectiveness is likely to be highest where timber volumes in the first few decades after initial logging are comparable under conventional and improved logging. This is likely where topography is relatively flat, biodiversity values are low, wastage of felled timber is high and the policy environment is favourable. A number of proactive measures are suggested to expand the niche for forest management carbon projects. These measures are justified because the incremental carbon and biodiversity benefits in the long run may be higher than previous studies have indicated.

Smith, J. and S. J. Scherr (2003). "Capturing the value of forest carbon for local livelihoods." World Development **31**(12): 2143-2160.

Authors contribute to the debate on the social implications of carbon forestry projects by showing that tradeoffs exist between social benefits of projects and their cost-effectiveness. Large-scale industrial plantations and strict forest protection are economically viable, but pose the highest social risks. Socially beneficial projects are less cost-effective because of their higher transaction costs. Enabling policies are also required for their success. Regulation of carbon markets will therefore be required to reduce social risks and enhance benefits. Authors propose a number of regulatory and proactive measures and justify them on the basis of market imperfections and concepts of sustainable development.

Smith, J. and S. J. Scherr (2002). Forest carbon and local livelihoods: assessment of opportunities and policy recommendations. CIFOR Occasional Paper, Jakarta, Indonesia.

Projects implemented as part of the Clean Development Mechanism (CDM) of the Kyoto Protocol will have the dual mandate of mitigating greenhouse gas emissions and contributing to sustainable development. Basic agreement on core elements was reached in 2001, including the decision to allow afforestation and reforestation projects. However, it is not yet clear what rules will address social concerns. Many types of projects could potentially contribute to local livelihoods and ecosystem restoration, as well as to carbon emission offsets, including those using natural forest regeneration, agroforests, improved forest fallows and agroforestry. Averted deforestation projects with multiple-use forestry, though not eligible in the first CDM period, could be reconsidered in the future. Such projects can be designed to rigorously meet CDM criteria for carbon impact, additionality, leakage and duration. If suitably targeted, they can be cost-effective for investors in terms of production costs. Some, however, may have higher transaction costs.

Proactive efforts are needed to enable community-based CDM forestry projects and local land uses to compete effectively in carbon trading markets with projects managed by large-scale operators. The CDM should require mandatory social impact assessments, harmonise the CDM with social principles of other global conventions, promote measures to reduce transaction costs and explicitly include assisted natural regeneration and forest rehabilitation in the definition of afforestation and reforestation. Most developing countries will require policy action to establish the enabling conditions for forest carbon projects to contribute on a large scale to local livelihoods, integrate CDM projects within national development frameworks, attract investors, establish social criteria, secure local rights and promote support services for local people. Cost-effective project design requires attention to local participation, transparency, suitable compensation mechanisms, strategies to reduce transaction costs and risks and extend the scale of projects, and to enhance profitability of land uses.

Smith, J. B. (1996). "Development of adaptation measures for water resources." International Journal of Water Resources Development **12**(2): 151-163.

An assessment process for anticipatory adaptation measures that will enable countries to identify, select and implement measures to adapt to climate change is proposed. These measures anticipate potential climate changes and thus must be flexible enough to meet objectives under a wide variety of future climate conditions. The process built on assessments of vulnerability by focusing on adaptation measures for the most sensitive regions, or populations, within a country. Potential anticipatory adaptation measures were identified and two or three were chosen based on expert judgment regarding which measures would produce the greatest benefits and be easiest to implement. Formal analytic techniques were used to assess the benefits and costs of each of the measures and to evaluate barriers to implementation. The measure that had the greatest net benefits and was easiest to implement was selected. The final step was preparing an implementation plan. The application of the process was illustrated by examining a hypothetical reservoir threatened by climate change.

Smith, J. B. and S. S. Lenhart (1996). "Climate change adaptation policy options." Climate Research **6**(2): 193-201.

Africa is one of the world's potentially most vulnerable regions in terms of climate change. Policy makers in regions such as Africa need to consider what measures they should take to adapt to the potential consequences of climate change. A number of adaptation policies are suggested. The policies address general adaptation measures as well as specific measures for water resources, coastal resources, forests, ecosystems and agriculture. The measures would

enhance the flexibility of resources to adapt to climate change and would have net benefits greater than costs. In some cases the measures make sense without considering climate change because they help address current climate variability. In other cases the measures should be implemented in anticipation of climate change because they would be ineffective if implemented as a reaction to climate change.

Smith, J. B. (1997). "Setting priorities for adapting to climate change." Global Environmental Change 7(3): 251-264.

It is not likely that efforts to control greenhouse gas emissions will completely eliminate the risk of climate change. Thus, policymakers will eventually have to address adaptation to the effects of climate change. Given the uncertainties about the timing, direction, and magnitude of regional climate change, it might seem preferable to postpone adaptive measures until after climate changes. Yet, this may not produce satisfactory results if climate change impacts are irreversible or catastrophic, long-lived resource systems are affected, or current trends make adaptation less likely to succeed in the future. In these cases, policy changes in anticipation of climate change may be justified. Anticipatory climate change measures need to be flexible--they should absorb impacts or enable a system to quickly recovery under a wide variety of climate situations. In addition, they should be economically efficient, that is their benefits should exceed their costs. Although many measures are appropriate anticipatory measures, not all of them need to be implemented now. Those most in need of immediate implementation should meet at least one of the following criteria: (1) address irreversible or costly impacts; (2) be urgent, i.e. reverse trends that make adoption of the measure more difficult over time; or (3) address long-term decisions, such as building infrastructure. A method is proposed for natural resource policymakers to use in analyzing the need for anticipatory adaptation policies and the effectiveness of policy options to anticipate climate change. This method enables policy makers to identify those anticipatory policies most in need of immediate implementation.

Smith B., I. Burton, R. J. T. Klein, J. Wandel. (2000). "An anatomy of adaptation to climate change and variability." Climatic Change 45(1): 223-251.

Adaptation to climate variability and change is important both for impact assessment (to estimate adaptations which are likely to occur) and for policy development (to advise on or prescribe adaptations). This paper proposes an "anatomy of adaptation" to systematically specify and differentiate adaptations, based upon three questions: (i) adapt to what? (ii) who or what adapts? and (iii) how does adaptation occur? Climatic stimuli include changes in long-term mean

conditions and variability about means, both current and future, and including extremes. Adaptation depends fundamentally on the characteristics of the system of interest, including its sensitivities and vulnerabilities. The nature of adaptation processes and forms can be distinguished by numerous attributes including timing, purposefulness, and effect. The paper notes the contribution of conceptual and numerical models and empirical studies to the understanding of adaptation, and outlines approaches to the normative evaluation of adaptation measures and strategies.

Smithers, J. and A. Blay-Palmer (2001). "Technology innovation as a strategy for climate adaptation in agriculture." Applied Geography **21**(2): 175-197.

Technological research and development are among the most frequently advocated strategies for adapting agriculture to possible future changes in climate. However, while many statements point to the reliance that is placed on technology, and to the power of induced innovation, the actual process of agricultural research and development has received little explicit consideration in the context of climatic constraints on food production. This paper offers both a descriptive assessment and empirical analysis of the place of technology research and development in climate adaptation research and planning. Insights into the assumed role of technology are developed through a review of the published literature and recent commentary. The role of technological innovation in the handling of climatic risks is then explored empirically in an analysis of innovation research and development in the Ontario (Canada) soyabean industry. This reveals an array of technological innovations (mainly related to breeding) that have helped Ontario soyabean-growers manage climatic challenges to date, as well as a range of potential constraints on the innovation process itself.

Smithers, J. and B. Smit (1997). "Human adaptation to climatic variability and change." Global Environmental Change **7**(2): 129-146.

Recent developments in both the policy arena and the climate impacts research community point to a growing interest in human adaptation to climatic variability and change. The Importance of adaptation in the climate change question is affirmed in the Intergovernmental Panel on Climate Change (IPCC) Technical Guidelines for Assessing Impacts and Adaptations and the IPCC's more recent Second Assessment Report. Yet, the nature and processes of human adaptation to climate are poorly understood and rarely investigated directly. Most often, human responses of one form or another are simply assumed in impacts research. Analyses that do address adaptation use a variety of interpretations and perspectives resulting in an Incomplete, and at times inconsistent, understanding of human adaptation to environmental variations. This paper reviews and

synthesizes perspectives from an eclectic body of scholarship to develop a framework for characterizing and understanding human adaptation to climatic variability and change. The framework recognizes the characteristics of climatic events, the ecological properties of systems which mediate effects, and the distinctions which are possible among different types of adaptation. A classification scheme is proposed for differentiating adaptation strategies.

Sohngen, B. and R. Alig (2000). "Mitigation, adaptation, and climate change: results from recent research on US timber markets." Environmental Science & Policy 3(5): 235-248.

This paper reviews recent studies that have addressed how US timber markets may adapt to climate change, and how US forests could be used to mitigate potential climate change. The studies are discussed in light of the ecological and economic assumptions used to estimate adaptation. Estimates of both economic impacts and carbon sequestration costs depend heavily on the assumptions and methods used, although some general conclusions can be drawn. Studies of economic impacts suggest that average market effects in the United States may range from +\$1.3 to +7.4 billion per year by the middle of the next century. Estimates of the cost of sequestering carbon have generally increased over the last 10 years, with a current range of <1-73 million metric t per year of additional sequestration from afforestation projects costing \$5-66 per metric t. Estimates of the potential for alternative methods for carbon sequestration, such as product markets and recycling, are as large as afforestation estimates, with up to 50 million metric tons per year of additional storage considered possible. Cost estimates have not been developed for these alternative methods, however.

SongCai, Y. (2001). "Agricultural adaptation to climate change in China." Journal of Environmental Sciences 13(2): 192-197.

This paper presents a study on adaptation of agriculture to climate change by adopting the planned land use change strategy to overcome the water shortage and to build the capacity to adapt to the expected climate change in northern China. Results of a cost benefit analysis shows that an assumed land use change from rice cultivation with a high irrigation requirement to other crops, such as maize, with a lower irrigation requirement is very effective. Over 7 billions m³ of water can be saved. Potential conflicts between different social interest groups, different regions, supply and demand, and present and future interests have been analysed to form a policy to implement the adaptation strategy. Trade, usually taken as one of the adaptation strategies, was suggested as a policy option to support land use change, which not only meets the consumption demand, but also, in terms of resources, imports water resources.

SongCai, Y., K. Takahashi, Y. Matsuoka. (2001). "Investment as an adaptation strategy to climate change: case study of flood damage in China." Environmental Economics and Policy Studies 4(1): 45-65.

The objective of this research was to evaluate investment as a robust adaptation strategy in response to projected climate change in China. Four scenarios combining climate change and investment have been simulated in the model, which was established by adopting the standard approach of modern optimal economic growth theory; it also includes two discount factors from the climate sector (i.e., flood damage from climate variability and climate change). Relations between the flood prevention infrastructure and flood damage to the agricultural and the nonagricultural sectors were established from historical data and applied to estimate the benefit of investment to mitigate flood damage from climate variability. By assuming that the marginal adaptation costs to flood damage from projected climate change is the same as those from current climate variability, these relations were applied to estimate the benefit of investing in the mitigation of flood damage due to climate change. Tests were made to verify the model's validity when the marginal adaptation cost for flood damage due to climate change was increased by 10%, 20%, and 30%, respectively. The conclusion is that optimized investment, taking climate change into consideration, effectively reduces the damage due to climate change and promotes the capacity to mitigate flood damage due to climate variability. Moreover, consumption and production increases regardless of whether climate change occurs.

Stahle, D. W., M. K. Cleaveland, D. B. Blanton, M. D. Therrell, D. A. Gay. (1998). "The lost colony and Jamestown droughts." Science 280: 564-567.

Tree-ring data from Virginia indicate that the Lost Colony of Roanoke Island disappeared during the most extreme drought in 800 years (1587-1589) and that the alarming mortality and the near abandonment of Jamestown Colony occurred during the driest 7-year episode in 770 years (1606-1612). These extraordinary droughts can now be implicated in the fate of the Lost Colony and in the appalling death rate during the early occupations at Jamestown, the first permanent English settlement in America.

Stakhiv, E. Z. (1998). "Policy implications of climate change impacts on water resources management." Water Policy 1(2): 159-175.

Policy makers and water resources managers should be aware of the evolving information on climate change impacts as an activity that is preparatory, but not central, to sound decision making on current water resources management actions. Policies that ensure effective contemporary water management will form the core of a "no regrets" strategy that will contemporaneously serve adaptation to

climate change and uncertainty. Hence, an "adaptive management" approach rather than an "anticipatory strategy" is warranted for most water management actions. An effective water management system depends, to a large extent, on a well-functioning institutional framework and the treatment of water as an economic and social good, both of which are a prerequisite for adaptation to contemporary climate variability. It will also serve as the foundation for responding to uncertain climate change scenarios.

Stanley, D. J. and A. G. Warne. (1993). "Sea level and initiation of Predynastic culture in the Nile delta." *Nature* **363**: 435 – 438.

Predynastic occupation of the Nile valley and delta, dating back to at least 5000 BC, has been attributed by most archaeologists to environmental factors, primarily regional climate change and fluctuating Nile flood stages. Here authors propose instead that initiation of farming settlements in the Nile delta was closely related to eustatic sea level. They present geological analyses of late Quaternary subsurface sections throughout the delta which reveal that the deceleration in sea-level rise that occurred at about 6500–5500 BC was a prime factor in the accumulation of Nile silt, and the creation of the widespread and fertile delta plain. As rising sea level reduced the gradient of the river course, a system of meandering Nile distributaries evolved, with increased overbank deposition burying the former (early Holocene), partially vegetated sandy plain. The broadening, seasonally flooded, fecund plain, with its increasing plant cover, provided a setting that was conducive to evolving agricultural activity and was therefore instrumental in the development of Predynastic communities in the Nile delta.

Staubwasser, M., F. Sirocko, P. M. Grootes, and M. Segl. (2003). "Climate change at the 4.2 ka BP termination of the Indus valley civilization and Holocene south Asian monsoon variability." *Geophysical Research Letters* **30**(8): 1425.

Planktonic oxygen isotope ratios off the Indus delta reveal climate changes with a multi-centennial pacing during the last 6 ka, with the most prominent change recorded at 4.2 ka BP. Opposing isotopic trends across the northern Arabian Sea surface at that time indicate a reduction in Indus river discharge and suggest that later cycles also reflect variations in total annual rainfall over south Asia. The 4.2 ka event is coherent with the termination of urban Harappan civilization in the Indus valley. Thus, drought may have initiated southeastward habitat tracking within the Harappan cultural domain. The late Holocene drought cycles following the 4.2 ka BP event vary between 200 and 800 years and are coherent with the evolution of cosmogenic ^{14}C production rates. This suggests

that solar variability is one fundamental cause behind Holocene rainfall changes over south Asia.

Stepp, J. R., E. C. Jones, M. Pavao-Zuckerman, D. Casagrande, and R. K. Zarger. 2003. "Remarkable properties of human ecosystems." *Conservation Ecology* 7(3): 11. [online] URL: <http://www.consecol.org/vol7/iss3/art11>

This paper explores some of the remarkable properties that set human ecosystems apart from nonhuman ecosystems. Authors use the term "human ecosystem" to refer to human-dominated ecosystems in which the human species is a central agent. Authors have organized the presentation of these properties into three categories: (1) information and belief systems, (2) historical vectors of information in human ecosystems, and (3) new kinds of material, energy, and information flows and sinks not found in nonhuman ecosystems. The identification of these properties provides a framework for bridging the theoretical and methodological divide between biological ecology and human ecology. The unique information-processing capability of humans in ecosystems is central to this framework. Article discusses several manifestations of human cognitive and behavioral abilities, termed "remarkable properties" of human ecosystems. A cross-cultural and historical approach is taken in demonstrating some of these properties. Related to these properties are the ways in which complex functional and dysfunctional or maladaptive processes take place in human ecosystems. Authors assert that one of the greatest challenges for human ecology is to integrate belief systems as a major component of human ecosystems.

Stothert, K. E., D. R. Piperno, T. C. Andres (2003). "Terminal Pleistocene/Early Holocene human adaptation in coastal Ecuador: the Las Vegas evidence." *Quaternary International* 109-110: 23-43.

Preceramic sites located on the Santa Elena Peninsula in southwestern Ecuador and occupied in the Terminal Pleistocene and during the Early Holocene (10,800–6600 BP) have produced evidence of a durable Las Vegas adaptation focused on marine, estuarine and terrestrial resources. The Las Vegas people were among the earliest cultivators in America who participated in the domestication of useful plant species and progressively intensified their efforts in both fishing and horticulture.

Strzepek, K. M. and D. N. Yates (1996). "Assessment of water resources vulnerability and adaptation to climate change." *International Journal of Water Resources Development* 12(2): 111-119.

An overview of the standard methodology developed for the US Country Studies Program on the Assessment of Water Resources Vulnerability and

Adaptation to Climate Change is presented. A standard methodology was developed for two reasons: (i) for countries with little or no experience in hydrological and water resources modelling it provides a simple, yet appropriate, set of modelling tools that can be quickly learned and applied with a limited dataset; (ii) it provides a consistent methodology for synthesizing results for regional and global assessments as well as cross-country and cross-regional comparisons.

Suárez, R. and J. M. López. (2003). "Archaeology of the Pleistocene–Holocene transition in Uruguay: an overview." Quaternary International **109-110**: 65-76.

In Uruguay, evidence of early human occupation comes from different archaeological regions, including the Basin of Uruguay and Cuareim Rivers, Basin of Negro mid River, and the Atlantic littoral. This paper presents a synthesis and overview of the poorly known archaeology of the Pleistocene/Holocene transition of Uruguay, including archaeological, sedimentological and palaeontological information related to the early human occupation. In this region, the ancient human settlements occurred in various environmental settings including riverbanks, hilltops, and maritime landscapes. New Fell type or "*fishtail*" projectile points and preliminary results of the current research in Pay Paso locality are presented. Evidence from Pay Paso site 1 indicates that during Early Holocene, the shore of the Cuareim River was a paleosurface that was occupied by early human groups. A new and previously unpublished type of projectile point from early hunter-gatherers (ca. 9300–9100 yr BP) was recovered from excavation of Pay Paso site 1. Finally, some comments and observations about culture material and lithic technology for early people of Uruguay are explored.

Subak, S. (2000). "Climate change adaptation in the U.K. water industry: managers' perceptions of past variability and future scenarios." Water Resources Management **14**(2): 137-156.

In this article, the relationship between U.K. water companies' perceptions of past climatic extremes and their effect on resilience to future climatic change is explored. Perceptions and activities related to past and future dry periods was investigated through interviews with managers at the ten major English and Welsh water supply/sewerage companies, and several smaller, water-only companies. Several of the companies report that they have observed a trend towards drier summers in their regions, and a number of companies say that they have observed a change towards more intensive rainfall of shorter duration. Recent supply measures in a number of regions have been aimed at improving storage and distribution related to the perceived change in rainfall intensity. A new requirement to incorporate regional climate change scenarios in future supply

assumptions appears to have had little impact on planning in the region to date. Many water resource planners believe that the scenarios generated are too aggregated and do not encourage a precautionary approach to planning. Some managers believe that records of historical drought conditions, such as experienced in 1933-34 or 1995-96, as worst-case scenarios provide a better basis for planning.

Sukumar, R. (2000). "Climate and ecosystem change: what does it mean for biodiversity conservation in India?" Journal of the Indian Institute of Science **80**(6): 609-618.

Climate change as a consequence of human activity such as emission of greenhouse gases into the atmosphere is now a distinct possibility according to the assessment of the Intergovernmental Panel on Climate Change. During the 21st century climate change can be expected to make impacts on ecosystems and biodiversity on a global scale. In this paper, author briefly reviews the implications of climate change for forest and wildlife conservation in India. Outputs from general circulation models of temperature and precipitation changes over India are examined in the context of possible impacts on forests. A regional model of climate and vegetation change in Nilgiri Biosphere Reserve of south India is presented. Implications of this model for conservation of various vegetation types and endemic species such as the tahr (*Hemitragus hylocrius*) are discussed. Some adaptation strategies are outlined.

Sutherst, R. W. (2004). "Global change and human vulnerability to vector-borne diseases." Clinical Microbiology Reviews **17**(1): 136-173.

Global change includes climate change and climate variability, land use, water storage and irrigation, human population growth and urbanization, trade and travel, and chemical pollution. Impacts on vector-borne diseases, including malaria, dengue fever, infections by other arboviruses, schistosomiasis, trypanosomiasis, onchocerciasis, and leishmaniasis are reviewed. While climate change is global in nature and poses unknown future risks to humans and natural ecosystems, other local changes are occurring more rapidly on a global scale and are having significant effects on vector-borne diseases. History is invaluable as a pointer to future risks, but direct extrapolation is no longer possible because the climate is changing. Researchers are therefore embracing computer simulation models and global change scenarios to explore the risks. Credible ranking of the extent to which different vector-borne diseases will be affected awaits a rigorous analysis. Adaptation to the changes is threatened by the ongoing loss of drugs and pesticides due to the selection of resistant strains of pathogens and vectors. The vulnerability of communities to the changes in impacts depends on their adaptive

capacity, which requires both appropriate technology and responsive public health systems. The availability of resources in turn depends on social stability, economic wealth, and priority allocation of resources to public health.

Thamban, M., V. Purnachandra Rao, R. R. Schneider. (2002). "Reconstruction of late Quaternary monsoon oscillations based on clay mineral proxies using sediment cores from the western margin of India." *Marine Geology* **186**(3-4): 527-539.

In order to reconstruct the variations in the intensity of summer monsoon precipitation during the late Quaternary, two sediment cores from the southwestern continental margin of India were studied for their clay mineral composition and grain size parameters. Kaolinite, illite and gibbsite were dominant in a core off Cochin. Illite with increasing kaolinite content towards the core top was found to dominate in a core from the continental slope off Goa. Major sources of clays at both the core sites were from the hinterland rocks and soils. Careful evaluations of several factors that could complicate the clay distribution in marine environment indicate that the clay mineral parameters can be used as proxies for the intensity of summer monsoon precipitation in the past. The relatively low values of humidity proxies (kaolinite content, K/C and K/I ratios) and higher illite crystallinity with significant variations indicate that the summer monsoons in general were weaker during the late glaciation, with distinct events of intensification at ~28000 and 22000 yr BP. The last deglaciation was characterised by an increased terrigenous input with high values of humidity proxies during 15700-14800 cal yr BP, indicating an early strengthening of summer monsoon activity in the region. The most remarkable increase in kaolinite content, K/C and K/I ratios associated with much reduced values of chlorite and illite and illite crystallinity, however, occur between 8800 and 6400 cal yr BP. It appears that the Holocene precipitation maxima occurred after 9000 cal yr BP and lagged behind the precessional forcing. The late Holocene witnessed reduced rainfall activity and resultant decrease in hydrolysis starting at 5600 cal yr BP.

Thomas, D. S. G. and Twyman, C. (2005). "Equity and justice in climate change adaptation amongst natural-resource-dependent societies." *Global Environmental Change Part A* **15**(2): 115-124.

Issues of equity and justice are high on international agendas dealing with the impacts of global climate change. But what are the implications of climate change for equity and justice amongst vulnerable groups at local and sub-national levels? We ask this question for three reasons: (a) there is a considerable literature suggesting that the poorest and most vulnerable groups will disproportionately experience the negative effects of 21st century climate change; (b) such changes

are likely to impact significantly on developing world countries, where natural-resource dependency is high; and (c) international conventions increasingly recognise the need to centrally engage resource stakeholders in agendas in order to achieve their desired aims, as part of more holistic approaches to sustainable development. These issues however have implications for distributive and procedural justice, particularly when considered within the efforts of the UNFCCC. The issues are examined through an evaluation of key criteria relating to climate change scenarios and vulnerability in the developing world, and second through two southern African case studies that explore the ways in which livelihoods are differentially impacted by (i) inequitable natural-resource use policies, (ii) community-based natural-resource management programmes. Finally, we consider the placement of climate change amongst the package of factors affecting equity in natural-resource use, and whether this placement creates a case for considering climate change as 'special' amongst livelihood disturbing factors in the developing world.

Thompson, L. G., T. Yao, E. Mosley-Thompson, M. E. Davis, K. A. Henderson, P. N. Lin. (2000). "A high-resolution millennial record of the south Asian monsoon from Himalayan ice cores." *Science* **289**: 1916-1919.

A high-resolution ice core record from Dasuopu, Tibet, reveals that this site is sensitive to fluctuations in the intensity of the South Asian Monsoon. Reductions in monsoonal intensity are recorded by dust and chloride concentrations. The deeper, older sections of the Dasuopu cores suggest many other periods of drought in this region, but none have been of greater intensity than the greatest recorded drought, during 1790 to 1796 A.D. of the last millennium. The 20th-century increase in anthropogenic activity in India and Nepal, upwind from this site, is recorded by a doubling of chloride concentrations and a fourfold increase in dust. Like other ice cores from the Tibetan Plateau, Dasuopu suggests a large-scale, plateau-wide 20th-century warming trend that appears to be amplified at higher elevations.

Tinner, W., A. F. Lotter, B. Ammann, M. Conedera, P. Hubschmid, J. F. N. van Leeuwen, M. Wehrli. (2003). "Climatic change and contemporaneous land-use phases north and south of the Alps 2300 BC to 800 AD." *Quaternary Science Reviews* **22**(14): 1447-1460.

Fluctuations in the $\Delta^{14}\text{C}$ curve and subsequent gaps of archaeological findings at 800–650 and 400–100 BC in western and central Europe may indicate major climate-driven land-abandonment phases. To address this hypothesis radiocarbon-dated sediments from four lakes in Switzerland were studied palynologically. Pollen analysis indicates contemporaneous phases of forest

clearances and of intensified land-use at 1450–1250 BC, 650–450 BC, 50 BC–100 AD and around 700 AD. These land-use expansions coincided with periods of warm climate as recorded by the Alpine dendroclimatic and Greenland oxygen isotope records. Our results suggest that harvest yields would have increased synchronously over wide areas of central and southern Europe during periods of warm and dry climate. Combined interpretation of palaeoecological and archaeological findings suggests that higher food production led to increased human populations. Positive long-term trends in pollen values of *Cerealia* and *Plantago lanceolata* indicate that technical innovations during the Bronze and Iron Age (e.g. metal ploughs, scythes, hay production, fertilising methods) gradually increased agricultural productivity. The successful adoption of yield-increasing advances cannot be explained by climatic determinism alone. Combined with archaeological evidence, our results suggest that despite considerable cycles of spatial and demographic reorganisation (repeated land abandonments and expansions, as well as large-scale migrations and population decreases), human societies were able to shift to lower subsistence levels without dramatic ruptures in material culture. However, our data imply that human societies were not able to compensate rapidly for harvest failures when climate deteriorated. Agriculture in marginal areas was abandoned, and spontaneous reforestations took place on abandoned land south and north of the Alps. Only when the climate changed again to drier and warmer conditions did a new wide-spread phase of forest clearances and field extensions occur, allowing the reoccupation of previously abandoned areas. Spatial distribution of cereal cultivation and growth requirements of *Cerealia* species suggest that increases in precipitation were far more.

Tol, R. S. J., S. Fankhauser, J. B. Smith. (1998). "The scope for adaptation to climate change: what can we learn from the impact literature?" Global Environmental Change 8(2): 109-123.

This paper discusses the extent to which the vast body of literature on climate change impacts can provide insights into the scope and likely cost of adaptation. The ways in which the impacts literature deals with adaptation can be grouped into four categories: no adaptation, arbitrary adaptation, observed adaptation (analogues), and modelled adaptation (optimization). All four cases are characterized by the simple assumptions made about the mechanisms of adaptation. No or only scant attention is paid to the process of adapting to a new climate. Adaptation analysis has to acknowledge that people will be neither dumb nor brilliant at adapting. They are likely to see the need for change, but may be constrained in their ability to adapt or in their comprehension of the permanence and direction of change.

Tompkins, E. L. and W. N. Adger (2004). "Does adaptive management of natural resources enhance resilience to climate change?" *Ecology and Society* **9**(2): 10. [online] URL: <http://www.ecologyandsociety.org/vol9/iss2/art10>.

Emerging insights from adaptive and community-based resource management suggest that building resilience into both human and ecological systems is an effective way to cope with environmental change characterized by future surprises or unknowable risks. Authors argue that these emerging insights have implications for policies and strategies for responding to climate change. Authors review perspectives on collective action for natural resource management to inform understanding of climate response capacity. Article demonstrates the importance of social learning, specifically in relation to the acceptance of strategies that build social and ecological resilience. Societies and communities dependent on natural resources need to enhance their capacity to adapt to the impacts of future climate change, particularly when such impacts could lie outside their experienced coping range. This argument is illustrated by an example of present-day collective action for community-based coastal management in Trinidad and Tobago. The case demonstrates that community-based management enhances adaptive capacity in two ways: by building networks that are important for coping with extreme events and by retaining the resilience of the underpinning resources and ecological systems... Although much adaptation to climate change is anticipatory, some also takes place in response to the impacts of single extreme events. Further, some climate change impacts, such as a significant and rapid rise in sea level, are likely to significantly alter the resource systems and their ecosystem services. The processes needed to adapt to catastrophic system changes would involve a major restructuring of the economy and society. Clearly, these are dangerous thresholds in the climate system that need to be avoided. There is, in effect, no substitute for the significant mitigation of emissions at the present time. Adaptation to both gradual and significant changes should involve encouraging the evolution of new institutions that are sensitive to the resilience of the ecosystems they are managing and knowledgeable about the specific nature of the risks of climate change.

Toomey, III, R. S., M. D. Blum S. Valastro, Jr. (1993). "Late Quaternary climates and environments of the Edwards Plateau, Texas." *Global and Planetary Change* **7**(4): 299-320.

Fossil vertebrate, pollen, and plant macrofossil data from the Edwards Plateau, Texas and throughout the southcentral United States permit reconstruction of regional changes in temperature and effective moisture. Full-glacial temperatures were significantly cooler than those of today, at least 6°C during the summer months, but by ca. 13,000 yrs B.P. summer temperatures were within 2–3°C of present values. There was more effective moisture during the full-

glacial period than at any time since then. During the late-glacial, ca. 14,000–10,500 effective moisture first decreased then increased, while the early to middle Holocene was dominated by a protracted decrease in effective moisture. This long-term trend culminated in conditions that were drier than modern during the early part of the late Holocene from ca. 5000 to 2500 yr B.P. Conditions were more mesic than present from ca. 2500 and 1000 yr B.P., while the modern drought-prone climate has characterized the last 1000 years.

Fossil vertebrates and the characteristics of cave fill sediments show that late Pleistocene and Holocene changes in temperature and moisture regimes were coupled with vegetation changes and a gradual degradation of upland soils. During the full- and late-glacial much of the upland landscape was covered by thick, deeply weathered reddish clay-rich soils and an open savanna vegetation with a mixed tall and short grass understory. Changes to Holocene climatic conditions promoted a diminished vegetation cover and initiated the gradual degradation of soil mantles, whereas minimum effective moisture during the earlier part of the late Holocene resulted in upland landscapes that were covered by a mixture of short grasses and scrub vegetation, and the near complete removal of the remaining soil mantle. Vegetation changes during the last 2500 years are poorly known, but the upland landscape has consisted of exposed bedrock with little soil cover.

Comparison of empirical data and the results of paleoclimate models shows good correspondence for the full-glacial through middle Holocene when climate system boundary conditions that drive model simulations were substantially different from today. Climate models also provide plausible physical explanations for climatic and environmental changes identified by empirical data. Our synthetic reconstruction, based on both empirical data and climate model simulations, provides a framework for evaluation of the impacts of climatic and environmental changes on earth surface processes and landforms, and a basis for discussion of prehistoric human adaptations to different environmental conditions.

Tschakert, P. and G. Tappan (2004). "The social context of carbon sequestration: considerations from a multi-scale environmental history of the Old Peanut Basin of Senegal." *Journal of Arid Environments* **59**(3): 535-564.

This paper presents the results of a multi-scale investigation of environmental change in the Old Peanut Basin of Senegal throughout the 20th century. Based on historical accounts, ethnographies, aerial photos, satellite images, field and household surveys as well as various participatory research activities with farmers in selected villages, the study attempts to make explicit layered scales of analysis, both temporally and spatially. It shows that, despite

some general trends of resource degradation in the Old Peanut Basin, local farming systems have embarked on different pathways of change to adapt to their evolving environment. It also illustrates that high diversity with respect to soil fertility management exists at the farm and household level. Finally, the paper proposes a farmer-oriented approach to carbon sequestration in order to integrate recommended technical options more efficiently into the complex and dynamic livelihoods of smallholders in dryland environments. This approach includes pathway-specific land use and management options at the level of farming systems and, at the level of individual households, a basket of possible practices from which farmers can choose depending on their multiple needs, capacities, and adaptive strategies to cope with risk and uncertainty.

Valcarce, R. F., A. M. Cortizas, R. B. Chao, W. Chesworth. (2003). "Environmental change and social dynamics in the second–third millennium BC in NW Iberia." *Journal of Archaeological Science* **30**(7): 859-871.

Analysis of different sediments in NW Spain suggests that a series of abrupt climatic changes occurred between 3500 and 1000 BC. These involved some episodes of cooling and others of drought. There were also changes to the coastline of Galicia. Taken together, these would have offered new opportunities to Copper Age communities who had already embarked on a process of agricultural intensification. The result was a growth of internecine competition.

Verschuren, D., K. R. Laird, B. F. Cumming. (2000). "Rainfall and drought in equatorial east Africa during the past 1,100 years." *Nature* **403**: 410 – 414.

Knowledge of natural long-term rainfall variability is essential for water-resource and land-use management in sub-humid regions of the world. In tropical Africa, data relevant to determining this variability are scarce because of the lack of long instrumental climate records and the limited potential of standard high-resolution proxy records such as tree rings and ice cores. Here authors present a decade-scale reconstruction of rainfall and drought in equatorial east Africa over the past 1,100 years, based on lake-level and salinity fluctuations of Lake Naivasha (Kenya) inferred from three different palaeolimnological proxies: sediment stratigraphy and the species compositions of fossil diatom and midge assemblages. The data indicate that, over the past millennium, equatorial east Africa has alternated between contrasting climate conditions, with significantly drier climate than today during the 'Medieval Warm Period' (~AD 1000–1270) and a relatively wet climate during the 'Little Ice Age' (~AD 1270–1850) which was interrupted by three prolonged dry episodes. Authors also find strong chronological links between the reconstructed history of natural long-term rainfall variation and the pre-colonial cultural history of east Africa, highlighting the importance of a

detailed knowledge of natural long-term rainfall fluctuations for sustainable socio-economic development... Comparison of this record with the pre-colonial history of east Africa recounted in oral traditions testifies to the importance of rainfall and drought in agricultural and pastoral societies. In the six centuries before AD 1895, evidence for drought-induced famine, political unrest, and large-scale migration of indigenous peoples is concentrated in three periods around AD 1390–1420 (Wamara), AD 1560–1625 (Nyarubanga), and AD 1760–1840 (Lapanarat-Mahlatule) that match the reconstructed sequence of Lake Naivasha lowstands. The intervening 'first and second Age of Prosperity'—relatively uneventful periods of political stability, consolidation of kingdoms, agricultural success and population growth—are coeval with the two most prominent Lake Naivasha highstands. In the near-complete absence of archeological data, the Lake Naivasha record establishes the environmental background for political and cultural change in pre-colonial east Africa, indicates strong links between cultural development and climate change, and reinforces the chronology of historical events as derived from oral traditions. The magnitude of natural decade-scale rainfall variability in sub-humid east Africa implies that sustainable development and protection of food security will require agricultural management strategies adjusted to major long-term variation in water-resource availability, irrespective of any future effects of anthropogenic climate change on the hydrological cycle.

Vitousek, P. M., T. N. Ladefoged, P. V. Kirch, A. S. Hartshorn, M. W. Graves, S. C. Hotchkiss, S. Tuljapurkar, O. A. Chadwick. (2004). "Soils, agriculture, and society in precontact Hawai'i." *Science* **304**: 1665-1669.

Before European contact, Hawai'i supported large human populations in complex societies that were based on multiple pathways of intensive agriculture. Authors show that soils within a long-abandoned 60-square-kilometer dryland agricultural complex are substantially richer in bases and phosphorus than are those just outside it, and that this enrichment predated the establishment of intensive agriculture. Climate and soil fertility combined to constrain large dryland agricultural systems and the societies they supported to well-defined portions of just the younger islands within the Hawaiian archipelago; societies on the older islands were based on irrigated wetland agriculture. Similar processes may have influenced the dynamics of agricultural intensification across the tropics.

Authors conclude that low soil fertility precluded the development of large-scale intensive dryland agricultural systems on stable upland surfaces on the older islands of the Hawaiian archipelago. The resulting contrast in the agricultural bases of societies on the younger versus older islands (rain-fed dryland versus irrigated wetland) influenced the archipelago-wide pattern of sociopolitical complexity that emerged late in Hawaiian prehistory. In comparison to irrigated wetlands, dryland

agricultural systems are more labor-intensive, yield smaller surpluses, and are more vulnerable to climatic perturbations—features that probably contributed to the development of the aggressive and expansive chiefdoms that arose on the younger islands.

It is believed that the implications of these results extend well beyond the Hawaiian Islands. Although the particular thresholds of rainfall and substrate age here are specific to the basaltic bedrock of Hawai`i, the underlying processes that shape soil fertility (and so the potential for agricultural intensification) are general ones. Just as in Hawai`i, sustained rain-fed agriculture developed first and most intensively in tropical dry forests as opposed to rain forests on continents; consequently, few of these drier forests escaped clearing and cultivation. Many tropical rain forests have a history of shifting cultivation that influences their modern composition. However, except for irrigated systems or areas with relatively fertile young soils and/or lower rainfall, few rain forests have experienced large-scale intensive agriculture.

Vörösmarty, C. J., P. Green, J. Salisbury, R. B. Lammers. (2000). "Global Water Resources: Vulnerability from Climate Change and Population Growth." *Science* **289**(5477): 284-288.

The future adequacy of freshwater resources is difficult to assess, owing to a complex and rapidly changing geography of water supply and use. Numerical experiments combining climate model outputs, water budgets, and socioeconomic information along digitized river networks demonstrate that (i) a large proportion of the world's population is currently experiencing water stress and (ii) rising water demands greatly outweigh greenhouse warming in defining the state of global water systems to 2025. Consideration of direct human impacts on global water supply remains a poorly articulated but potentially important facet of the larger global change question.

Watts, M. J. (1983). "The political economy of climatic hazards; a village perspective on drought and peasant economy in a semi-arid region of West Africa." *Cahiers d'Etudes Africaines* **23**(1/2, No. 89/90): 37-72.

On the basis of an analysis of the social consequences of the recent drought in the Hausa lands, a criticism is made of the purely geographical approach to the study of climatic accidents and their effects on society. Even the description in terms of social ecology and collective adaptation to the constraints of the physical milieu should be replaced in the more general context of the system of reproduction of the society. In the sort of case studied the vulnerability of the Hausa peasant societies results from the conflict between two types of production, the transition from a pre-capitalist local type to a global capitalist type.

The climatic accident is not "natural"; it acts as a detonator of a crisis which is actually the result of an incapacity of the socio-economic system to respond to the ecological conditions.

Wilkie, M. L. (2002). "Climate change, forests and SIDS." International Forestry Review 4(4): 313-316, 333, 335.

This paper discusses the effects of long term climate changes, viz., temperature, precipitation, carbon dioxide levels and extreme climatic events, on forest resources in Small Island Developing States (SIDS). The vulnerability of SIDS to climatic change and the different adaptive strategies to address problems on climatic changes are described. Also described are the regional and sub-regional initiatives which deal specifically with climate change in SIDS such as: Caribbean Planning for Adaptation to Climate Change Project; The Pacific Islands Climate Change Assistance Programme; The Pacific Islands Regional Assessment of the Consequences of Climate Variability and Change; and The South Pacific Sea Level and Climate Monitoring Project.

Williams, J. E. (2000). "The biodiversity crisis and adaptation to climate change: a case study from Australia's forests." Environmental Monitoring and Assessment 61(1): 65-74.

If current trends continue, human activities will drastically alter most of the planet's remaining natural ecosystems and their composite biota within a few decades. Compounding the impacts on biodiversity from deleterious management practices is climate variability and change. The Intergovernmental Panel on Climate Change (IPCC) recently concluded that there is ample evidence to suggest climate change is likely to result in significant impacts on biodiversity. These impacts are likely to be exacerbated by the secondary effects of climate change such as changes in the occurrence of wildfire, insect outbreaks and similar disturbances. Current changes in climate are very different from those of the past due to their rate and magnitude, the direct effects of increased atmospheric CO₂ concentrations, and because highly modified landscapes and an array of threatening processes limit the ability of terrestrial ecosystems and species to respond to changed conditions. One of the primary human adaptation options for conserving biodiversity is considered to be changes in management. The complex and overarching nature of climate change issues emphasizes the need for greatly enhanced cooperation between scientists, policymakers, industry and the community to better understand key interactions and identify options for adaptation. A key challenge is to identify opportunities that facilitate sustainable development by making use of existing technologies and developing policies that enhance the resilience of climate-sensitive sectors. Measures to enhance the

resilience of biodiversity must be considered in all of these activities if many ecosystem services essential to humanity are to be sustained. New institutional arrangements appear necessary at the regional and national level to ensure that policy initiatives and research directed at assessing and mitigating the vulnerability of biodiversity to climate change are complementary and undertaken strategically and cost-effectively. Policy implementation at the national level to meet responsibilities arising from the UNFCCC (e.g. the Kyoto Protocol) and the UN Convention on Biological Diversity require greater coordination and integration between economic sectors, since many primary drivers of biodiversity loss and vulnerability are influenced at this level. A brief case study from the Australian continent (which addresses biodiversity management with emphasis on temperate native forest ecosystems) is used to illustrate some of the technical, institutional and policy challenges indicated above, and discuss a basis for reform, including recommendations for facilitating adaptation to climate variability and change.

Woodward, A., S. Hales, N. Litidamu, D. Phillips, J. Martin. (2000). "Protecting human health in a changing world: the role of social and economic development." Bulletin of the World Health Organization **78**(9): 1148-1155.

The biological and physical environment of the planet is changing at an unprecedented rate as a result of human activity, and these changes may have an enormous impact on human health. One of the goals of human development is to protect health in the face of rapid environmental change, but we often fail to do this. The aim in this paper is to distinguish between socioeconomic aspects of development that are likely to be protective and those that are likely to increase vulnerability (the capacity for loss resulting from environmental change). Examples include climate change in the Pacific. Authors conclude that protecting human health in a changing world requires us to take steps to minimize harmful change wherever possible, and at the same time to be prepared for surprises. The goals of mitigation (reducing or preventing change) and adaptation (response to change) are not mutually exclusive. In fact, steps to make populations more resilient in the face of change are often similar to those that are needed to lighten the load on the environment. We need social policies that convert economic growth into human development. Wider application of sustainable development concepts is part of the solution. In particular, there is a need to promote health as an essential asset of poor and vulnerable populations. It is their key to productivity and to surviving shocks; it is also the key to achieving broader development goals such as universal education. For these reasons it is in the interests of all sectors - economic, social and environmental - to play their particular roles in protecting and improving health.

Wright, E. L. and J. D. Erickson (2003). "Climate variability, economic adaptation, and investment timing." International Journal of Global Environmental Issues **3**(4): 357-368.

Recent models of adaptation to climate change have allowed economic agents perfect foresight about future climatic conditions. Authors argue that it is time to move beyond assumptions of perfect foresight to consider the impacts of changing climate predictability on adaptation dynamics. An option value investment model is used to illustrate the impact of one significant determinant of predictability - climate variability - on the timing of adaptation. Decreased predictability leads to postponed adaptation and increased pre-adaptation damage costs, indicating that estimates of the damage reductions to be gained through adaptation based on perfect foresight have been excessively optimistic.

Yasuda, Y., K. Yamaguchi, T. Nakagawa, H. Fukusawa, J. Kitagawa, M. Okamura. (2004). "Environmental variability and human adaptation during the Lateglacial/Holocene transition in Japan with reference to pollen analysis of the SG4 core from Lake Suigetsu." Quaternary International **123-125**: 11-19.

High-resolution pollen analysis of annually laminated sediments from Lake Suigetsu in Japan revealed that climate amelioration at 16,500 varve years before present (vy BP) triggered the expansion of cool temperate deciduous broad-leaved forest. The oldest pottery appearance in Japan coincided with this climate amelioration. Significant vegetation change occurred from 15,000 to 14,500 vy BP. The period during 15,000-14,500 vy BP was a time of ecological transition from a Glacial-type ecosystem, eventually destroyed by global warming, to a new Postglacial-type ecosystem represented by that in Lake Suigetsu. It is believed that the completion of this ecological transition actually took nearly 500-800 years. This drastic change in the ecosystem had forced people to create a new strategy of adaptation. The Japanese Neolithic Jomon culture, mainly sustained by gathering nuts and fishing, was widely established at this time. On the other hand, the cold period which correlates with the Younger Dryas in Europe had no significant ecological influence on the Japanese ecosystem and human culture.

Yasuda, Y., T. Fujiki, H. Nasu, M. Kato, Y. Morita, Y. Mori, M. Kanehara, S. Toyama, A. Yano, and M. Okuno. (2004). "Environmental archaeology at the Chengtoushan site, Hunan Province, China, and implications for environmental change and the rise and fall of the Yangtze River civilization." Quaternary International **123-125**: 149-158.

Fortified settlements had emerged as early as 6400–6100 cal yr BP in the middle reaches of the Yangtze River during the early Daxi culture, particularly at the Chengtoushan site in Hunan Province, China. There were four major stages

for the development of the Yangtze River civilization in the middle reaches of the Yangtze at ca. 6400–6100 cal yr BP (beginning of early Daxi culture); ca. 5800 cal yr BP (beginning of middle Daxi culture); ca. 5300 cal yr BP (beginning of Qujialing culture) and ca. 4500 cal yr BP (beginning of Shijiahe culture). These periods correspond to times of climate deterioration, especially of weakened summer monsoon. The decreased rainfall in summertime resulting from the weakened summer monsoon would have necessitated a system for securing water supply by irrigation, and this, in turn, may have led to the rise and development of urban settlements and monarchs to govern the irrigation and new social systems. The Yangtze River civilization began to decline at 4200–4000 cal yr BP and the great settlements were abandoned. This event was also considered to be the consequence of a severe climate deterioration that swept through Eurasia ca. 4200–4000 cal yr BP.

Yesner, D. R. (2001). "Human dispersal into interior Alaska: antecedent conditions, mode of colonization, and adaptations." *Quaternary Science Reviews* **20**(1-3): 315-327.

In spite of more than a half-century of exploration, no definitive evidence has yet come to light for human occupation in eastern Beringia preceding 12,000 yr BP. The oldest dates — between 11,500 and 12,000 yr BP — are from sites in interior and northern Alaska. Archaeological sites dating to this time period, such as the Broken Mammoth site in the central Tanana River Valley, have yielded evidence of pioneer colonization by groups with relatively little knowledge of lithic resources. Three possibly older cave sites — Bluefish Caves, Lime Hills Caves, and Trail Creek Caves — have stratigraphic and taphonomic problems that are not easily resolved. No sites in the glaciated coastal zone of southern Alaska are Pleistocene in date, and numerous objections can be raised to the viability of the coastal migration hypothesis, particularly in the western Gulf of Alaska region. For northern and interior Alaska, the earliest colonization appears to have been a "push-pull" phenomenon, linked to the dissolution of the Bering Land Bridge through a combination of rising sea levels and ameliorating climate. The climate of the "Birch-Poplar" rise in the terminal Pleistocene may have forced the extinction of obligate grazers such as mammoth and horse, but it seems to have favored other taxa such as bison and elk, at least until 9000 yr BP. Faunal data from the Broken Mammoth site in the central Tanana valley, with good organic preservation, demonstrate the utilization of a wide diversity of taxa, including small game, waterfowl, and fish. Faunal and sedimentological data give slight support to a Younger Dryas reversal, but this was dwarfed by the mid-Holocene period of dry, windy conditions during which interior Alaska may have been largely abandoned.

You, S. C. (2001). "Agricultural adaptation of climate change in China." Journal of Environmental Sciences (China) **13**(2): 192-197.

This paper presents the study on agriculture adaptation to climate change by adopting the assumed land use change strategy to resist the water shortage and to build the capacity to adapt the expected climate change in the northern China. The cost-benefit analysis result shows that assumed land use change from high water consuming rice cultivation to other crops is very effective. Over 7 billions m³ of water can be saved. Potential conflicts between different social interest groups, different regions, demand and supply, and present and future interests have been analyzed for to form a policy to implement the adaptation strategy. Trade, usually taken as one of adaptation strategies, was suggested as a policy option for to support land use change, which not only meets the consumption demand, but also, in terms of resources, imports water resources.

Yuan, D., Cheng, H., Edwards, R. L., Dykoski, C. A., Kelly, M. J., Zhang, M., Qing, J., Lin, Y., Wang, Y., Wu, J., Dorale, J. A., An, Z., Cai, Y. (2004). "Timing, duration, and transitions of the last Interglacial Asian monsoon." Science **304**: 575-578.

Thorium-230 ages and oxygen isotope ratios of stalagmites from Dongge Cave, China, characterize the Asian Monsoon and low-latitude precipitation over the past 160,000 years. Numerous abrupt changes in ¹⁸O/¹⁶O values result from changes in tropical and subtropical precipitation driven by insolation and millennial-scale circulation shifts. The Last Interglacial Monsoon lasted 9.7 ± 1.1 thousand years, beginning with an abrupt (less than 200 years) drop in ¹⁸O/¹⁶O values 129.3 ± 0.9 thousand years ago and ending with an abrupt (less than 300 years) rise in ¹⁸O/¹⁶O values 119.6 ± 0.6 thousand years ago. The start coincides with insolation rise and measures of full interglacial conditions, indicating that insolation triggered the final rise to full interglacial conditions.

Wade, R. (1985). "The market for public office: Why the Indian state is not better at development." World Development **13**(4): 467-497.

How and why officials are transferred from one post to another can—in India, does—have far-reaching consequences for the effectiveness of public service organizations, such as Irrigation, Agriculture, Forestry and Soil Conservation Departments. The transfer mechanism used in many departments of Indian states involves a kind of 'internal labor market' (a truer market than in the way that term is often used by labor market economists). It allows pressures for corrupt behavior to bear down on the incumbents of certain posts, and itself amplifies those pressures. Frequently, the pressures on officials to be corrupt cause them to behave in ways contrary to the ostensible objectives of their

departments. Why is the Indian state not better at promoting development? To an important degree, because of the corruption-transfer mechanism and its effects on bureaucratic initiatives.

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society* 9(2): 5. [online] URL: <http://www.ecologyandsociety.org/vol9/iss2/art5>

The concept of resilience has evolved considerably since Holling's (1973) seminal paper. Different interpretations of what is meant by resilience, however, cause confusion. Resilience of a system needs to be considered in terms of the attributes that govern the system's dynamics. Three related attributes of social–ecological systems (SESs) determine their future trajectories: resilience, adaptability, and transformability. Resilience (the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks) has four components—latitude, resistance, precariousness, and panarchy—most readily portrayed using the metaphor of a stability landscape. Adaptability is the capacity of actors in the system to influence resilience (in a SES, essentially to manage it).

There are four general ways in which this can be done, corresponding to the four aspects of resilience. Adaptability is the capacity of actors in a system to influence resilience. In a SES, this amounts to the capacity of humans to manage resilience. A characteristic feature of complex adaptive systems is self-organization without intent (Levin 1998), and although the dynamics of SESs are dominated by individual human actors who do exhibit intent, the system as a whole does not (as in the case of a market). Nevertheless, because human actions dominate in SESs, adaptability of the system is mainly a function of the social component—the individuals and groups acting to manage the system. Their actions influence resilience, either intentionally or unintentionally. Their collective capacity to manage resilience, intentionally, determines whether they can successfully avoid crossing into an undesirable system regime, or succeed in crossing back into a desirable one. There are four ways to do this, corresponding to the four aspects of resilience. Actors can move thresholds away from or closer to the current state of the system (by altering (1) above), move the current state of the system away from or closer to the threshold (altering 3), or make the threshold more difficult or easier to reach (altering 2). In addition, actors can manage cross-scale interactions to avoid or generate loss of resilience at the largest and most socially catastrophic scales (altering 4).

Transformability is the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable. The

implications of this interpretation of SES dynamics for sustainability science include changing the focus from seeking optimal states and the determinants of maximum sustainable yield (the MSY paradigm), to resilience analysis, adaptive resource management, and adaptive governance.

Wamukonya, N. and M. Skutsch. (2002). Gender angle to the climate change negotiations." *Energy & Environment* **13**(1): 115-124.

The South is likely to suffer more from climate change than the North due to its already vulnerable situation and lack of the necessary resources to adapt to change. But do the interests of men and of women differ as regards climate change and does this have a South-North dimension? This paper attempts to establish whether gender issues need to be addressed in the climate change debate. Towards this goal, a number of different issues within the climate change debate, in particular the instruments proposed, are analysed. These include responsibility for emission of greenhouse gases (GHGs), studies on vulnerability to the effects of climate change, mitigation of emissions, capacity building for participation in flexible mechanisms and adaptation to climate change. Authors conclude that while there are many gender angles related to the climate change convention and the instruments therein, some are more strategic than others. There is little to be gained by looking at the responsibility for emissions on a gendered basis. But in mitigation activities, Clean Development Mechanism (CDM), capacity building, technology transfer, vulnerability studies and projects for adaptation, the poor, the majority of who are women, should be targeted and active participants in decision-making.

Wang, S., T. Zhou, J. Cai, J. Zhu, Z. Xie, and D. Gong. (2004). "Abrupt Climate Change around 4 ka BP: Role of the Thermohaline Circulation as Indicated by a GCM Experiment." *Advances in Atmospheric Sciences* **21**(2): 291–295.

A great deal of palaeoenvironmental and palaeoclimatic evidence suggests that a predominant temperature drop and an aridification occurred at ca. 4.0 ka BP. Palaeoclimate studies in China support this deduction. The collapse of ancient civilizations at ca. 4.0 ka BP in the Nile Valley and Mesopotamia has been attributed to climate-induced aridification. A widespread alternation of the ancient cultures was also found in China at ca. 4.0 ka BP in concert with the collapse of the civilizations in the Old World. Palaeoclimatic studies indicate that the abrupt climate change at 4.0 ka BP is one of the realizations of the cold phase in millennial scale climate oscillations, which may be related to the modulation of the Thermohaline Circulation (THC) over the Atlantic Ocean. Therefore, this study conducts a numerical experiment of a GCM with SST forcing to simulate the impact of the weakening of the THC. Results show a drop in temperature from

North Europe, the northern middle East Asia, and northern East Asia and a significant reduction of precipitation in East Africa, the Middle East, the Indian Peninsula, and the Yellow River Valley. This seems to support the idea that coldness and aridification at ca. 4.0 ka BP was caused by the weakening of the THC.

Of course, it is not held that climate deterioration is the only factor that can be used to interpret the collapse or alternation of ancient civilizations. Also, the weakening of the THC is, perhaps, only one of the possible factors responsible for the deterioration of the climate in ca. 4.0 ka BP. However, synthesis studies of climate change and numerical experiments conducted by the authors indicated that the weakening of the THC is one of the most probable factors that caused or accelerated changes in the civilizations in 4.0 ka BP. Of course, the circulation mechanisms and climate processes responsible for the drop in temperature are yet to be understood. Interactions between the THC and atmospheric circulation should also be considered. Therefore, the present paper is preliminary in character. Its central idea is to emphasize the possible important role of the weakening of the THC in the climate alternation, and then in the collapse and alternation of ancient civilizations in ca. 4 ka BP.

Weiss, B. (1982) "The decline of late Bronze Age civilisation as a possible response to climatic change." *Climatic Change* 4(2): 173-198.

The disintegration of E Mediterranean civilization at the end of the late Bronze Age has traditionally been attributed to the arrival of new peoples. However, the nearly contemporaneous decline of highly organized and powerful states in Greece, Anatolia, Egypt, and Mesopotamia warrants consideration of possible environmental causes likely to operate over sizable areas, especially since archaeological research has not succeeded in establishing the presence of newcomers at the onset of the Bronze Age disturbances. Climatic change is a particularly attractive candidate since temperature and precipitation variations persisting over relatively short times can adversely affect agricultural output. It is hypothesized here that a drought induced migration of Luwian peoples from W Antolia occurred early in the 12th century BC, that it was associated in some fashion with the invasion of Egypt by the 'Sea Peoples' in the reign of Ramesses III, and that the defeated remnants of these peoples settled along the Levantine coast and filtered into N Syria and the upper Euphrates valley.

Weiss, H., M.-A. Courty, W. Wetterstrom, F. Guichard, L. Senior, R. Meadow, A. Curnow. (1993). "The Genesis and collapse of third millennium North Mesopotamian civilization?" *Science* 261: 995-1004.

Weiss, H. and R. S. Bradley. (2001). "What drives societal collapse?" Science **291**: 609-610.

The archaeological and historical record shows many instances of societal collapse. These events have traditionally been explained by a combination of social, political, and economic factors. Authors argue that there is increasing evidence for climate as the primary agent in the collapse of prehistoric and early historic societies. They also consider the possible effects of future anthropogenic climate change.

Weiss, E. (2002). "Drought-related changes in two hunter-gatherer California populations." Quaternary Research **58**(3): 393-396.

Skeletal remains from two California cemeteries bracketing a severe drought that began around 1200 yr B.P. are analyzed to determine drought-related quality of life changes in Native Americans. Cemetery 1 predates the drought at 2895 ± 160 yr B.P. to 1845 ± 90 yr B.P. and Cemetery 2 dates it at 1100 ± 90 yr B.P. to 1220 ± 200 yr B.P. Quality of life was assessed through femoral computerized tomography scan measures of cortical thickness, age at adult death, and pathology/trauma frequency. After controlling for age and sex differences, changes from Cemetery 1 to Cemetery 2 showed decreases in cortical thickness and age at death and increases in pathology and trauma frequency.

Weng, Q. (2000). "Human-environment interactions in agricultural land use in a South China's wetland region: a study on the Zhujiang Delta in the Holocene." GeoJournal **51**(3): 191-202.

The formation and evolution of agricultural land uses in the Zhujiang Delta of south China are examined in the light of the dynamics of people and the environment and their interplay. The origin and propagation of agriculture are found to have a close relationship with the climate and sea level changes in the Holocene era. The development of rice cultivation, horticulture, and dike-pond system exemplifies human-environment interactions in a specified geographical and social context, which are manifested by the impact of environmental changes and population growth on agricultural innovations. The technologies of dike building and land reclamation, which represent local farmers effort to build a new and harmonious relationship with the changed environment, were critical to the agricultural success and sustainability. Imprudent use of a new agricultural technology could damage the environment, as evidenced by a frequent flooding that followed inappropriate dike building and premature reclamation. Diverse agricultural land uses are as a result of the adaptation of agricultural technology innovations to the environmental conditions.

Whitehead, A. (2002). "Tracking livelihood change: theoretical, methodological and empirical perspectives from North-East Ghana." Journal of Southern African Studies **28**(3): 575-598.

This paper discusses a methodology in which livelihood change is investigated through the livelihood strategies of individually traced households that have been studied at two separate points in time. The area studied is in the north of Ghana, where anthropological fieldwork was carried out in 1975 and again in 1989. The paper discusses significant changes in the macro-context between the two dates and then examines three linked case study households. Some of the processes of household accumulation and impoverishment become evident in the detailed accounts of changes in household membership and in livelihoods. The case studies show individuals and household heads making strategic choices, in circumstances where the room for manoeuvre is very limited. Climate change, government economic policy centred on adjustment measures and changes in the local and national markets for labour and products created a highly constrained and unpredictable environment for individuals and households. However, to make these arguments, the paper also draws on the findings from the author's quantitative surveys from several nearby communities and from more macrolevel research, so the use of the matched case studies is set within research of considerable complexity and duration. Some of the most significant processes are uncovered when case study data collected in qualitative surveys are filled out with data collected in the course of ethnographic research. Equally important is the additional secondary and historical research that allows links to be made between micro and macrolevels. The paper concludes that using panel case studies is a potentially very useful complementary method, but it is not a short cut.

Williams, P. R. (2002). Rethinking disaster-induced collapse in the demise of the Andean highland states: Wari and Tiwanaku." World Archaeology **33**(3): 361-374.

The role of drought in the collapse of the ancient states of the Andean Middle Horizon has received a great deal of attention in recent years. The only Andean valley where both principal states of this time period, Wari and Tiwanaku, had established settlements is in Moquegua, Peru. Based on a GIS network analysis of ancient irrigation systems and detailed palaeoclimatic data, Author assesses the assertion that a centuries-long drought caused the collapse of state colonies in this valley circa AD 1000. It is concluded that the onset of the drought significantly postdated collapse and suggest that factions of Tiwanaku social groups who allied themselves with Wari settlers upset the ecological balance of water use in the valley prior to the end of the first millennium AD. The increase in agricultural activity in the upper sierra in conjunction with the political instability caused by the fissioning of Tiwanaku political power in the valley created an

environment of vulnerability for the Tiwanaku state colonies. It was the complex interaction of social and ecological factors that led to the collapse of the largest western colony of the Tiwanaku state. The Wari imperial colony played a pivotal role in this collapse by establishing an administrative center in the upper valley that drew away resources from the Tiwanaku state below. Ironically, the political instability caused by the Tiwanaku colonial collapse may have been instrumental in the downfall of the Wari colony as well.

Willis, K. J., L. Gillson, T. M. Brncic. (2004). "How "virgin" is virgin rainforest?" *Science* **304**: 402-403.

The three largest undisturbed rainforest blocks remaining worldwide are located in the Amazon basin, Congo basin, and the Indo-Malay region of Southeast Asia. Authors discuss a number of recent archaeological and paleoecological studies that reveal disturbance of these tropical rainforests by prehistoric human settlements and their subsequent regeneration once the human populations moved on or died out. This suggests that given sufficient time, tropical rainforests disturbed by modern human activities may be able to regenerate.

Wirtz, K. W. and C. A. Lemmen. (2003). "Global dynamic model for the Neolithic transition." *Climatic Change* **59**(3): 333-367.

During the Holocene strong gradients in the distribution of technology including subsistence ways emerged on a global scale. These patterns were further amplified in historic times and are still visible through worldwide differences in national wealth. In order to evaluate major factors responsible for the shift from foraging to food production authors here employ quantitative methods by developing a deterministic but simple model. After compiling existing maps of potential vegetation at 5000 BP the inhabited world is split into 197 regions with homogeneous environmental conditions. Suitable variables for the macro-economic and cultural development in the Neolithic period are found to be farming to hunting-gathering ratio, number of agricultural economies and a technological development index. The model explicitly describes economic adaptation, growth and migration of human populations together with the spread of their cultural characteristics; it accounts for over-exploitation of natural resources, crowding mortality and the climate variability on a millennium scale. In a thorough model validation region specific trajectories are compared to archaeological evidence revealing a high correspondence. Major parts of the known sequence of Neolithic centers including the timing differences are robustly reproduced. A series of known problems in prehistory is discussed comprising the lag between domestication and full scale farming, the off-leveling of the

technological boost following the transition, the emergence of distinct migration waves and sensitivity to climate fluctuations. Not mere population pressure but continuous innovation and competition between subsistence strategies is identified as a prime mover of agricultural development. The results suggest that few aspects of biogeography may have determined the observed continental gradients in the number of domesticable species ultimately leading to an increasing differentiation in technology and demography.

Wu, W. X., T. S. Liu. (2004) Possible role of the "Holocene Event 3" on the collapse of neolithic cultures around the Central Plain of China. Quaternary International **117**: 153-166.

In recent years there has been an increase in interdisciplinary studies of paleoenvironments and their role on social processes, especially the rise and fall of pristine civilizations. Special attention is paid to climatic change around 4000 yr BP, which has been termed the "4000 yr BP Event" or the "Holocene Event 3" and its possible role on the collapses of ancient civilizations in Egypt, Indus, and Mesopotamia. Profound archaeological transformations that mark the collapse of Neolithic Cultures around Central China during the late third millennium BC have been identified widely. However, the causes for their collapse have been disputed. In this paper, paleoclimatic data are synthesized to show that an interval of severe climatic anomalies occurred across much of China, which were synchronous with a climatic event identified at least in the Northern Hemisphere. Our syntheses also indicate that this climatic interval was not only one of several climatic events during the Holocene, but marked the middle Holocene climatic transition (the ending of Holocene optimum). Based on geological evidences and analysis of relationships between variations in the intensity of the East Asian monsoon and changes in distributional pattern of monsoon-related rain belts in eastern China, authors suggest that this climatic anomaly was superimposed on the middle Holocene transition and significantly altered the hydrological regime. This generated an environmental framework of drought in the north and flooding in the south of China, which was mainly responsible for the collapse of Neolithic Cultures around the Central Plain.

Yohe, G. (2000). Assessing the role of adaptation in evaluating vulnerability to climate change. Climatic Change **46**(3): 371-390.

Three types of adaptation can influence significantly a system's prospective longevity in the face of climate change. The ability to cope with variation in its current environment can help a system adapt to changes over the longer term. The ability to take advantage of beneficial changes that might coincide with potentially harmful ones can play an even larger role; and focusing attention on maximizing a

system's sustainable lifetime can highlight the potential for extending that time horizon and increasing the likelihood that an alternative structure might be created. A specific economic approach to adaptation demonstrates that research can serve two functions in this regard. Research can play an important role in diminishing future harm suggested by standard impact analyses by focusing attention on systems where adaptation can buy the most time. It can help societies learn how to become more robust under current conditions; and it can lead them to explore mechanisms by which they can exploit potentially beneficial change. Research can also play a critical role in assessing the need for mitigating long-term change by focusing attention on systems where potential adaptation in both the short and long runs is so limited that it is almost impossible to buy any time at all. In these areas, switching to an alternative system or investing in the protection of existing ones are the last lines of defense. Real "windows" of tolerable climate change can be defined only by working in areas where these sorts of adaptive alternatives cannot be uncovered.

Yohe, G. and R. S. J. Tol (2002) "Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity". Global Environmental Change **12**(1): 25-40.

This paper offers a practically motivated method for evaluating systems' abilities to handle external stress. The method is designed to assess the potential contributions of various adaptation options to improving systems' coping capacities by focusing attention directly on the underlying determinants of adaptive capacity. The method should be sufficiently flexible to accommodate diverse applications whose contexts are location specific and path dependent without imposing the straightjacket constraints of a "one size fits all" cookbook approach. Nonetheless, the method should produce unitless indicators that can be employed to judge the relative vulnerabilities of diverse systems to multiple stresses and to their potential interactions. An artificial application is employed to describe the development of the method and to illustrate how it might be applied. Some empirical evidence is offered to underscore the significance of the determinants of adaptive capacity in determining vulnerability; these are the determinants upon which the method is constructed. The method is, finally, applied directly to expert judgments of six different adaptations that could reduce vulnerability in the Netherlands to increased flooding along the Rhine River.

Yu, S., C. Zhu, J. Song, W. Qu. (2000). "Role of climate in the rise and fall of Neolithic cultures on the Yangtze Delta." Boreas **29**(2): 157-165.

Climatic changes in the Yangtze Delta have played an important role in the emergence, persistence and collapse of civilization. Archaeological excavations in

the region over many years have demonstrated that there are several layers of fine sand or organic mud that interrupt the consecutive culture strata in a number of Neolithic culture sites. Continuous biostratigraphical and sedimentological records from the Maqiao cultural site, Shanghai, suggest that the fine sand and organic mud units resulted from expansion of water bodies both by sea-level fluctuations and from increased flooding during cold and humid episodes of Holocene climates. The absence of human settlement from 7240 BP to 5320 BP in the region was mainly caused by higher sea levels resulting from a warm and humid climate. The Neolithic cultures developed under conditions of lower and more stable sea level as well as warmer and dryer climates between about 4410 BP and 3250 BP. A flood-induced lake expansion interrupted the civilization in the region at about 4200 BP. Later, higher water tables and expansion of lakes between 3250 BP and AD 618 under a cold and moist climate temporarily terminated settlement on the delta. Later, during the Tang Dynasty, beginning at about AD 618, the region again became suitable for human settlement under conditions of more favourable climate and lower water tables.

Zhang, H., W. JianWei, Zheng QiuHong, Yu YunJiang. (2003). "A preliminary study of oasis evolution in the Tarim Basin, Xinjiang, China." Journal of Arid Environments 55(3): 545-553.

The causes of oasis evolution in the Tarim Basin of north-west China are discussed. Climate change and human activities play different roles in oasis evolution on different temporal scales. The impacts of climate change on oasis evolution are macroscopic and continuous, while the influences of human activities are local and disconnected. The climate of the Tarim Basin, since the late Pleistocene, has tended towards hyper aridity. The existence of oases has depended entirely on the runoff from thawed glaciers and snow, as well as orographic rainfall. Climate change on a geological scale led to variation of runoff flowing into oases. The alteration of water resources caused by climate change, therefore, was the fatal factor for oasis evolution in the Tarim Basin. Climate change was still the principal factor influencing the oasis evolution during historic times although human activities increasingly impacted oasis evolution in the Tarim Basin with the development of the settled human populations. In historic times, the socio-economic prosperity of oases and their expansion occurred largely during warm periods, while desertification and the deterioration of natural resources in oases mainly occurred during cool periods. Continuous trends of aridity brought about the damage of some ancient states in the oases of the Tarim Basin. Changes in oasis environments in modern times are mainly influenced by human activities in the Tarim Basin. Population growth and improvement of socio-economic conditions lead to the rapid expansion of cultivated land with reclamation and evident shrinkage of native vegetation. Irrational reclamation of

land and utilization of natural resources in oases by humans have had increasingly destructive effects on oasis environments in modern times.

Zhang, Q., Zhu, C., Liu, C. L. and Jiang, T. (2005). "Environmental change and its impacts on human settlement in the Yangtze Delta, P.R. China." *CATENA* **60**(3): 267-277.

Archaeological excavations and environment–archaeology studies over many years in the Yangtze Delta region have provided exceptional information about climatic variations, growth and demise of human civilization and human–environment interactions. The archaeological excavations show that the cultural layers of the Neolithic sites are interrupted by barren layers without any cultural relics (so-called cultural interruptions), which may be the result of harsh environmental conditions (arid, flooding, extreme cold or warmth). Temporal and spatial analyses of ¹⁴C-dates for buried trees, peat, shell ridges, and Neolithic sites show that environmental changes are responsible for the rise and fall of human civilization. The progress of human civilization was interrupted at least 5 times in the Yangtze Delta, matching 5 periods of high sea level, peat accumulation, and burial of trees. The collapse of the Liangzhu culture about 4000 BP was followed by the less-developed Maqiao culture and resulted from extreme environmental and hydrological conditions such as floods.

Zhang, Z. X. (1996). "Some economic aspects of climate change." *International Journal of Environment and Pollution* **6**(2/3): 185-195.

The paper reviews studies on the various economic aspects of climate change discussing the consequences of climate change, damage estimates for a doubling of atmospheric carbon dioxide concentration, and strategies for responding to climate change. These studies show that agricultural loss and loss from sea-level rise form the main sources of damage due to a doubling of carbon dioxide concentration. There is general agreement that less developed countries will suffer more than their developed counterparts, with China being the region hardest hit, but uncertainties regarding the magnitude of impacts exist. As a result agreement on choice of response strategy is hard to reach. Strategies described include the 'do nothing' vs 'do something' stance; the 'no-regrets' vs 'regrets' policies; limitation vs. adaptation strategies; and the 'hedging' strategy. It is concluded that the hedging strategy should be favoured as it avoids extreme and rigid mandates but pursues a number of low-cost options for preparing the ground should more severe measures be required later.

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