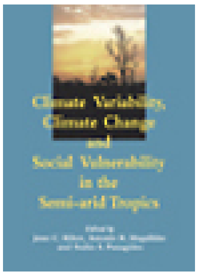

Climate Variability, Climate Change and Social Vulnerability in the Semi-arid Tropics

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1: Climate Variation, Vulnerability and Sustainable Development in the Semi-arid Tropics

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INTRODUCTION

This chapter aims to capture the central issues that emerged from the papers, presentations and discussions at the International Conference on the Impacts of Climatic Variations and Sustainable Development in Semi-arid Regions (ICID), held in Fortaleza-Ceará, Brazil from 27 January through 1 February 1992 (see Preface). But, given the breadth and depth of the 76 papers and the wide-ranging discussions during the conference, this chapter could cover only a small subset of the issues that arose. We chose to focus on the plight of socially, politically, economically and spatially marginal populations in semi-arid lands, and the urgent need for environmentally sound and equitable development efforts. These themes recurred throughout the papers, presentations and discussions at the conference.

This chapter draws from the materials and information presented at the conference, as well as the broader literature where relevant. While the themes within this chapter are derived largely from the conference, the arguments are shaped – as could not have been otherwise – by the experiences and perspectives of the authors. We did not try to represent the scope nor the depth of the issues covered at the conference, but rather, to characterize the problems and opportunities, and to explore what we felt were the most pressing concerns within the semi-arid regions of the world.

Climate variability, natural resources and development in semi-arid regions

Vulnerability to dislocation, hunger and famine are the most critical problems facing the inhabitants of semi-arid lands. These regions are subject to extreme variations in their relatively scant seasonal and inter-annual precipitation, resulting in recurrent droughts and floods. Natural resources of semi-arid zones, such as timely water supplies, fertile soils, vegetation and wildlife, tend to be scarce, and the existing resources are easily damaged by changes in precipitation patterns and by human action. Many of the semi-arid regions of the world, particularly the semi-arid tropics, are also characterized by subsistence vulnerability and insecurity for the large majority of their rural populations in the face of land degradation and climate variation. Vulnerability, social and geographic marginality, environmental change and dry-land degradation are central, interlinked and chronic problems.

Semi-arid regions cover between 13% and 16% of the earth's land area, and are home to approximately 10% of the global population (Heathcote, this volume).[1] They exist in tropical, sub-tropical and temperate zones and fall within or encompass both developed and underdeveloped nations (see Fig. 1). In developed areas, the southwestern United States, and parts of the Western Plains of Canada and the periphery of the Australian desert are semi-arid (see, for example, Cohen *et al.* 1992; Rosenberg and Crosson 1992; Schmandt and Ward 1992; Heathcote, this volume). The semi-arid tropics encompass large portions of the least-developed regions on earth. Of the 22 countries of Africa's Sudano-Sahelian region 18 are among the world's least-developed nations (Wang'ati, this volume). Brazil's semi-arid Northeast is its most economically deprived region (Magalhães and Glantz 1992). Semi-arid tropics also include Mexico's Central Plateau, parts of Argentina, Chile and Uruguay, Central and South India, western China (22% of the country), and northern Mongolia (Sen 1987; Drèze and Sen 1989; Tie Sheng *et al.* 1992; Zhao, this volume). Many of these regions are highly prone to anthropogenic and climatically related environmental deterioration, while their populations are prone to hunger and famine. Indeed, it is at this conjunction of climatic variability and underdevelopment that human vulnerability and calamitous social dislocations are most likely to occur.

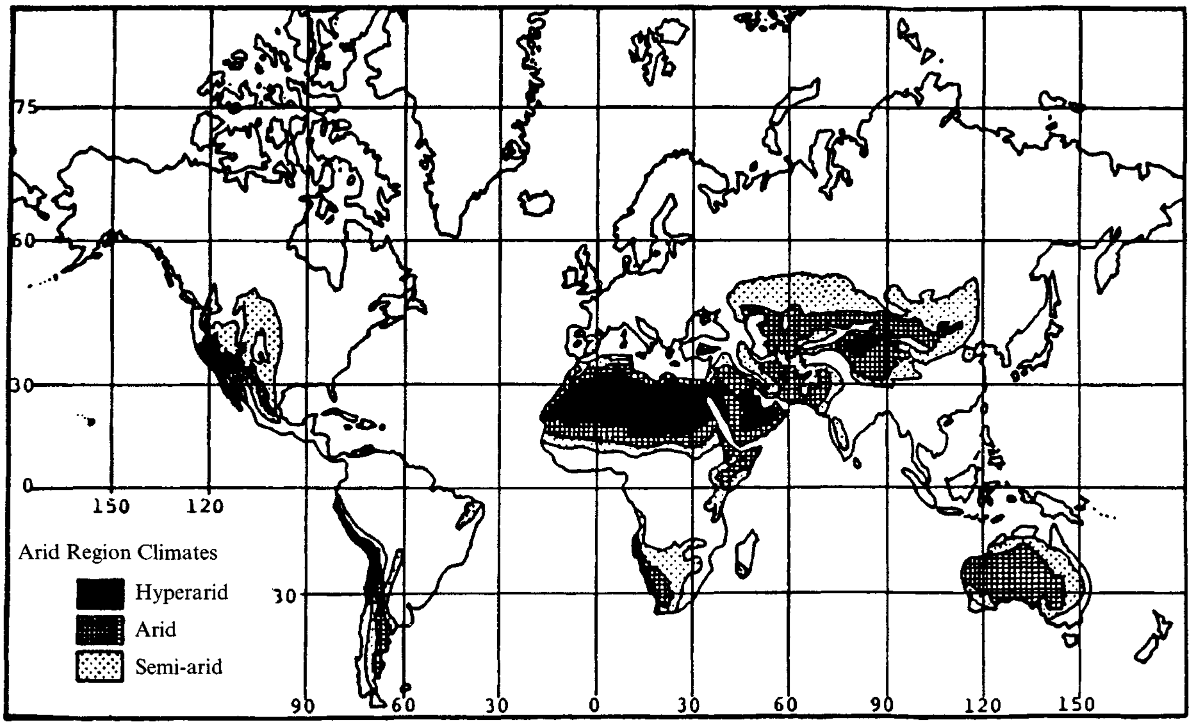

Figure 1: Arid and semi-arid regions of the world. (Source: Campos-Lopez and Anderson 1983:54.)

While rainfall, droughts and floods are physical phenomena, associated socioeconomic consequences (economic failure, food shortages and outmigration) are linked to the ability of affected populations to anticipate, prepare for and respond to these events. The most striking characteristic of the vast majority of the populations inhabiting the semi-arid tropics is their lack of adequate human and financial resources to cope with expected – even at times (with early-warning systems) predictable – variability in their climatic regimes (on early-warning systems, see Nobre *et al.* 1992; Servain *et al.* 1992; Wang'ati, this volume). Because of poor human, natural-resource and infrastructural development in these regions, large portions of the population of semi-arid tropics are vulnerable to hunger, famine, dislocation and the loss of both property and livelihood in the face of climatic, social, political or economic shocks. For the most part, their lives are shaped by chronic job and food insecurity, inadequate, and in many cases non-existent, health care, low wages, unemployment, under-employment and illiteracy, all of which tend to amplify the social consequences of natural phenomena.

Marginality and a low level of economic development both exacerbate and are exacerbated by environmental changes such as dryland degradation and deforestation.[2] Exploited or marginalized populations are often excluded from or bypassed by benefits of the development process, and are pushed against their resource base, further eroding its productive capacity. Mining the land (e.g. using land resources in a manner that reduces productivity in the long run) often becomes a necessity for those whose immediate survival depends on these lands (Bernstein 1979; de Janvry 1981; Blaikie 1985; Blaikie and Brookfield 1987). Those who are marginalized by the economic process onto the most economically and ecologically marginal lands are the most vulnerable populations. Under some conditions their marginality intensifies as they, and the marginal lands on which they subsist, are exploited beyond their productive capacity. The important question with respect to vulnerability in the face of climate variability and change is why and how these populations are marginalized and, hence, vulnerable. It is this question that guides our attention to the social determinants of vulnerability.

Antonio Rocha Magalhães (1991:1) brings into focus both who is vulnerable and why, when he characterizes the critical nature of society's relation to the natural environment in Northeast Brazil:

> Over the course of history, the economic, social and environmental impacts of adverse climatic events, especially droughts, have been calamitous. It is, however, the social dimension that accentuates the climatic problem in Northeast Brazil, as in many other developing regions. Here it represents a menace for the survival of a major part of the population because, unlike developed regions, the social agents are not equipped to face the consequences of adverse climatic events.

This chapter examines problems of the less-developed semi-arid regions, because these regions are in most urgent need of attention. Likewise, we focus on development as the path toward an environmentally secure and productive future.

Climate change

The regional consequences of anthropogenically enhanced global warming cannot yet be predicted with confidence. But some impacts are probable. Increases in temperature will result in an increase in evapotranspiration. This increase will be particularly significant in places where the climate is hot under current conditions. Whether rainfall in these regions will increase or decrease remains highly uncertain. But, the Inter-governmental Panel on Climate Change (IPCC 1990:iii, 12–13, and 20 ff.) indicates that semi-arid regions are among those areas most likely to experience increased climatic stress. Further, climatic change will have as yet unpredictable and perhaps unexpectedly extreme consequences with respect to frequency and intensity of precipitation and temperature variability for semi-arid regions.

Several regional climate-change scenarios designed to identify possible implications of global warming for semi-arid lands were generated by climatologists and social scientists and presented at the ICID conference. The tremendous uncertainty involved in projecting regional climate change is compounded by uncertainties in future productive capacities, demographic changes and socioeconomic development in these regions (see under Climate Variability and Change, below, for a discussion of these factors). There are nonetheless lessons that can be derived from climate change simulations and scenarios. For Mexico, O'Brien and Liverman (this volume) found decreasing soil moisture predicted by all climate-change models applied to Mexico. If soil moisture decreases in semi-arid regions, as can be derived from some general circulation models (GCMs) and is assumed in most of these scenarios, then productivity in these regions will most certainly decrease in the absence of considerable development efforts (Magalhães 1991; Downing 1992; El-Shahawy 1992; Schmandt and Ward 1992; Santibáñez 1992; Selvarajan and Sinha 1992; Cohen *et al.* 1992; O'Brien and Liverman, this volume). Most of the scenarios project worsening climatic conditions, in the form of more frequent droughts and shorter growing seasons. Some point to the possibility of a higher degree of inter-annual climate variability and of unexpected extreme meteorological events such as cool periods or more frequent floods (Izrael 1992:2–5). For these regions in which planning productive activities is already difficult due to the high climatic variability, climate change introduces even greater uncertainties and, thus, greater risks. A better regional understanding of climate change will help in planning for its consequences. But this is an insufficient policy response to the needs of semi-arid regions. To help cope with future regional uncertainties generated by climate warming, policy makers must also address issues associated with current climate variability. Policies to address problems of populations living under current variability will be an invaluable basis for coping and adapting should climate change increase variability or drought.

Even assuming continued current climatic conditions, semi-arid regions may well be worse off in 10, 20 or 30 years due to the declining productivity of the land and increasing populations without access to alternative income-generating options (see, for example, Wang'ati, this volume). Indeed, the magnitude of natural hazard losses has increased in the past even where meteorological records do not show increasing severity of weather events (see chapters by Glantz, by O'Brien and Liverman, and by Heathcote, this volume). Simply projecting dryland degradation, for example, highlights the need for long-term strategies to stop or reverse these trends in order to improve the productive capacity and security of populations in semi-arid regions. Each year large areas are being at least temporarily worked to the point of declining productivity (Ocana 1991:3; WRI 1991, 1992).

Today, in the semi-arid regions, vulnerability to the consequences of existing climate variation is already a major problem. Dryland degradation is widespread and progressive, while semi-arid populations are growing. These trends only compound the vulnerability of people and of social systems. Without addressing current problems, future vulnerability can only get worse, exacerbated or not by climate change, making the magnitude of future crises even greater. By addressing today's vulnerability we can increase the ability of semi-arid regions to adapt to and cope with the as yet unknown characteristics of a future climate change. Actions taken today to reduce vulnerability – actions which have been justified for a long time – will increase resilience and security by providing a buffer against vulnerability to future consequences of climate change. These are called 'no-regrets policies,' since they are valuable actions regardless of climate change probabilities.

From impacts to vulnerability and beyond

Climate *impact* assessment addresses the magnitude and distribution of the consequences of climate variability and change. *Vulnerability* assessment extends impact assessment by highlighting *who* (as in what geographic or socioeconomic groups) is susceptible, *how* susceptible they are, and *why*. Clearly these assessments are overlapping and interlinked. For informed policy-making purposes, both are necessary and neither is sufficient. Vulnerability analysis ensures that the assessment of impacts will be extended into the realm of social, political and economic causality that shapes susceptibility to impacts. Understanding causality, facilitates appropriate policy design.

Climate impact analysis often focuses on the range of consequences of a given climate event. Examining impacts is a way of looking at the range of consequences of a given stimulus. For instance, drought is associated with a number of outcomes including reduced crop yield, reservoir depletion, hydroelectric interruptions, dryland degradation, and some second-order effects such as economic loss, hunger, famine or dislocation. This type of analysis helps to focus attention on the range of outcomes associated with climate variability or change. But it is somewhat misleading to designate these as *climate* impacts, since they are usually the result of a *multitude* of causal agents. These may include level of development, market organization and prices, entitlement structures, access to productive resources, distribution, state policies, and local or regional conflicts (Blaikie 1985; Watts 1987*a*; Drèze and Sen 1989; Downing 1991, 1992; Schmink 1992). It is some combination of these factors, not the singular result of drought, that makes a family, household, enterprise, nation or region vulnerable. Vulnerability occurs at a conjuncture of physical, social and political-economic processes and events. Hence, complete climate impact analyses must include this multi-causal perspective, placing climate as one causal agent among many.

Downing (1992) presents a method for analyzing vulnerability in which he lays the groundwork for examining this conjuncture in a systematic way. In Downing's framework, vulnerability focuses on *consequences* such as dislocation, that is, vulnerability to having to migrate to the city or to some other frontier. Drought might be considered a cause, even a trigger of outmigration. But, outmigration is also examined as a function of such factors as exploitation, the lack of local alternative income opportunities or high food prices. So, this analysis aims to reveal the range of causes of this outcome – which is of particular social concern – rather than focusing on the impacts of one of many causes or triggering events.

Analysis of vulnerability focuses on the *relative* likelihood of different socioeconomic groups of geographic regions to experiencing each outcome. Hence, relative levels of vulnerability to hunger can be mapped out spatially (see, for example, Box 3, p. 30), temporally and socially. Spatial factors might include location on the rainfall gradient or on a geopolitical map, location with respect to transport or marketing systems, or *vis-à-vis* soil types and other geo-climatological factors. Temporal factors might include coincidence with an economic recession or depression, or perhaps the particular moment in political or development history of a region or country. And socioeconomic factors would include the level of economic development, type of livelihood, level of education, political party or socioeconomic group (gender, class, ethnic group, caste or religion).

By understanding socioeconomic and political factors associated with vulnerability, one can begin to trace out the chains of causal forces and relations that impinge on a given instance of environmentally related vulnerability, chronic deprivation or crisis. In the same way that human vulnerability is shaped by a multitude of causal agents, land degradation, deforestation and other forms of resource degradation are also located within a nested set of causal agents. They too can be evaluated in a similar way (see Blaikie 1985; Blaikie and Brookfield 1987; Schmink 1992). With an understanding of causality, appropriate policy responses can be developed to redress the causes of vulnerability, rather than just responding to its symptoms.

To address each of the causes of vulnerability or environmental decline might require policy interventions at different levels. Political-economic and geographical analysis of vulnerability's causes can be specific enough to allow policies to be tailored for a specific population, place and problem. And finally, since causality can be traced to international, national, household and individual levels, policies can be targeted at the appropriate level if the causes are understood.

In short, the object of vulnerability analysis is to link impact analysis to an understanding of the causes of vulnerability in order to facilitate a meaningful policy process. But, in carrying out such an analysis, one must be extremely careful not to mix correlation with causality. To map out the proximate vulnerability factors, such as location, livelihood, education and income level, tells only part of the story. Without looking at structural causes, such as the way in which the farm economy is embedded within a larger extractive economy, it is difficult to target extractive mechanisms, such as rent structures, sharecropping contracts, usurious credit arrangements, terms of trade and tax structures as causes of vulnerability and environmental decline (de Janvry and Kramer 1979; Deere and de Janvry 1984; Bitoun *et al.*, this volume). Hence, to reduce vulnerability, policy analysts must go beyond identifying its proximate causes to evaluating the multiple causal structures and processes at the individual, household, national and international levels.

We highlight this aspect of climate impact analysis since it (1) allows for a multi-level, multi-sectoral policy analysis, and (2) facilitates the analysis of both proximate causal factors and the broader political-economic forces that shape vulnerability.

Toward ecologically sound development

Access to education, employment, credit, licenses, markets, a healthy environment, land and labor are integral for development. Those on the social and geographical margins need to be able to diversify their income-generating activities in order to reduce their vulnerability. They need an income sufficient to invest in the maintenance of their land and in the stocking of buffers against adverse climatic events, as well as in non-climate-dependent production and survival strategies. The inability of peasant farmers to save and obtain necessary productive resources is a primary structural constraint on their ability to maintain and improve marginal agricultural land. Hence, poor access to infrastructure, inputs, markets, land and credit must be redressed in order to reduce or reverse the rural ecological decline currently under way in much of the semi-arid tropics around the globe. But, given that the processes of differentiation and marginalization that produce the current distribution of assets and patterns of access are ongoing, changes in access must be accompanied by political access to assure that resource access is maintained. They must be accompanied by enfranchisement and inclusion in the political processes (see Drèze and Sen 1989; Watts and Bohle 1993).

An important strategy for relieving a population's pressures on the land and raising rural and urban incomes is to support the development of diverse income-generating opportunities. Diversification of local economies also buffers against severe climatic events. In some regions this may mean fostering existing local productive activities or small-scale enterprises, and in others, encouraging regional pockets of industrialization. Such development is aimed at relieving the local pressures on the resource base and building a buffer against the inherent climatic variability of these regions. But diversification and development will accomplish little if the profits they generate are extracted from the regions and/or concentrated in the hands of a few.

International assistance may be needed for some types of development programs, as well as for avoiding potential ecological problems stemming from development in these regions. In addition, rising greenhouse gas emissions in these regions may need to be offset by reduced emissions or by forest-augmented sequestering elsewhere, such as in the industrial nations of the world. Given the severity of the existing problems the inhabitants and governments of these regions face, they will only be able to address these secondary, less immediate problems of industrial pollution and the emission of greenhouse gases by developing industries with outside assistance. With increased levels of development, the capacity to treat and prevent environmental problems and social vulnerability will increase, and these regions may then move in the direction of more environmentally sound economic-development strategies.

Conclusion

It is important to reduce the emission of gases that are projected to change the world's climate. It is also important to evaluate how that climate change will affect future populations and the future sustainability of the productive natural-resource base. But it is equally, if not more important to examine the current environmental degradation and the livelihood insecurity of the vast majority of people living in the world's semi-arid lands. For today's environmental decline will increase tomorrow's vulnerability. Today's vulnerability will reduce tomorrow's resilience. Today's underdevelopment will undermine the potential for increasing future resilience, productivity and development.

There is an old solution to the problems these regions face, and that is development. But this new development effort must occur within the ecological constraints. These constraints are integrally linked to the wellbeing of the most marginal people in these lands. There are numerous technical and institutional measures that can be taken to ameliorate current problems, most of which are worth while even without the specter of global warming – these are the 'no-regrets' strategies. But ultimately, addressing the struggles of the most vulnerable populations in semi-arid areas is what will help them move beyond 'no regrets' to more far-reaching environment and development policies.

The remainder of this chapter is organized into four sections. The first is Semi-arid Regions, in which the characteristics and problems of semi-arid lands are discussed. The second is Climate Variability and Change, which outlines the models and their limitations. The third is Responses, in which some approaches and options for development in semi-arid lands are discussed. A brief conclusion follows.

Table 1. *Land area within arid and semi-arid zones in developing regions (%)*

	Africa	Central America	South America	SE Asia	SW Asia, Middle East
Arid and semi-arid lands	66	60	31	33	80
Semi-arid lands	16	22	17	21	12

Source: Adapted from WRI (1990:287).

SEMI-ARID REGIONS

Characteristics

Semi-arid regions are characterized by dry, warm-to-hot extensions of land with low and erratic rainfall, thin and nutrient-poor soils which are prone to salinization, and limited or discontinuous natural vegetation cover (see Fig. 1, depicting the semi-arid regions of the world, and Table 1, showing the proportions of the developing world's land areas

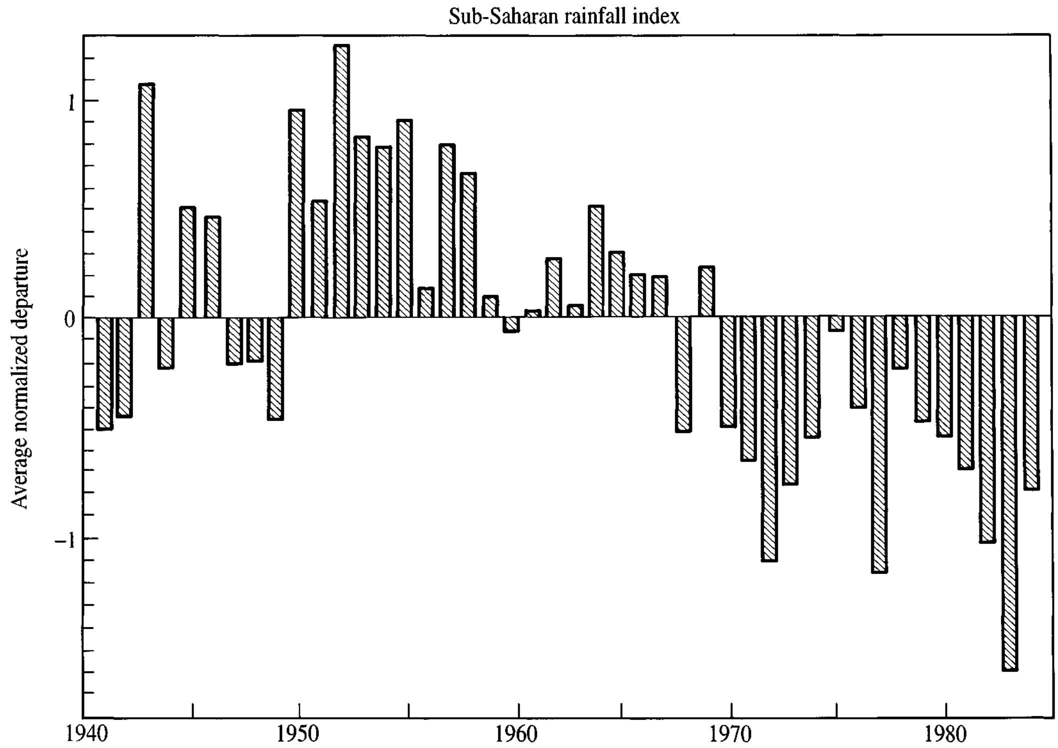

Figure 2: Twenty-year precipitation phases in the Sahel. (Source: Glantz 1989:49.)

that are arid and semi-arid). Drought events, or periods of prolonged dry spells, are inherent characteristics of semi-arid regions. While some semi-arid regions experience season-to-season dry spells, in other semi-arid regions, the dry and wet cycles are much longer, with dry periods extending over a number of years (see, for example, Fig. 2, showing 20-year wet and dry phases in the Sahel). While the vegetation growing in semi-arid regions is well adapted to extreme conditions, the ecosystems are vulnerable to environmental degradation from climatic events and human interventions.

Water is the most precious and limiting factor in agricultural, industrial and urban development in semi-arid lands. Limited water, along with nutrient-poor soils, overgrazing, intensive agricultural practices and mineral extraction, easily surpass the regenerative capacity of the semi-arid ecosystem. They can strip semi-arid ecosystems of their protective vegetation, leading to a process of soil erosion and desiccation, reduced water retention, and ultimately at times desertification (Swindale 1992; Zhao, this volume; Rodrigues *et al.* 1992; UCAR 1991). The term 'desertification' is usually reserved for permanent land degradation. There is, however, considerable debate over the permanence of most land degradation (see the discussion below under Dryland Degradation and Desertification).

Semi-arid regions encompass some of the least-developed areas of the world. Although there is great developmental disparity among the semi-arid regions of the world, they are generally characterized as having a large portion of their population engaged in subsistence agriculture, with a smaller, more economically dynamic sector engaged in large-scale commercial agriculture or industry. The frequent dry periods lead to a high level of uncertainty in production. Those who rely primarily on subsistence plots are particularly susceptible to these variations. Subsistence and pastoral producers frequently migrate within semi-arid regions to more favorable areas, or out of the region altogether, when conditions are sufficiently adverse.

At the regional level, semi-arid regions are on the one hand highly dependent on inputs from and trade with other regions, and on the other are marginalized geo-climatologically, economically, politically and socially. Water resources (as in river headwaters and groundwater recharge sources), agricultural inputs and markets for agricultural products are often centered outside these regions, introducing dependence on the outside, and vulnerability in the face of distribution disruption and market fluctuations. Yet because semi-arid regions have low market-oriented productivity rates (hence contributing relatively little to the gross domestic product), have low population densities, and are typically located far from industrial and urban centers where development policies are generated, they receive low priority in development strategies (Magalhães 1989).

This lack of priority is significant because subsistence and production hardships and opportunities are not based on the physical characteristics of the climate and environment alone. Political, social and economic structures mediate people's ability to cope with extreme climate events and adapt to changing conditions. For example, access to credit, irrigation water, distribution networks, agricultural extension assistance, education and health care are all shaped by people's social, economic and political position in society, and determine their ability to withstand periods of low rainfall (Blaikie 1985; Berry 1989; UCAR 1991:15; Downing 1992). This is particularly significant for the poorest producers, who have limited savings of their own to cushion against failed crops or reduced employment during bad years.

In order to develop policies that can help sustain human activities in semi-arid regions, it is important to examine some of the unique characteristics which have made these regions what they are today: poorly developed economies largely reliant on outside influences and support, susceptible to the effects of their highly variable climates, and at risk of large-scale physical degradation through misuse or overuse. The rest of this section presents a brief discussion of the nature, problems and potentials of semi-arid regions around the world.

Definitions

There are numerous definitions of what comprises a semi-arid region, some more sophisticated than others, but all flawed. The United Nations, for example, has defined semi-arid regions in climatic terms as those areas where the ratio between precipitation and potential evapotranspiration is between 0.21 and 0.50 (P/PET = 0.21–0.50). Semi-arid zones can also be defined as areas where rainfall is between 200 and 800 millimeters per year, and the year-to-year variability is relatively large, at ±20–30% from the annual mean (Rasmusson 1987). These narrowly technical definitions, however, are problematic on a number of grounds.

First, non-climatic factors such as topography, soil type and cover, and vegetation cover strongly influence local and regional water runoff and retention, affecting the availability of water resources for biological activities, and therefore must be considered in any discussion of semi-arid regions (Yair 1992). The duration and intensity of rainfall have significant effects on whether moisture is absorbed by soils or is lost as surface runoff (Downing 1992). Second, rainfall averages and local hydraulic balances naturally change over time. As a consequence, the physical area that is technically considered semi-arid will tend to shift around, while the reality of a variable climate and a vulnerable ecosystem will remain constant. For example, Sahelian isohyets have migrated 400 kilometers southward since the beginning of the drought in 1968 (Le Houérou 1989:70–4; also see Tucker *et al.* 1991). This type of effect is particularly salient where the historical record is short, and there is little basis for determining what is 'normal'. And finally, any discussion of semi-aridity that does not include social components is missing a key set of variables that shape people's ability to produce and thrive in these lands. As Rodrigues *et al.* (1992) points out, the lack of rainfall in an uninhabited region is an uninteresting fact. More comprehensive definitions and approaches can help illuminate the complex environmental and social interactions that shape survival and opportunity in semi-arid regions.

Drought

> Drought implies an extended and significant negative departure in rainfall, relative to the regime around which society has stabilized. (Rasmusson 1987:8)

Oscillating periods of dry and wet weather are a natural feature of semi-arid lands. Some semi-arid regions, such as the Sahel, experience extended dry periods, while others have dry spells during the growing season, or from year to year, as in Canada's Great Plains areas (Glantz 1987; Swindale 1992).

Definitions of droughts, their causes and frequency trends are widely debated (see Box 1, which details some definitional difficulties). Some researchers believe that the severity and longevity of dry episodes witnessed over the past two decades in semi-arid regions around the world represent long-term trends towards greater aridity (Huss-Ashmore 1989:10; IPCC 1990; Zhao, this volume). Some believe that this trend is a natural occurrence, while others attribute it to anthropogenic causes. This latter group points to both global climate change from greenhouse gas buildup, and locally reduced rainfall due to changes in surface reflectance (albedo) and changes in evapotranspiration rates from the clearing or changing vegetation cover (Huss-Ashmore 1989). Other analysts argue that while dryland degradation and global climate change may be occurring, extended drought episodes are in fact the norm in semi-arid regions. Erroneous expectations for consistent wet periods lead to the perception of drought as an anomaly, or as an indicator of worsening conditions (Glantz 1987).

Drought has often been blamed for hardships and lack of development in dry regions. Yet, as Rodrigues *et al.* (1992) points out, 'due to the particular characteristics of semi-arid climates, drought – although not always predictable – will always be a probable phenomenon and thus it should never be considered as a factor of social commotion.' The devastation triggered by drought results from people's *vulnerability* in the face of climatic events, and not the fact of the climatic event itself. As Magalhães (1989:2.27) points out, 'droughts do not cause poverty, they just reveal it, exposing a

Box 1. On defining droughts

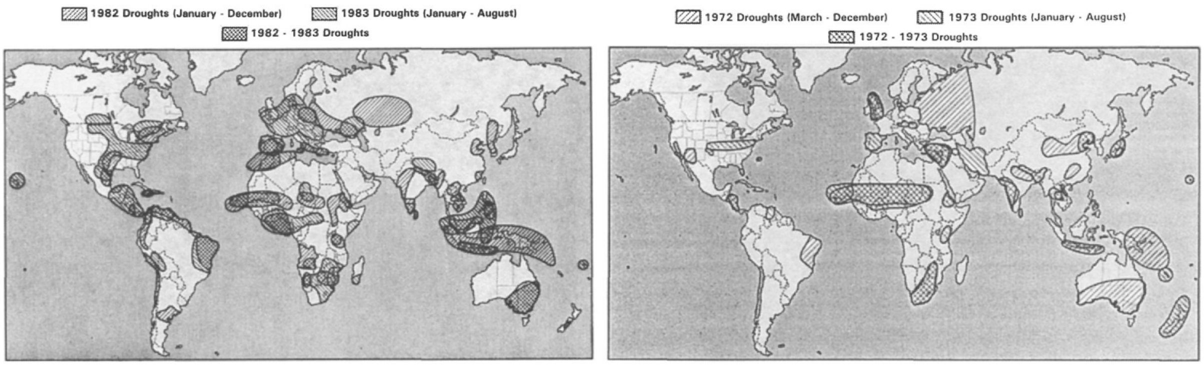

Figure A: Drought in semi-arid regions. (Source: Glantz 1989.)

For the semi-arid regions of the world the single most important, and least welcomed, climatic event is the drought. Drought is an expected phenomenon in the semi-arid regions (see Fig. A). Periods of insufficient rainfall frequently occur within the growing season as well as over entire seasons, making agriculture a risk-prone activity.

The definitional debate on what exactly constitutes a drought is long and as yet unresolved: what may be welcomed as 'abundant' rainfall on the fringes of Africa's Sahel would be accounted as a dry year in North America's corn belt (Hare 1987:4). Yet the debate has led to an in-depth analysis of the concept of droughts and an improved understanding of the climatic as well as socio-economic importance of the phenomenon.

Drought is frequently defined according to disciplinary perspectives, with differing meteorological, climatological, atmospheric, agricultural, hydrologic, water-management, economic and socioeconomic derivatives (Rasmusson 1987; Wilhite and Glantz 1987:14–19; Heathcote, this volume).[1] In discussing the drought phenomenon Wilhite and Glantz (1987) acknowledge that the lack of a precise (and objective) definition of drought in a specific situation has been an obstacle to understanding the concept and has led to indecision and/or inaction on the part of managers, policy makers and others. Yet they stress that there cannot (and should not) be a universal definition of drought, since definitions should reflect regional specificity. While the available definitions demonstrate a multidisciplinary interest in drought, this interest has not yet translated into a multidisciplinary definition of the phenomenon.

Even though it is recognized that drought is a complex phenomenon with pervasive social ramifications, most scientific research has emphasized its physical, rather than societal aspects. Vulnerability occurs at the conjuncture of drought and a whole host of other physical, social and political-economic processes. Not only are the social and ecological consequences of meteorological drought often caused and aggravated by social and political–economic factors, but these consequences often linger for many years after the event and the secondary and tertiary effects are felt even beyond the spatially defined borders of the drought (Wilhite and Glantz 1987).

[1] The Palmer Drought Severity Index (PDSI), developed in 1965 by W. C. Palmer, is one of the best known and most used definitions of drought. Primarily a meteorological description, it relates drought severity to the accumulated weighted differences between actual precipitation and the precipitation requirement of evapotranspiration (Wilhite and Glantz 1987).

plethora of social and economic problems that remain hidden during normal rainy seasons. When droughts occur, they disturb the tenuous production and survival system of the poor and destroy what little progress in their station was achieved since the previous dry spell.'

Semi-arid regions in developing countries have highly unequal asset distribution patterns resulting from economic and social processes, and government interventions. It is often the result of historical processes, associated with colonization (when previously accessible lands were closed off through new land-tenure structures) or land 'reforms' in which the most marginal lands were distributed to the poorest producers (Box 2). Government policies, the expansion of large-scale agriculture or livestock production, and population pressures have pushed small farmers into dryer and dryer regions. Where resources are scarce, a period of wet weather can lead farmers to move into marginal regions, made more fertile by the increased rains. When the dry period returns, they are unable to maintain production (see Glantz, this volume).

Box 2. Marginality and drought in Northeast Brazil

Agriculture in the semi-arid areas in Northeast Brazil is predominantly based on small producers, landowners or tenants, and waged workers who produce for their own subsistence, scarcely participating in the market economy. In their paper 'Effects of drought on agricultural sector of Northeast Brazil,' Khan and Campos (1992) focus on these most marginalized groups.

The 1987 'Green Drought' in the Northeastern state of Ceará resulted in a 7% reduction in the area under cultivation. More alarming, however, was the finding that for subsistence crops the difference between harvested production and expected production reached 80% for rice, 75% for beans, and 79% for maize. The earlier 5-year drought (1979–83) had similarly dramatic impacts with the agricultural production diminishing by 83% in relation to 1978, a year with normal rainfall. In each case the scars of drought ran markedly deeper for subsistence farmers, who emerged as the most vulnerable to disaster.

The social result of drought is the formation of virtual clusters of misery and poverty, composed basically of small rural producers who migrate from the countryside to the cities, where they embark upon a futile search for dwindling employment and basic services, adding to the already unmanageable numbers of the displaced. According to a 1984 Northeast Development Superintendency (SUDENE) estimate, the migration balance in Brazil's Northeast for 1980 stood at −5.5 million people.

A study of the 1979 drought showed that the plight of the small landowners and landless producers became all the more miserable because even in times of normal rains their meager resource reserves are barely enough to meet their subsistence needs. Under these conditions, drought acts as an 'aggravating agent' which further depletes their already marginal productivity, leaving them unable or barely able to subsist. It concluded that 'food and debt payment' constituted nearly 80.5% of the 'drought-stricken' worker's expenditure. Debt payment implied goods supplied (primarily foodstuff, plus some other items including kerosene, soap and pharmaceuticals) in advance by the landlord to the workers, sharecroppers and wage earners.

Sometimes, however, these workers succeed in getting temporary jobs at the 'work-fronts' created by the government to provide relief to drought victims by offering employment in government civil works. This also benefits the medium-sized and large landowners by relieving them of having to sustain labor during the drought period. In order to prevent a massive exodus during the droughts occurring between 1979 and 1983, the work-fronts had to create nearly 500000 jobs in 1979 (9% of the rural economically active population), 720000 in 1980 (13%), 1.2 million in 1981 (21%), 747000 in 1982 (13%) and 3.1 million in 1983 (55% of the rural economically active population in 1980). These numbers, however, may be exaggerated primarily because the work-fronts have yet to adopt efficient criteria of hiring, and a large proportion of the unemployed urban populace is also attracted to them. However, the figures highlight both the magnitude of the problem created by labor displacement and an approach towards its solution (Kahn and Campos 1992).

The cycle of drought exacerbates the social inequalities that make dry spells into crises. In times of drought, producers who already exist in precarious conditions are the first to be affected (Watts 1983; Demo 1989; Magalhães 1989, 1992; Khan and Campos 1992; Rodrigues 1992; O'Brien and Liverman, this volume). Pre-existing social inequalities are exacerbated in times of drought, often leading to increased poverty on the one hand and land concentration on the other (Watts 1983; Lemos and Mera 1992:4; Magalhães 1992). Marginal subsistence producers and smallholders have fewer assets to buffer them against poor harvests, and are more likely to resort to selling off assets, eating seeds for survival, intensifying their cultivation practices (thus degrading their soil assets) or abandoning their cultivation altogether and migrating out of the region. Large producers tend to have multiple and diverse assets which they can afford to sell off or utilize more intensively before actually suffering from the effects of droughts. Large cattle ranchers in Northeast Brazil, for example, who rent land to tenant farmers, will often put that land in forage cultivation to insure that their cattle survive the drought. The tenant farmers are then left with no means of livelihood, and must sell their labor to large farmers – who themselves are cutting their hired labor to reduce operating costs – or migrate to urban centers (Magalhães 1989).

Hence, regardless of the causes of climate variation or change, people's vulnerability in the face of drought is socially shaped. The devastation wrought by recent droughts cannot be attributed solely to climatological events. It occurs largely because nomadic and settled land-use patterns, along with low levels of technical and economic development, have become or been made incompatible with the inherent climatic variability of semi-arid zones. It is clear from this discussion that the effects of drought, and their implications for regional development within semi-arid zones, are socially mediated. Land-holding structures, geographic distribution of holdings, the level of technology, access to resources and markets, and ability to command policy attention are all functions of socioeconomic standing. To address the consequences of drought, people's differentiated vulnerability to its effects must be examined.

Dryland degradation and desertification

Human interventions can increase the productive capacity of semi-arid regions by introducing resources such as water and soil nutrients, thus increasing the intensity of biotic production the system can maintain. This is the ideal. Human interventions can also decrease the productive capacity by reducing soil fertility, water retention capacity and protective ground cover, and causing soil erosion, compaction and salinization. Soils in semi-arid regions, and particularly those in the tropics, suffer significant declines under the pressure of excessive cultivation, livestock herds, and polluting industrial processes. Climatic events such as heavy rains, winds and prolonged dry periods interact with the effects of human actions, exacerbating degradation. If these processes are severe enough, desert-like conditions can result.

Desertification refers to a severe form of dryland degradation. It goes beyond other forms of degradation because its effects may be irreversible. The World Commission on Environment and Development reported that: 'the process of desertification affects almost every region of the globe, but it is most destructive in the drylands of South America, Asia, and Africa . . . Land permanently degraded to desert-like conditions continues to grow . . . Each year, 6 million additional hectares provide no economic return because of the spread of desertification. These trends are expected to continue despite some local improvements' (WCED 1987:127–8). But, like climate change, much remains to be learned about the process of desertification. Indeed, there is no unanimity on the extent or meaning of desertification. Some scientists question the idea of desertification arguing that it has often been based on poor data, research conducted at the end of an exceptionally dry period, and extrapolation of data far beyond the regional specificity of the observed phenomenon (Rhodes 1991; Stevens 1994; Little 1994:1). As Rhodes points out, technical definitions and regional generalizations may do more harm than the attention they focus on the issue does good. But, he continues, 'this assessment should not lead to the conclusion that desertification is not an environmental issue; rather, it should lead to an awareness of the necessity to distinguish between and among dryland degradation processes in order to identify appropriate responses and management strategies' (Rhodes 1991:1141). It can take soils a generation to regenerate, if they can be regenerated at all (Swindale 1992). Thus, whether the creation of desert-like conditions through excessive cultivation and industrial activities should be called 'desertification' or not, the impact of these activities merits concern.

As Demo (1989:1.14) points out, 'dealing with drought becomes a lost cause for technicians who perceive, sometimes quite competently, the physical restrictions and the reasonable chances of reversing them, but who do not know how to address the political problems.' As with other consequences associated with drought, dryland degradation results from a mix of climatic, social, political and economic conditions and events. The conjuncture of these factors and their human consequences are discussed in the section From Impacts to Vulnerability and Beyond, below.

Regional specificity

No discussion about semi-arid regions can do justice to the conditions – ecological, geological, hydrological, social, economic, or political – that shape development without examining each region in its particular context. Each semi-arid region has its particular characteristics, history, problems and potential. Specific policy recommendations must be founded on the regional and local conditions of each area. As discussed in the following section, general circulation model (GCM) projections, even if accurate, are of little use without a detailed understanding of the local dynamics (see O'Brien and Liverman, this volume; Wang'ati, this volume). This is equally true of the policies that are guided by GCM projections. Indeed, semi-arid zones around the world are quite different, with some highly productive regions in North America and famine-prone regions in Africa. Differences are also reflected in different population densities, production mixes, land distribution, available hydrological resources, technological level, etc. The obstacles and opportunities for development in each region are shaped by these characteristics. Policies to bring about sustainable development must therefore reflect the unique cultural, political, economic and environmental nature of each region.

Diversity in semi-arid lands

The discussion to this point has treated the common characteristics of semi-arid regions, and pointed to some differences among them. There is also tremendous diversity within semi-arid regions. One of the natural development potentials of semi-arid regions is, in fact, the presence of sub-areas within them that have greater natural-resource endowments (Netto *et al.* 1992; also see Albergel 1992; Cadier *et al.* 1992; Castellanet 1992; Chevallier *et al.* 1992; Reyniers 1992; Serpantié 1992). Another resource for development is adjacent resource-rich regions that can help sustain development within the semi-arid regions by providing access to missing inputs such as water for irrigation and domestic use. But such transfers can also be quite dangerous if poorly managed (Zhao, this volume).

Development potential also comes from the diversification of activities within semi-arid zones. While semi-arid regions are largely developed for agriculture and livestock, portions of them may be suited to other activities, such as industry, mining and forestry. Some regional needs can be met using alternative technologies that take advantage of abundant resources in semi-arid zones, such as solar, wind, and sometimes geothermal energy, as is found along East Africa's Rift Valley (Milukas *et al.* 1984). Another way to foster development is to base it on activities that are not vulnerable to the natural climate variations of these regions. Semi-arid regions suffer from structural limitations because of their relative dependence on drought-susceptible agriculture and outside regions for inputs and markets. Industrial, manufacturing, and service-sector growth within these regions would not only reduce climate and market dependence but also increase regional development. Industries that are not dependent on agricultural resources are least vulnerable to climate variation and change. Indeed, there is evidence that industrial growth outstrips agricultural growth in semi-arid zones (World Bank 1990; Magalhães 1992; Zhao, this volume). Diversification of the production mix within semi-arid regions has clear benefits, not only for the development of these regions but also for their ability to withstand the climate variability inherent in them.

In the following section, issues surrounding the modelling and projection of climate change and its impacts are discussed.

CLIMATE VARIABILITY AND CHANGE —

Introduction

Climate has always been a dynamic entity. It varies across all terrestrial scales of time and space. Large areas of the earth experience wide uncertainty as part of normal climate. This is especially true of the arid and semi-arid areas, where precipitation varies greatly. Change over longer periods of time is also a 'normal' climatic phenomenon (Riebsame 1989:6).

What makes the current concern for climatic change different from past interest in its perturbations and anomalies is the unprecedented pace and magnitude of the predicted change and the attendant dangers to human and environmental systems. While the global mean surface air temperature has increased by 0.3–0.6 °C over the last 100 years, its average rate of increase during the next century is predicted at 0.3 °C per decade (IPCC 1990:2–3).[3]

This dramatic change is the projected result of increasing atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases such as methane, nitrous oxide and chlorofluorocarbons (CFCs). The greenhouse effect is an established physical principle that has enabled life on this planet. It is the accelerated accumulation of these anthropogenic greenhouse gases, however, that threatens to cause rapid climate change (IPCC 1990).

The findings of the Intergovernmental Panel on Climate Change (IPCC 1990:3) mark an emerging, but unsure, consensus amongst experts about the effects of such a greenhouse gas buildup. Attempting to model for the radiative equivalent of a doubling of CO_2 concentration, the major global climate models predict a global-average warming of between 1 and 5 °C (Downing 1992:1). This is not much different from the first such estimate made nearly a century ago, in 1896, by the Swedish scientist Arrhenius. While the apparent similarity of these estimates makes the possibility of global warming appear more likely, the inherent uncertainties of climate modelling science and inadequacies of the modelling tools leave all predictions open to challenge (Stone 1992:34).

In this section we begin by outlining the concept of climate variability and change in semi-arid lands. We then proceed to discuss the limitations of the tools now available for projecting climate change and its consequences. Finally we highlight the urgency of acting within, and despite, the uncertainty of climate-change predictions.

Climate variability

There are two aspects of climate variability that are of concern: its effects on the present populations of semi-arid lands, and the projection of its magnitude and consequences into the future.

Hare (1985:41) defines climatic 'variability' as the observed year-to-year differences in values of specific climatic variables *within* an averaging period (typically 30 years), and climatic change as longer-term changes *between* averaging periods, either in the mean values of climatic variables or in their variability.[4] The distinction between short-term climatic *variability* and long-term climatic *change* is critical. 'One affects the range and frequency of shocks that society absorbs or to which it adjusts, the other alters the resource base' (Parry and Carter 1985:95).

Drought is the most common consequence of current climate variability in semi-arid lands (Wilhite, this volume). And the most vulnerable to its effects are the most marginalized populations: those deprived of the mechanisms and/or resources to prepare for and adapt to climate variation, let alone to climate change (Nobre *et al.* 1992). Ironically, while many recent models and analyses (including the majority presented at ICID) are focusing on the impacts of future climate *change*, the problems of climate *variability*, which may indeed get worse under conditions of climate change, are here today. The consequences are not hypothetical, but are already real and known.

Scientific investigations of global climate change have focused on projecting net or average change, rather than the changed variabilities within it. This focus is due to limitations of the available forecasting tools. Projecting variability is, nonetheless, a major concern in its own right. As an intrinsic characteristic of climate regimes in semi-arid regions, variability defines the many decisions made by those who inhabit these areas (Burton and Cohen 1992). Traditional practices of crop and income diversification, as well as spatial mobility, are a few examples (see Wisner 1976; Parry and Carter 1988; Huss-Ashmore 1989; Watts 1987*a*). This is an area of research that deserves considerable attention.

Projecting climate change and impacts

Projecting climate change is an important first step in evaluating the consequences associated with global warming. Modelling climate change is inherently difficult. It involves simulating the behavior of intricately linked and complex oceanic and atmospheric processes, some of which are not fully understood. In fact, major scientific uncertainties and knowledge gaps persist at every level from predicting just how fast greenhouse gases might build up to forecasting even the simplest climatic variable of temperature (Stone 1992:34–7).[1]

> Any effort to predict climate changes assumes that climate is predictable – but this is not guaranteed. Forecasts of the efforts of a rise in greenhouse gasses are really just predictions of what will happen in the absence of the unpredictable. (Stone 1992:37)

Working within these uncertainties, and acknowledging them, climate-change projections by the Intergovernmental Panel on Climate Change (IPCC), and others, have used various methods to arrive at best estimates within the available scientific knowledge and tools. Amongst them is the use of historical and paleoclimatic data (IPCC 1990), spatial and temporal analogs (Burton and Cohen 1992) and use of the convenient increment approach (Riebsame 1989). While these have their specific strengths and uses, the most highly developed tool to project climate change is the general circulation model or GCM (IPCC 1990).

Working according to the laws of physics, GCMs simulate possible change by using simplified equations (or 'parameterizations') based in part on current climate conditions and in part on approximations of future factors (IPCC 1990). The projections are, therefore, only as good as the parameterizations. The strength of a parameterization, however, is restricted by two factors: (1) the major gaps in our knowledge and understanding of complex climatic process and systems, and (2) the capacity and speed inadequacies of even the most modern computers that force all climate models to make trade-offs between the number of locations they simulate, the number of climate processes they calculate, and the accuracy of the results (Stone 1992:37).

These general limitations translate into a number of major problems associated with relying too heavily on GCM climate-change projections. The more important include the following:

(1) Different models produce similar trends but differ sufficiently that impact projections can vary with choice of model (Riebsame 1989:66).
(2) Variations in grid sizes[5] and low spatial representation make for coarse resolution of GCMs, and hence local specificity is difficult to obtain (Cohen *et al.* 1992:11).
(3) Complex topographical features are represented differently in different models with high uncertainty as to how to handle these factors (Cohen *et al.* 1992; O'Brien and Liverman, this volume).
(4) Sub-grid-scale weather patterns, which can be important determinants of precipitation, are ignored (O'Brien and Liverman, this volume).
(5) Inadequate understanding of and assumptions about cloud formation could result in major errors in GCM results (Stone 1992).
(6) Lack of coupling of GCMs with dynamic ocean and biosphere models reduces accuracy (Downing 1992:2–3).

These problems highlight the dangers of interpolating global projections from GCMs to arrive at regional forecasts. In general, the confidence in regional estimates of critical climatic factors, especially precipitation and soil moisture, is low (see Cohen 1990; IPCC 1990:4; Downing 1992:2; Yair 1992:2; Schmandt and Ward 1992:3; Wang'ati, this volume; O'Brien and Liverman, this volume).

Long-term regional precipitation estimates are even more uncertain than regional temperature projections. This is particularly disturbing in semi-arid areas, where rainfall amounts and patterns are the key variable (Parry and Carter 1988:11). For example, using five major GCMs for projecting climate changes in Mexico, O'Brien and Liverman (this volume) found that the projected changes in annual average precipitation varied from a 23% decline to a 3% increase.

As summarized by Cohen (Fig. 3), the state of understanding in climate-change projections provides credible certainty in the trends in atmospheric compositions; fair certainty in the magnitude of global warming and the regional distribution of its causes; uncertain estimations of the role of global warming, large-scale shifts in precipitation and the magnitude of regional warming; and very uncertain projections on regional water resources. Furthermore, consensus amongst experts is that these uncertainties are not likely to narrow in the immediate future (IPCC 1990) (see Fig. 4 on time scales for narrowing uncertainties).

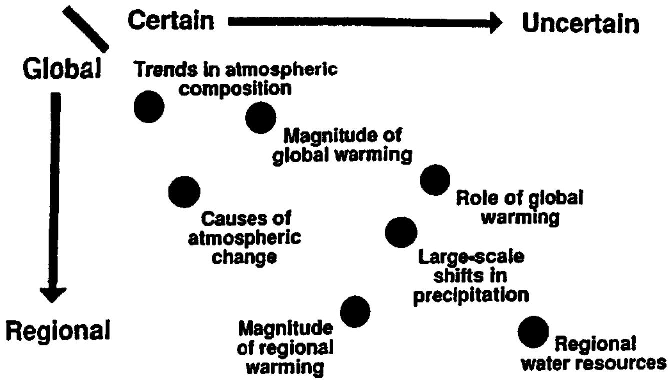

Figure 3: State of understanding of global warming and its consequences. (Source: Cohen 1992).

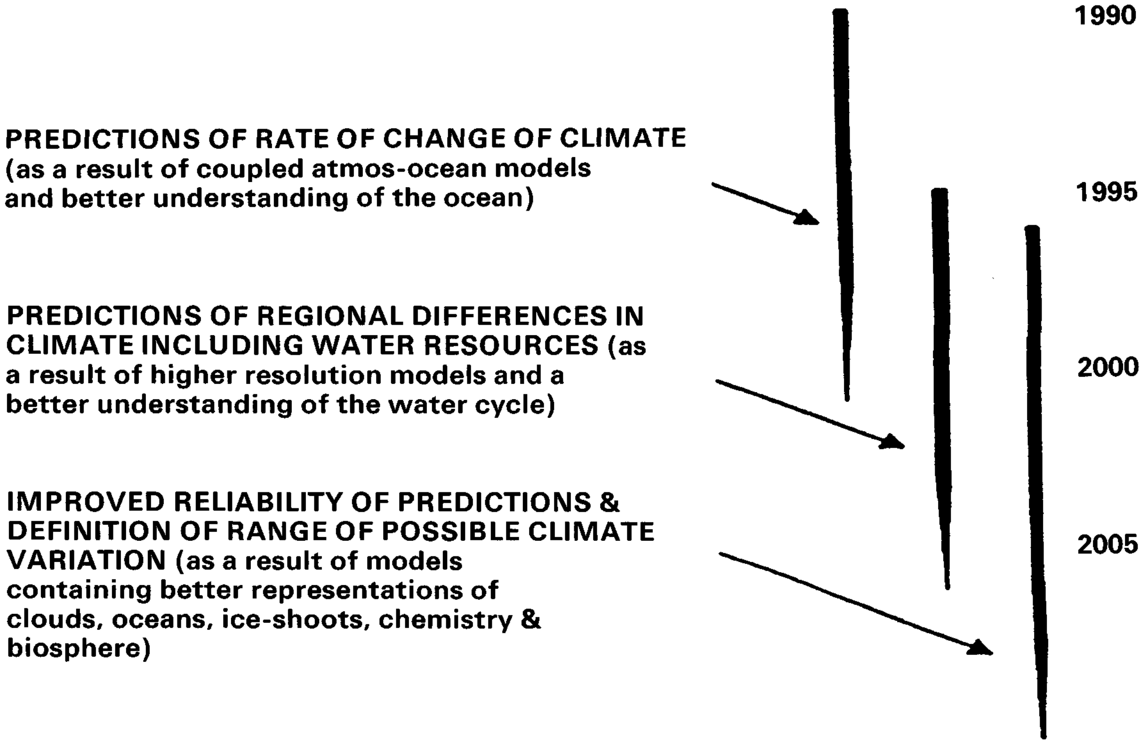

Figure 4: Time scale for narrowing uncertainties. (Source: IPCC 1990).

In the light of all these uncertainties, over-reliance on initial GCM results for projecting impacts and consequences of climate change can often compound issues. This can happen by:

(1) Imposing the climate of the future abruptly on the world of today, without allowing for adjustment and feedback.
(2) Imposing uniform climate changes derived from GCM grid cells onto large regions, thereby eliminating the natural variability in time and space that characterizes real climates.
(3) Dealing with individual economic sectors but not addressing inter-sectoral linkages within the region and/or the linkages between the region and the rest of the world.
(4) Failing to consider how technology and policy may facilitate adaptation to climate change.
(5) Forecasting productivity on incomplete understanding of existing baseline and uncertain projections for changing the technical, social and economic baseline.
(6) Opting for simplistic, and sometimes misleading, carrying-capacity definitions.
(7) Ignoring the role of the socioeconomic structure in affecting vulnerability to climatic change (Rosenberg and Crosson 1992; Downing 1992; Cohen *et al.* 1992; Wang'ati, this volume).

As better computers become available, understanding of physical climatic processes is enhanced, and more developed methods become operational (e.g. fine-resolution, limited-area models) our ability to simulate climate change, and its consequences, is likely to increase, but the ingredient of uncertainty will remain important, at least in the foreseeable future (Cohen 1990, Stone 1992).

Acting in the face of uncertainty

Despite their limitations GCMs are valuable tools for students of climate change. Like any tool, they are most effective when used with care and with understanding of their capabilities and limitations. Climate models are only as good as our understanding of the processes which they describe, and this is far from perfect (IPCC 1990:19).

Despite their many problems GCMs provide basic scenarios against which to explore various climate-change possibilities. Even if we had more refined tools, three crucial problems would arise in projecting future impacts:

> First, of course, no one knows how future climate might evolve; climate forecasting is an uncertain science. Second, any impact projection is only as reliable as the understanding, validity and strength of the assumed relationships between climate and the resource or human activity in question. Finally, even with a good understanding of past and current climate–society linkages, changes in technology and society may exacerbate or mitigate future impacts; and projecting social change is at least as difficult as predicting climate change. (Riebsame 1989:68)

While uncertainty in climate studies needs to be recognized, it must not be allowed to become an excuse for inaction. We should not allow uncertainty to obscure the very real need for policy analysis. Rather, that uncertainty should be incorporated in a credible manner into contemporary policy discussions (Riebsame 1989:68; Burton and Cohen 1992:10).

Many facets of the climate issue, like those of climate variability, are here now. They justify immediate action. The IPCC Working Group on the Formulation of Response Strategies reminds policy makers that amongst the most effective response strategies (especially in the short-run), are the 'no-regrets' strategies – those which are beneficial even without climate change and justifiable in their own right (IPCC 1990:11). Riebsame (1989: 67) articulates the sentiment with much more urgency, pointing out that:

> the large uncertainty surrounding predictions of climate change may not be reduced to levels at which policy makers would be comfortable taking preventive or adaptive actions until the effects themselves become obvious. By then we may be on the verge of unpreventable and irreversible changes in the environment. Uncertainty makes planners adopt a 'wait and see' attitude to account for climate change in their decisions. It can be argued, however, that the changes which might accompany greenhouse warming are sufficiently large and sufficiently imminent (i.e., they will occur in the next few decades) that planners making decisions affecting long-term resource activities such as water development, agriculture, and settlements should consider their implications now.

This general question of action, or response, is discussed in detail in the next section below. While there may be great uncertainties in future climate projections, vulnerability in the face of current climate conditions necessitates and justifies action now.

RESPONSES

Introduction

Current knowledge about climate change is insufficient for planners and policy makers to use models as precise predictive tools. Great uncertainty remains as to the actual mechanisms and potential effects of global warming. While enough is known to argue convincingly that greenhouse gases will result in general climate warming, the specific effects at the regional and local levels are sketchy at best. But it is not necessary to wait for tangible proof of climate change before acting. Climatic variability is currently a major problem in semi-arid regions. In conjunction with other physical, social and political-economic factors, climate variability contributes to vulnerability to economic loss, hunger, famine and dislocation. Reducing this vulnerability by increasing people's ability to cope is an immediate need. This will not only buffer them against the existing climatic variability but would increase their resilience to possible future climate change.

Adaptation is our natural response to the environment. As Burton and Cohen (1992) argue, when and what we plant, how and where we build structures, and what infrastructure we develop, are all contingent responses to environmental constraints. Adaptation is based on immediate observation of our surroundings, our knowledge of environment variation from the past, and on projections of future needs and events. Adaptation is what makes extreme events within the normal climate variation survivable, rather than catastrophic. In highly variable climates such as semi-arid regions adaptive responses mean the difference between a dry spell with some economic losses, and a deadly famine.

No regrets

Climate change introduces the possibility of climatic conditions not previously experienced in a given region. Planners and policy makers are naturally reluctant to invest in adjustments to an uncertain future scenario that may decrease productivity in the short run, or require difficult negotiation with other countries and regions. Yet much adaptation, unlike multilateral agreements about greenhouse gas reduction, is not dependent on cooperation with other nations, can be implemented locally, and can include measures that have immediate benefit, in and of themselves (Burton and Cohen 1992). They are worth doing even if climate does not change. For example, developing drought-resistant crops for semi-arid regions can both help farmers hedge against increasingly arid conditions, and decrease water consumption needed for irrigation (O'Brien and Liverman, this volume). As semi-arid regions become dryer, water conservation will be increasingly important. Using less water is also beneficial because it reduces the likelihood of soil salinization, waterlogging of root areas, and overdraft of the water-table. In regions where water is purchased from sources outside the region, using less water means less expenditure, with resources remaining for reinvestment within the region.

As Wang'ati (this volume) argues, 'sustainable development is achievable provided that development policies put less emphasis on 'change' in favor of 'progressive improvement' on those strategies and technologies which have enabled the populations to cope in the past.' Purposeful adaptation to climate variation will save costs and 'buy time' needed to develop and implement greenhouse gas reduction strategies (Burton and Cohen 1992). The real opportunity in adaptive strategies, however, lies in their coincidence with long-term development aims. Sustainable development does not have to mean sacrificing increased wellbeing in order to preserve resources. Rather, it can mean insuring wellbeing through measures that conserve and improve productive capacity.

Long-term adaptation versus short-term crisis response

> as droughts come and go, left behind are . . . the usual debates over the efficacy of ad hoc relief efforts and at best inadequate or incomplete plans for dealing with future droughts. With the first rains comes a new sense of security, relief efforts are dismantled, plans for the next drought forgotten, and society resumes its so-called harmony with climate until the rains fail and the cycle begins anew. (Easterling 1987, as quoted by Farago 1992)

Just as policy makers are reluctant to act on uncertain information about future climate change, investments to reduce vulnerability to current climate variability have been insufficient. Crisis-induced responses far outweigh preventive measures (Wilhite, this volume). Famine relief, emergency food and seed distribution during droughts, and public works projects to employ affected rural workers are all part of the crisis response mode. With the possible exception of public works projects, crisis responses tend to have immediate palliative results but no lasting effects on the resilient capacity of the population. In fact, short-term crisis-induced responses can have perverse effects on regional resilience to severe events by making governments and the population complacent in the face of repeated crisis events (Downing 1992; Wilhite, this volume; Glantz, this volume). Rather than a strategy for change, the crisis management approach can be a recipe for maintaining, or worsening, the status quo. For example, providing food and input supports to farmers who are trying to cultivate extremely marginal lands may allow them to weather the current crisis but leaves them susceptible to future events and without incentive to buttress their defenses against vulnerability (Wilhite, this volume).

Wilhite (this volume) argues that agriculturalists must either be equipped to adapt to the natural variability of the lands they are on, or should relocate to more viable areas. Glantz (this volume), however, argues that all viable agricultural tracts are already under cultivation, suggesting that adaptation is the more promising policy response.

Planning for sustainable development

As will be discussed in the following section, the vulnerability of agriculturalists and pastoralists is not solely due to climatic events, but instead comes at the intersection of social, economic, political and cultural factors. Any approach to developing adaptive responses must include all of these spheres. Our discussion is necessarily incomplete, because the specific responses in any area will vary with local conditions and needs, something that would be impossible to do justice to here. Nevertheless, there are a number of general 'design criteria' to guide policy makers, engineers, local entities and the local population in their attempts to respond to the needs of people living in semi-arid regions.

First, responses to climate variability must be adaptive. By adaptive, we refer not only to the spontaneous adaptive responses of local populations, which generate a certain degree of innovation and locally appropriate responses, but also to purposefully adaptive responses on the part of population and government. Many of these responses will need to be corrective measures to increase people's access to productive resources. They will also need to include forward-looking strategies that aim to increase the availability, stability and resilience of infrastructure, markets, institutions, and productive processes.

Second, adaptive responses must be integrative. Experience shows that strictly technical solutions are insufficient to address the vulnerability of people living in semi-arid regions. Economic approaches can address only part of the problem. 'Getting the prices right' cannot protect the poor against volatile prices and declining terms of trade (Bernstein 1979; Sen 1987). Policy measures must not only include a multi-sectoral analysis, but should be formulated through an inclusive process that involves the entire affected population, from small producers to the business community to donors. This will help assure that technologies and policies match the resources and needs of the people concerned.

Third, responses must be incremental and iterative, guiding existing institutional, technical, and socioeconomic structures to a more flexible and appropriate coexistence with semi-arid conditions. The comprehensive project approach can rarely encompass and project the multiple repercussions of policy interventions, not to mention unforeseen future events. An incremental, iterative approach that incorporates active feedback mechanisms to monitor and adjust to emerging events can help overcome these problems.

Finally, there must be active participation of all the parties concerned. Policy formulation, however 'comprehensive' and 'interdisciplinary,' is useless unless it responds to local needs and conditions. Policy interventions include economic and social measures which shape people's participation in economic development by effecting their access to productive resources. These policies, such as how to structure agricultural subsidies, credit systems, technical assistance, etc., have inherent distributional implications, and are therefore political decisions (Demo 1989; Rodrigues *et al.* 1992; de Almeida 1992; O'Brien and Liverman, this volume).

Demo (1989), Rodrigues *et al.* (1992), Vallianatos (1992), Wang'ati (this volume) and others argue that mechanisms to include community organizations, small-scale producers, and other marginalized populations must be developed if the effects of unequal development within semi-arid regions are to be redressed. Pressure from the affected communities, such as rural labor unions, organized community groups, producer cooperatives, etc., is a key element for transforming unequal social and economic arrangements. Together with purposeful policies aimed at increasing producer access to productive resources, this local pressure may be capable of reducing development imbalances within semi-arid regions. Approaches that recognize these groups as legitimate stakeholders, and provide some means for including them in the decision-making process, is critical in redressing marginalization (Demo 1989).

The following discussion provides an analysis of people's vulnerability to the consequences of climate variability, and the technical, governmental, and international responses that this analysis suggests. Again, though this discussion is necessarily incomplete, the aim is to sketch out some of the more important factors that might help shape policy decisions that are compatible with the development aims of semi-arid regions.

From impacts to vulnerability and beyond

The primary problem of semi-arid regions is not climate variability, drought, soil erosion or floods, but more centrally, people's vulnerability to the effects of these events. While droughts, floods and the ecological character of the land are natural phenomena, vulnerability to the effects of environmental change or natural hazards is a social matter. It is not so much the droughts or floods that are alarming, but people's vulnerability to the consequences associated with them: hunger, famine, dislocation from land or livelihood, economic loss, and the loss of ecological assets. Vulnerability comes at the confluence of underdevelopment, social and economic marginality, and the inability to garner sufficient resources to maintain the natural-resource base and to cope with the climatological and ecological instabilities of semi-arid zones.

When we write of vulnerability we are not implying that it is a thing of the future or of mere potentiality. Vulnerability to hunger does not mean that people are not hungry yet. It simply is a way of identifying the populations most likely to be hungry. The word may imply potential problems that are not yet here, but in the semi-arid regions, hunger and frequent crisis are pervasive. We therefore use this term with caution, emphasizing that many vulnerable populations suffer chronic or frequent crises.

Vulnerability is a function of a number of interlinking factors. Neither chronic nor periodic crises emerge from any single agent. Rather, they occur at the conjuncture of many. Famine, for instance, occurs at the intersection of phenomena such as drought, human need, grain prices, wars or frontier settlement policies. It is not a singular result of drought. One aim of this section is to sketch out these forces in order to help develop their policy implications and point to policy responses.

Because the purpose of this chapter is to cover the climate-related issues most pressing in the semi-arid regions of the world, we focus on those groups within these regions whose livelihoods and lives are most at risk. These include the landless and smallholder farmers, pastoralists, and small ranchers in the less-developed regions whose physical well-being is tied to the rains and the land. Risk of economic loss – which in this case is rarely life threatening – is the primary concern within more-developed semi-arid regions. We also examine the linkages between the most vulnerable populations and the population at large, because without a broad and integrated economic development of these lands, chronic underdevelopment and frequent crises will continue.

This section is devoted to defining and discussing the concept of vulnerability.

A formal definition of vulnerability

Here, we adopt Thomas E. Downing's method for evaluating vulnerability when assessing the potential consequences of climate variability and change. Downing's (1992:3–4) methodology consists of:

> identifying the multiple dimensions of vulnerability . . . [to a specific consequence such as hunger]; determining socioeconomic groups with similar patterns of vulnerability; assessing their location and degree of vulnerability; delineating pathways by which their vulnerability may be altered by trends in resources (including climate), population, and economy; judging the risk of future climate change, in the context of other expected risks to sustainable agricultural development; and, finally reviewing potential responses that reduce the risk of adverse climate change and enhance the prospects of food [or for our purposes food, job or economic] security. (Downing 1992:3)

Focusing on food insecurity, Downing describes vulnerability as 'an aggregate measure, for a given population or region, for the underlying factors that influence exposure to food shortage and predisposition to its consequences' (Downing 1992:4). Below we discuss the principal characteristics of the concept of vulnerability.

Adverse, specific consequences

The concept of vulnerability is linked to *adverse* consequence. Hence, the concept has an ethical basis – in focusing on the adverse outcomes – which distinguishes it from more neutral terms such as 'sensitivity,' 'consequences' or 'impacts.' Indeed, the concept is designed to help identify those groups within society most likely to experience *negative* outcomes. While crop yield may be sensitive to drought, different households may be more or less vulnerable in the face of the same low-rainfall event. For example, those who have excess grain to sell at a high price during drought-triggered food scarcity will benefit from a drought. Those who have water resources on their private property can sell access or use it to produce goods that are otherwise made scarce by drought. In addition, those with capital can buy land and equipment at low prices from those who are forced to sell out of desperation (see, for example, Demo 1989; Magalhães 1992; Rodrigues *et al.* 1992). While these households are affected by drought, they are not as vulnerable to its consequences as are others in the same community (Downing 1992:5).

Vulnerability is *specific* in that it is concerned with a particular consequence, such as famine, hunger or economic loss. Vulnerability to famine, or to these consequences, can then be evaluated with respect to multiple events such as drought, access to resources, market fluctuations, state policies, or regional conflicts. This is a fundamentally different formulation from previous analyses which link a single cause to an outcome, such as drought to crop yields. Rather than focusing on the consequences of a single event, vulnerability analysis traces out the multiple causes of a single consequence.

The several specific negative consequences that are discussed in the climate variability and climate-change literature include vulnerability to dislocations, hunger, famine and economic loss. These can easily be extended to include the vulnerability to loss (or degradation) of assets, which in turn can be broken down into natural assets such as land, forests and water resources, and human-made capital such as farm machinery or other infrastructure. While these consequences are often discussed together, vulnerability to them must be evaluated separately, for each may have different causes.[6]

Vulnerability is relative

Vulnerability is a scale of the relative likelihood of different socioeconomic groups and geographic regions experiencing negative consequences, such as hunger, famine, economic loss or the loss of productive assets. While everyone is susceptible to all of these adversities, some socioeconomic groups and some areas are more susceptible than others. Clearly the semi-arid rain-fed agricultural regions at the tail end of the rainfall gradient are more likely to experience famines than are cities (see for example, Box 3, and Gasques *et al.* 1992:38).[7] In the same regions, the poor are more likely to experience hunger than are the rich. While all are vulnerable to food shortages, some groups and regions are more vulnerable than others. And, as Downing (1992:4) states, 'ultimately, the analysts must assign the thresholds for concern and action.'[8]

Vulnerability and socioeconomic status

Vulnerability is a function of the relative status of socioeconomic groups. As we will see below, vulnerability is a function of income as well as class, caste, clan, religion, political party, livelihood, race, ethnicity, family, gender and age. Different socioeconomic groups have differing assets as well as differing levels of access to productive resources. Their assets and access are critical aspects of their vulnerability.

Vulnerability is also a function of the degree of development. As Wilhite *et al.* (1987:558) point out:

> In developed countries the proportion of commercial agricultural producers who can withstand a short-term occurrence of drought is high, in terms of both business resilience and human welfare. The impact of short-term drought is significantly reduced because of irrigation and the availability of sufficient forage (fodder) and water for livestock. Even in the case of longer-term drought, the use of irrigation coupled with sufficient grain and forage storage facilities and a fully developed infrastructure can significantly lessen the impact on society and livestock. For example, in Australia, 40% of the farming community is not greatly affected by a drought.

For subsistence farmers, even a short-term drought can be disastrous, especially for the peasant farmer whose only security is a small piece of land on which to grow food and

Box 3. Climate change and vulnerability in Kenya

Table A. *Estimated prevalence of food poverty in 1984 and sensitivity to climatic variations in Kenya*

	Central	Coast	Eastern	Nyanza	Rift Valley	Western	NE	Nairobi	Total	%
Estimated prevalence of food poverty in 1984 (in 1000s)										
Pastoralists										
Nomadic	0	37	77	0	713	0	268	0	1095	19
Agro-pastoral	1	4	3	0	29	0	11	0	48	1
Migrant farm	0	0	14	0	128	0	48	0	190	3
Landless										
Poor	159	88	155	139	310	45	3	0	899	16
Skilled	0	0	0	0	0	0	0	0	0	0
Rural Landholders										
Large farm squatters	53	62	61	68	36	49	0	0	329	6
Smallholder	555	179	637	705	377	511	5	0	2969	53
Gap farms	0	0	0	0	0	0	0	0	0	0
Large farms	0	0	0	0	0	0	0	0	0	0
Urban										
Nairobi	0	0	0	0	0	0	0	32	32	1
Other	9	26	13	14	16	7	1	0	86	2
Total 1984	777	396	960	926	1609	612	336	32	5648	100
Sensitivity to climatic variations										
Current agroclimatic zone suitable for maize (km² × 10³)	13.2	44.7	51.2	14.2	104.7	9.1	7.8	0.7	245.6	42
Decrease with a 10% reduction in length of growing period (%)	0	21	11	0	21	0	16	0	16	35
Decrease with a 20% reduction in length of growing period (%)	0	29	20	0	28	0	20	0	23	32

Source: Downing (1992).

The first step in analyzing vulnerability to hunger and famine is to identify the socioeconomic groups expected to have different patterns of food security or different levels of food poverty. Given these different patterns, different socioeconomic groups would be expected to have different levels of risk in the face of climate change or other resource, social and economic perturbations. In most instances vulnerability to hunger and famine can be correlated with principal means of livelihood, skill level, reliability of income (perhaps as related to tenure), wealth, land-holding size and geographic location (this is a function of natural resources, distance from transportation and marketing infrastructure, as well as other political-economic factors that structure development assistance, and so forth). Rates of food poverty – the proportion of people with insufficient incomes to procure the recommended minimum level of food – were estimated by Hunt for 11 socioeconomic groups in eight regions of Kenya (see Table A). Though pastoralists show a higher rate of food poverty, the largest vulnerable group – over half of the food-poor population – consists of smallholder agriculturalists (Downing 1992.)

To examine some potential consequences of climate change, Downing uses a scenario in which the length of the growing period is altered through a combination of temperature and precipitation changes. In Kenya, a 10% decrease in the length of the growing period could result from either an increase in temperature of approximately 1 °C or a decrease in the precipitation of around 10%. Assuming a 10% decrease in growing period, there are major shifts in Kenya's agricultural zones. Growing season changes are shown in Figs. B and C. The threshold of reliable agriculture (60–90 days for maize) would move well into Kenya's highlands as the total area suitable for

Box 3. (*cont.*)

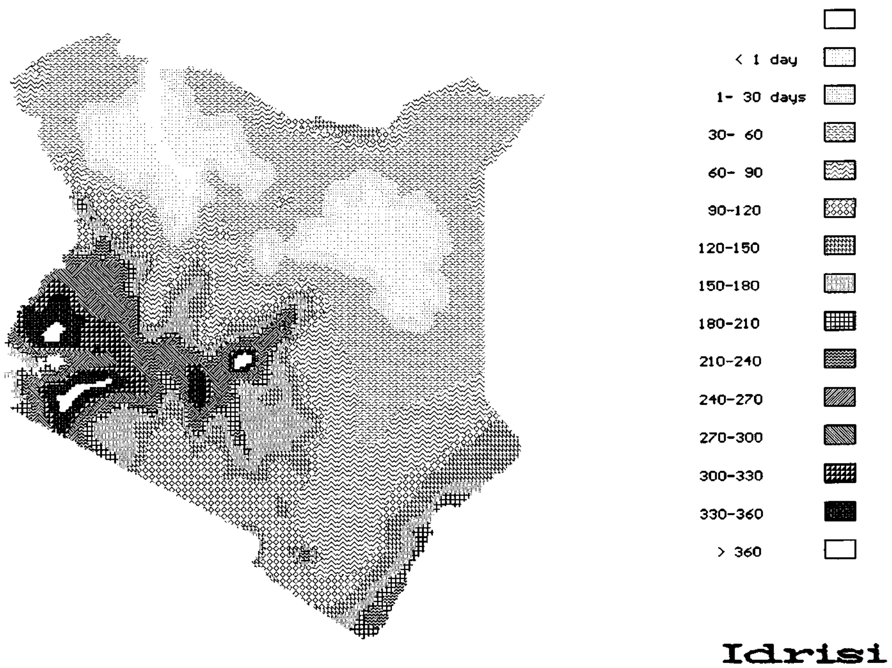

Figure B: Length of the growing period in Kenya (days). (Source: Downing 1992.)

Source: Downing 1992.

Figure C: Length of the growing period in Kenya (days) reduced by 10%. (Source: Downing: 1992.)

Box 3. (*cont.*)

maize shrinks about 15% compared with present conditions. While the lowland ranching zone would expand, the tea–dairy zone may disappear, becoming more suitable for coffee.[1]

Downing has estimated the impacts of this climate-change scenario on the socioeconomic groups defined by Hunt; the results are presented in the bottom half of Table A. Clearly, the most direct effects will be felt by groups who rely on their own agricultural production for a major share of their food consumption: pastoralists and smallholder agriculturalists. Reductions of 15–30% in the area suitable for maize cultivation in the sub-humid and semi-arid areas would significantly increase the number of people with climatic resources inadequate to sustain agriculture. The shortening of the growing season would further increase vulnerability as the probability of achieving yields is reduced.

While other socioeconomic groups will also be affected through changes in the agricultural ecoomy, they may be better able to adapt or adjust to the change. It is those who are already the most vulnerable and most marginalized who stand to lose the most.

[1] A 2 °C reduction, or a 15% drying, or a combination of an increase of 1 °C and a 10% reduction in precipitation, would correspond to a 20% reduction in the length of the growing season, and even more dramatic contractions in the length of the growing season.

some cash crops. If seasonal rains fail, no alternative supply of water is available to sustain growth. The result is critical shortages of food, inadequacy of grazing land, suffering and possibly loss of life for both human beings and livestock. The lack of adequate infrastructure (related to the lack of proactive government programs) and the high price of grain from external markets impede governmental ability to rescue inhabitants of such distressed areas.

While China and India used to be thought of as lands of drought and famine, they appear to have reduced their vulnerability by bringing these problems under control – at least temporarily. It is now Africa that is plagued by famines. While the climate variability in India and China has not been altered, critical political, social and economic factors have changed over time. 'Although there were major droughts and climate-induced food shortages around the globe – in various parts of Africa, India, China, Indonesia, Brazil – famines occurred only in Africa' (Glantz 1989:46) (also see Sen 1987; Drèze and Sen 1989). At the same time, droughts in the southwestern United States, central Canada and Australia have led primarily to economic loss (Wilhite and Glantz 1987:20–3; Rosenberg and Crosson 1992; Cohen *et al.* 1992:7–11). Here again there is a critical difference in vulnerability to hunger, famine and economic loss from place to place. Climate variability alone cannot account for vulnerability or outcomes. Both the magnitude and the type of vulnerability are different in different regions of the world, at different times, under different social and political-economic conditions, and different levels of development.

Developing countries are more vulnerable than developed ones. Not only does the level of vulnerability differ, but the type of vulnerability experienced in developing regions differs from that experienced in the industrial countries of the world. Magalhães (1991:7) point out that 'while in developed areas the impacts are mainly of an economic and environmental nature, in developing areas they are mostly social.' Clearly, vulnerability is a strong function of the level of regional development.

Vulnerability, causality and policy

Analysis of vulnerability has several ramifications in the policy sphere. In giving a *relative* indication of the level of vulnerability, policies can be aimed at the most vulnerable populations. Policy priorities can be established according to need. And, since vulnerability analysis focuses on the *multiple causes* of a single consequence, it allows policies to be designed for the range of causes that make climate events into economic and social crises. In addition, given the specificity of this type of analysis, policies can be tailored for a specific population in a specific place. And lastly, since causality happens at international, national, household and individual levels, policies can be targeted at the appropriate level *if* the causes are understood.

Knowing that vulnerability to dislocation, hunger or famine is a function of geographic location and income is a first step in evaluating vulnerability. But this does not tell us why people end up on submarginal lands or how and why they are impoverished. The causes of such spatial and economic marginality, and hence vulnerability, must usually be understood historically. Such marginality could be partly a function of land concentration, as is the case in Brazil's Northeast (Demo 1989; Magalhães and Glantz 1992; Rodrigues *et al.* 1992). It could be due to state policies encouraging cultivation on marginal lands as in parts of West Africa, or as in Australia it could be a result of people moving onto these lands not knowing that they are making this move during an unusually wet period (Glantz, this volume; Wilhite, this volume). It could also be due to the inability of a farm household to accumulate sufficient capital to invest in the maintenance of the land, or to have sufficient assets to buffer against the consequences of a drought (Sen 1981; Blaikie 1985; Downing 1991; Watts and Bohle 1993). Where these vulnerabilities are a function of class or other forms of social status, they may be results of lack of access to inputs to the productive process. Alternatively, vulnerability may be due to market instabilities or to the classic case of declining producer prices with increasing input and consumption-good prices, as in a 'simple-reproduction squeeze' (Bernstein 1979; Blaikie 1985; Sen 1987; Swift 1989).

The focus on different socioeconomic groups and on specific kinds of vulnerability or threats, such as famine or economic loss, facilitates the policy-analysis process. First, it allows policy makers to identify those groups and regions most at risk. And second, it can illuminate the causal variables, and hence the links to appropriate policy interventions for each group *vis-à-vis* specific kinds of vulnerability (Downing 1992:4).

For example, the analysis of vulnerability to specific outcomes also often reveals different causal factors for different groups. Herders and farmers may be vulnerable to hunger for different reasons. For the pastoralist it may be a function of access to dry season pastures, while for a farmer vulnerability may be due to a low savings rate and a lack of fall-back income opportunities or inability to diversify assets. It is in response to these types of causal factors, and the political-economic forces that shape them, that specific and appropriate policy options can be chosen and applied.

Climate variability affects rich as well as poor sectors of society. But, while hunger, famine and dislocation tend to threaten the poor, economic losses threaten the better off. Those who are well off may experience great material losses without ever going hungry. Thus, policies targeting both food security and economic security may be in order. But accumulation on the part of the wealthy, and policies justifying or structurally disposed to economic growth in already more economically productive regions or on larger farms, have often been part and parcel of the problem of marginalization – marginalization being a flip side of concentration. Hence, special attention must be focused on intervening in ways that do not exacerbate marginalization and vulnerability by reinforcing ongoing differentiation processes. That is, policies must acknowledge the role of accumulation and the lack of it (e.g. differentiation processes) in creating and maintaining vulnerability.

In short, the object of vulnerability analysis is to link impact analysis to the causes of vulnerability in order to facilitate the policy process. But analysts must go beyond the proximate causes of vulnerability to root causes. Correlation does not explain causality. To map out the vulnerability factors or indicators, such as location, livelihood, education and income level, is an incomplete analysis. Without addressing structural causes, such as the political economy of resource access and control – that is, the politics of accumulation and marginalization or the ongoing processes of differentiation – it is difficult to target the root causes of marginality, poverty and the resultant vulnerability to hunger and famine.

It is in response to these non-climatic causes of vulnerability that policies to reduce vulnerability can be made. Because these causes are usually multiple, interlinked and historically contingent, it is all the more important to understand their roots. It is identifying causal links that facilitates a meaningful and effective policy process, for it is in addressing the root causes of vulnerability that vulnerability can be reduced.

Levels of analysis and vulnerability

Causes of vulnerability and environmental decline, and the opportunities for their alleviation, reside at a multitude of levels within the social and political-economic context that shapes the options of individuals, enterprises and farm households. Schmink (1992) uses what she calls a 'socioeconomic matrix' when evaluating the causes of deforestation, and the policy handles by which deforestation can be addressed. This matrix can be adapted to the issues of vulnerability and dryland degradation, as has been done in Table 2. In this schematic, the various forces that bear on vulnerability at different levels are sketched out.

In brief, access to and control over resources necessary for production and reproduction at the local level are shaped by forces at a multitude of levels. Because vulnerability is partly a function of access and control over productive resources, vulnerability itself is shaped by all of these factors. While different levels of the system will exert differing degrees of influence on the local dynamic, all of these levels are relevant. The activities and options of a resource user must be examined from all these levels if a complete understanding of that user's vulnerability is to be achieved.

Conclusion

Climate events, although they can trigger catastrophes or contribute to chronic poverty, do not cause vulnerability. Rather, vulnerability is the product of international, national, household and individual level socioeconomic forces shaping people's livelihood options and choices. Catastrophe, as well as chronic underdevelopment, in the semi-arid zones comes at the intersection of nature and society. It comes at the conjunction of ecological limits, climatological events, the social organization of alternatives available to those pressed by exploitation, market prices, state policies and environmental change against falling productivity.

The most acute problems in semi-arid lands are products of a chronic lack of development, that is, a lack of the resources necessary to hedge against extreme, but expected, events: events that would surprise only a stranger to these

Table 2. *The socioeconomic matrix of vulnerability*

GLOBAL CONTEXT	
Markets	*International aid policies*
Demand for natural resources (mineral, forest, and agricultural goods)	Development lending
	Structural adjustment
	Environmental conditionality
Foreign investment	
International agreements and cooperation	
Inter-regional cooperation	
Technology transfer	
Trade agreements	
NATIONAL CONTEXT	
Markets	*Policy*
Transportation	Roads and infrastructure
Prices	Price supports and subsidies
Financial markets	Extension services
Migration	*Land tenure*
Population pressures	Land distribution
Frontier expansion	Property regimes
REGIONAL/LOCAL CONTEXT	
Settlement patterns	*Interest groups*
Localized population pressures	Conflicts over resources
	Coalition and alliances
Resource distribution	
HOUSEHOLD/COMMUNITY CONTEXT	
Gender relations	*Family/community strategies*
Division of labor and resource access control	Access to resources
	Income sources and employment
Family size and composition	
Control over fertility	Temporary migration

Source: Adapted from Schmink (1992).

regions, but which most local farmers know present a risk. It is not that the risk is unknown nor that the methods for coping do not exist, for people have been coping with climate variability for millennia. Rather, inability to cope is due to the lack of – or the systematic alienation from – resources needed to guard against these events.

The central issue of semi-arid regions is one of development and its distribution. Subsistence farmers need a margin of security and a level of savings sufficient to invest in maintaining, upgrading and developing their assets. They need access to infrastructure and to research commensurate with their needs and relevant to their goals. They also need access to alternative income-generating opportunities so as to increase their security in times of drought and to complement their agricultural activities.

In the final analysis, it is accumulation and concentration that marginalize, and it is marginality that makes people vulnerable in the face of environmental change. Marginality can also push people to 'mine' their natural resources, which only increases their vulnerability. But, so too do accumulation and concentration contribute directly to the ecological decline that makes marginal populations more vulnerable. Certainly, concentration and the drive for accumulation are important causes of widespread ecological insults. Pesticide and fertilizer overuse, uncontrolled effluents and speculative deforestation are all associated with concentration and wealth. These insults all increase vulnerability of marginal populations. They too must be taken into account in evaluating both environmental decline and vulnerability. Indeed, marginality of the environment, just as the marginality of the poor, results in higher vulnerability of both.

Development with a focus on equity and access is part of the solution to this set of problems. Productive security and environmental quality depend on development, access and inclusion – indeed, empowerment and enfranchisement. However, that development must be a conscientious development that accounts for the need to maintain a healthy natural-resource base and a secure population.

Governmental, institutional, and policy responses

Introduction

The problems facing semi-arid regions are multiple and overlapping; so too are the opportunities. There are no purely economic strategies that will reduce regional vulnerability or increase security, just as there are no purely technical strategies that will increase production, reduce poverty and reverse dryland degradation. The papers presented at ICID were unanimous in their call for adopting a multidisciplinary approach to development in semi-arid lands. Any environmentally sound development policy requires an integrated approach that allows for iterative responses to multiple, interrelated spheres – social, economic, technological, biological, political, cultural, etc. – through which policies reverberate and by which policies are reshaped.

The need to reduce and, it is hoped, reverse, the possibility of climate change cannot be overemphasized. Although these responses rightly fall into the government (domestic and international) arena, policies that aim at reducing greenhouse-gas emissions are beyond the scope of this chapter. Rather, we limit ourselves here to governmental, institutional and policy responses that may help enable the inhabitants of semi-arid regions to overcome their vulnerability in the face of current climate variations and possible future climate change. We highlight some of the important ingredients necessary for reducing vulnerability, and increasing resilience to climate variability and change.

Economic development

Environment and development are tightly linked. Unless semi-arid regions are developed, smallholders and landless peasants will continue to exert pressure on the natural-resource base in their attempts to eke out a subsistence living. Due to the lack of access to resources and minimal locally retained surplus, they often cannot buffer against the effects of drought; they are forced to 'mine' the land, simply to survive. Without the resources to invest in the maintenance and development of the land, productivity declines. As alternatives diminish, they are forced to migrate into the cities or onto increasingly marginal lands and new frontiers. Without addressing the lack of adequate farm incomes and alternative income-generating activities, preparing for drought and maintaining the resource base seem to have little chance.

A major question in development debates concerns whether to focus on large-scale and commercial agriculture and industrialization, or to support the small subsistence farmers and pastoralists. The first method has been the mode. The plight of small farmers and the landless has been seen as an inevitable cost of development, as their traditional forms of cultivation become 'outmoded.' It has often been argued that the transient inequities caused by the development process would be offset by the development to come. It would be better, the proponents of this strategy argue, to get the peasant farmers to 'modernize' or to get off the land, into the cities and the non-agricultural sector, or off to the opening of new frontiers. In short, it is better to make room for modern agriculture and industry rather than to support a 'backward' form of subsistence. While there may be truth in the notion that mechanization and modernization of agriculture is inevitable, and in many cases desirable, the dislocation of rural peasants has additional and persistent problems. Cities are overburdened with unemployed, while 'frontier' areas, typically more marginal and fragile environments than those left behind, are stressed by the influx of new migrants. In both places, the rural out-migrants often find themselves in exploitative circumstances similar to those they suffered previously.

Poverty did not disappear with agricultural mechanization. Rather, it increased during the 1960s, 1970s and the 'lost decade' of the 1980s (World Bank 1990), leading to a call for basic needs guarantees. Later, policy makers recognized the environmental ramifications of poverty (Eckholm 1979). Poverty leads smallholders to overuse their resource base, thus increasing their vulnerability in the face of climate variation (Blaikie 1985; Downing 1992). Hence it is in alleviating poverty that people's basic needs can be met, and the resource base maintained. But basic needs remain unmet and the poverty experienced by the majority of the developing world's rural populations persists.

It now seems clear that neither the modernization nor the basic needs development approach is sufficient. Development requires supporting both large commercial agriculture and small subsistence farmers. Dynamic economic regional development relies on well-integrated markets where increased production leads to increased savings, investment and consumption at the local and regional levels. Because semi-arid regions are so dependent on the primary production sector relative to other regions, the cycle of impoverishment of small rural producers and resource depletion described in the previous section signals a structural weakness in the economy (World Bank 1990; Goldsmith and Wilson 1991). This structural weakness is especially significant in semi-arid regions because agriculture there is highly susceptible to wide output variations with small changes in climate variability (UCAR 1991). Unless the pattern can be reversed, it is unlikely that integrated rural development can take root (Goldsmith and Wilson 1991; Bitoun *et al.*, this volume).

Unfortunately, reactive famine relief has long been the only form of policy attention the semi-arid areas have received. These short-term relief measures cannot, however, solve these regions' chronic problems. While responding to emergencies will always be a part of government responsibility, policy makers must focus on developing long-term strategies that reduce semi-arid regions' vulnerability to the consequences of climatic events (Wilhite, this volume). Resilient and dynamic economic development, unlike emergency, stop-gap measures, holds more hope for semi-arid regions' economies, their ecosystems, and the people in them.

Regional development strategies for semi-arid regions often focus on diversifying regional production, particularly through industrialization (Goldsmith and Wilson 1991; Magalhães and Glantz 1992). The hope is that a dynamic economic process will set in, where local businesses and firms will develop to meet industrial input needs, generating an integrated and thriving economy. This strategy is particularly attractive in areas where agriculture is susceptible to wide output variations associated with periodic droughts. Focusing on industries, manufacturing, and product processing industries that are not directly dependent on rain or agricultural inputs can buffer the economy from the vagaries of weather. This strategy, however, is frustrated by the structural limitations of semi-arid regions. The relative dominance of agricultural production, and the dominance of subsistence agriculture in terms of the economically active population, lead to demand structures in semi-arid regions which are highly variable, coinciding with drought events. As a consequence, the expected local multiplier effect of industrial development is hampered, local marketing and repair shop networks do not develop, and it becomes easier for industries and manufacturers to obtain inputs and market products outside the region from more stable sources in more developed areas (Goldsmith and Wilson 1991). The result is well-developed economic linkages with industrial areas and markets outside the semi-arid region, and a disarticulated and stagnant economy within. For the countries of the Sahel, where the entire national territory is often within the semi-arid region, reliance on outside markets for non-agricultural development places them at the mercy of the fluctuations and generally unfavorable terms of international product markets, resulting in large deficits and continual dependence on foreign aid (Watts 1987*a*; Mackintosh 1990).

This analysis demonstrates the importance of developing a viable local demand structure within semi-arid regions. Without sufficient local demand, no amount of local product diversification will lead to an economic dynamism necessary to absorb labor from the rural sector. At best, a small sector of well-off industries will develop that are less vulnerable to climatic events than the rest of the local economy.

Development strategies must increase agricultural output and income, and absorb labor. Increasing farm output and incomes provides the basis for increased demand structure, and labor-intensive activities absorb under- and unemployed labor (Perrings 1991; Lemos and Mera 1992). As farm incomes increase, consumer demand at the local level increases. Increased demand for consumer products causes local businesses to expand and new ones to form. Part-time workers are employed full-time, and new workers are taken on. As the regional economy diversifies it becomes less susceptible to climatic events. Increased incomes and security allow producers to invest in improving their farm management practices such as mechanization, irrigation and use of improved seeds. These measures often increase the number of crops possible each year, thus increasing year-round agricultural employment and the need for local distributors, repair shops, etc. Hence, the multiplier effect of increased farm output and increased incomes can contribute to integrated and sustainable rural economic development (Ranis and Stewart 1987; Storper 1991; Timmer 1992).

As argued in the section on technological responses in agriculture, government interventions to increase agricultural productivity must be focused on technologies, institutions and infrastructure that are compatible with producers' needs, present knowledge and adaptive capacities. Building on established coping strategies, strategies must be step-wise improvements that increase producers' resilience to climate variation while increasing their ability to produce and save (Rodrigues *et al.* 1992; Wang'ati, this volume). Clearly, increases in agricultural production and incomes must be accompanied by opportunities to leave the agricultural sector. Income-earning alternatives such as commerce, service, and small-scale or household manufacturing at the local level provide an exit response that can reduce out-migration to major urban centers where industrial and service sectors are insufficient to absorb all the excess rural labor (Perrings 1991; Gomes *et al.* 1992).

Farm income increases in a highly stratified economy tend to accrue predominantly to the already better-off because access to inputs such as credit, irrigation technologies and water, new seed varieties, etc., is shaped by socioeconomic standing and politics (Demo 1989; Lemos and Mera 1992; O'Brien and Liverman, this volume). Larger producers tend to spend more of their increased income outside the local area, in large cities, while small producers, who are less mobile, consume more locally, contributing more to the local economy. Inputs and markets for commercial agriculture also tend to be located outside the region, particularly in a disarticulated, subsistence economy. A context of skewed land holdings, therefore, will tend to retard any multiplier effects of increased incomes in the rural sector.

These observations lead to two conclusions. The first is that land distribution is a critical issue. The second is that particular emphasis must be placed on increasing smallholder output and incomes (including the creation of job opportunities in other sectors). Large agricultural production and industrial sectors already receive significant government attention and support relative to smallholdings, and generally experience dynamic growth relative to the smallholder agricultural sector. The task is not to focus on poor peasant farmers at the expense of large, and typically more dynamic agriculture and industry. Rather, it is to provide the necessary opportunities to smallholders and landless peasants so that they can enter into a process of dynamic economic growth.

Below we discuss several important factors that need to be considered when structuring policies that will foster dynamic agricultural growth.

Infrastructure

Water storage and irrigation are the first interventions that policy makers think of when trying to improve agricultural output and reduce vulnerability to the consequences of climate variation. Yet building reservoirs is not sufficient. Careful attention must be paid to the ecological ramifications of this approach, to who is going to have access to irrigation water, and to how this access will be controlled. (See the discussion of technological responses, below, for a more detailed discussion of irrigation technologies.) This is particularly important when water infrastructure projects are managed by the private sector, where market-based distribution of benefits will tend to exclude those most in need. Alternative water storage and distribution technologies may be more appropriate to local management practices and social networks (Moench 1991*b*; Courcier and Sabourin 1992) (see Box 4). Policy makers must assess the viability of multiple-scale and technology alternatives.

In general, irrigated agriculture involves a higher level of

Box 4. Combating drought with small dams

While the *amount* of annual precipitation remains an immediate concern for all semi-arid areas, the *distribution* is equally, if not more important. Many semi-arid regions are characterized by extremely intense, but very short periods of rain. Ironically, this can accentuate the harsh existence of an otherwise dry environment by the ravages of seasonal floods. Much of the precious rainwater can often be lost as runoff (Swindale 1992:7). In other areas, the average annual precipitation may be substantial but the high coefficient of variation perpetuates a continued sense of risk. The Brazilian Northeast, for example, faces severe uncertainty in both the precipitation amount and its seasonal distribution: the annual rainfall between years ranges from 400 to 800 millimeters and the variability coefficient from 0.35 to 0.40 (Cadier *et al.* 1992:1; Rodrigues *et al.* 1992:4).

To combat such uncertainty, water-harvesting structures such as small dams have historically been used in most semi-arid regions of the world. Yair (1992:25) describes how the ancient agriculture system in the Negev desert area in Israel, with annual rainfalls of only 75–100 millimeters, was based on an ingenious water-harvesting system using a network of cisterns.

Recently, as the long-term costs and attendant risks of large irrigation works have become evident, there is renewed emphasis on smaller, less cumbersome and simpler water-harvesting developments such as farm-level ponds, 'dug-outs', check-dams, siltation traps and multi-purpose reservoirs. These are seen as ways to boost the farm-level resilience to drought as well as productivity through demand-based water provision (Parry and Carter 1990:163; Moench 1991; Swindale 1992:9).

While discussing the utility of small dams as appropriate on-farm water-management systems for the semi-arid areas Cadier *et al.* (1992:8) describe a manual prepared by the Northeast Development Superintendency (SUDENE) for farmers and pastoralists of the Brazilian Northeast. The manual provides a range of specific and simple guidelines for efficient water harvesting in accordance with varying climatic, terrain and resource limitations. Verifying similar successes elsewhere, the SUDENE manual stresses that 'the advantage of a dam is not necessarily proportional to the stored volume.' Small tanks, when used for multiple purposes – e.g. irrigation, groundwater recharge, 'safety storage' for droughts, aquaculture (in conjunction with poultry, pig or duck farming) – often make for more effective and intensive use of the water than larger ponds.

In India, community-based participatory management of irrigation through siltation traps and check-dams has shown dramatic success with small land-holders. However, this success seems limited to homogeneous, non-stratified, 'tribal' communities, with problems emerging in communities where class, clan, caste and other distinctions create hierarchical orders of access and control over the community resource. Experiments in community management of small-scale irrigation projects are also under way in Africa (Jackelen 1992) (see Box 7). Given the importance of water to farmer communities in semi-arid areas, one can identify both opportunities and dangers in community management of irrigation projects. However, from the initial reports from both India and Africa it seems that small projects are much more conducive to such participatory management than larger ones.

technology than subsistence agriculture. The technical 'leap' can often be a significant barrier to small producers. The cost of hybrid seeds, fertilizers, and pesticides must be considered when proposing a transition to irrigated agriculture, and 'packaged' production strategies (de Almeida 1992). Often distribution networks are inadequate to allow the entire package to be applied effectively. While large producers tend to have established relationships with distributors, small producers are often located in remote areas, and may have variable demand for inputs depending on fluctuating household incomes or access to credit, making adoption of high-input technologies difficult. Small producers are likely to apply improvements selectively, and incrementally. Risking an entire crop on what, for the producer, is an untested technology, is an irrational choice. Instead, a small section of a plot may be chosen for a new seed variety, or a small amount of fertilizer will be applied to see the effect (J. Tendler, personal communication 1991). In general, these considerations indicate that agricultural packages requiring comprehensive application in order to achieve significant results are less appropriate for small producers. Rather, projects should involve a series of incremental improvements that build directly on producer experience, skill and financial ability.

Improved roads, communication networks, rural electrification, marketing networks, and product processing and storage are necessary for making integrated development possible (World Bank 1990; Perrings 1991; Gomes *et al.* 1992; Magalhães and Glantz 1992; Zhao 1992). Whether this kind of infrastructure is put in place during emergency make-work projects during a drought period, or is done gradually as a part of a regional development plan, care must be taken to design infrastructure and prioritized projects so that there the distribution of benefits is as even as possible. For example, wide high-grade roads in a few areas may come at the expense of narrow lower-standard roads distributed over a larger region. Narrower roads will go further, having a more extensive positive effect on the region. These kinds of trade-offs are present in nearly every kind of infrastructure project. A policy that is directed at improving the conditions of the most vulnerable, and fostering an integrated economy, implies that the decision must benefit the greatest number of people possible.

Semi-arid zones are seen as largely lacking in resources (water, soil nutrients, etc.), but they are rich in certain resources. Developing semi-arid regions must take full advantage of these resources. Solar, wind and geothermal energy may provide viable alternatives to dependence on water-based or non-renewable resource-based electricity generation (Wang'ati, this volume; Zhao, this volume). Development of both centralized and decentralized technologies should be pursued, aiming at developing technologies that are easily implemented and not dependent on outside inputs.

Credit, marketing and inputs

Small producers tend to go from season to season with a very limited safety margin because nearly all their earnings and production are used for subsistence or extracted from the local economy. Savings are limited, or non-existent. Lack of savings limits their ability to diversify into alternative income-generating activities, or to invest in increasing the productive capacity of their farms. This does not mean that smallholders are ill equipped to adopt improved management practices and technologies, or to diversify their economic activities. On the contrary, subsistence agriculturalists are by necessity diversifiers, adapters and survivors. Their lack of investment capital is a significant barrier for their adoption of more productive activities. Yet, as we argue, improving the productive capacity of smallholdings and the diversification of local economies within semi-arid regions is a basic requirement for regional development and economic growth. Credit is one possible solution to this barrier. Small producers, however, have less access to formal credit systems than better-off producers. Some have proposed alternative credit institutions that are more accessible to small producers (Caron and Da Silva 1992) (see Box 5). These types of flexible strategies demonstrate how government policies can be formulated to address the needs of small producers, and to structure projects that are responsive to them.

Problems of access to markets and productive inputs can constitute a more significant barrier to economic growth than lack of credit. Government interventions through 'variable' incentives, such as product and input prices, taxes, subsidies, and 'user' charges are one way for governments to intervene in facilitating small-producer access to viable commercialization of their products (Perrings 1991). Prices and financial incentives represent only part of the access equation, however. Institutional barriers also block small-producer access to productive resources. Perrings (1991) calls for user-enabling measures to correct these problems. These measures might include small grain storage facilities, small-producer product processing and marketing cooperatives, and management structures for common property resources such as grazing areas, water and forests.

Human resource development

Education, health care, safe water supplies and sanitation, and vocational training all fall within the area of human resource development. Projects and programs of these sorts can be grouped into two categories, based on the policy intent. On the one hand, developing human resources means insuring a basic level of wellbeing, related to life expectancy, health, literacy, etc. On the other hand, it means creating the capacity for people to increase their own wellbeing through diversification into more profitable activities, or improving current techniques. The two concepts are clearly related. Without the first, the second is impossible. However, the distinction is helpful in structuring government investment policies. Training that provides skills needed in growing sectors will enable people to move readily into economically viable activities while also contributing to the dynamic growth of the region. Conversely, training for activities which are needed outside of the region can facilitate out-migration when better opportunities are available elsewhere (Wang'ati, this volume).

Agricultural extension and training play a significant role in disseminating new technologies and inputs, responding to producer emergency needs, and developing adapted technologies that reflect the specific soil, water and landholding size agriculturalists are working within. Projects and programs dealing with agricultural research and extension must be oriented towards the needs of small producers, and be appropriate to cultivation limitations inherent in semi-arid regions. Ideally, these programs should develop institutional links with entities at the local level to broaden the dissemination of new adaptive technologies and techniques, and to make local decision makers aware of the need for sustainable and appropriate development policies (Rodrigues *et al.* 1992).

Alternative income opportunities

Much analysis of semi-arid regions focuses on the pressures of a growing population. This observation is useful only to the extent that it signals a shortage of opportunities available to people living in semi-arid regions. Rather than focusing solely on fertility controls – which are politically charged, difficult to implement, and of questionable efficacy – policies should also focus on improving the options available to people. As mentioned earlier, efforts to equip semi-arid populations with skills that are useful outside agriculture, or

Box 5. Credit for small producers

Small producers, though often viewed as a liability to regional development, can be an engine for growth. Caron and Da Silva (1992) note that by diversifying their production mix, small producers hedge against the impacts of drought, floods and frost. They argue that encouraging this kind of diversification can not only pull small producers out of a cycle of poverty, but stimulate rural growth. By making small-scale commercial activities possible for the rural poor, development programs can help buffer farmers against climate variability and change while stimulating rural dynamism and development with minimum external resources (Caron and Da Silva 1992:8).

Rural families often 'place' family members in alternative activities in order to insure a minimum family income at all times. This may involve: sending a family member to the city to earn wages, raising livestock, introducing technological improvements, wage work on others farms, or producing commercial products for supplemental income in case crops fail. Increasing rural incomes provides a foundation for development of local service sector employment through increased consumer expenditures by farm households. Focusing on small-scale producers is a key element in this growth strategy because smallholders, unlike large rural producers, tend to use labor-intensive technologies, rely on local materials and local craft people for repairs, and spend the majority of their incomes on local goods and services (Ranis and Stewart 1987). Yet small producers are often unable to diversify into profitable activities because they lack capital for investment.

Not only do small producers have little surplus to reinvest, but the formal credit system rarely reaches them (Caron and Da Silva 1992). With no credit history, and little or no collateral, few banks want to lend to small farmers. Further, the small size of the loan, the time needed to process each loan, and the difficulty of lending to often first-time borrowers who may need assistance reading and filling out the forms, all lead lending institutions to shy away from small rural loans (Tendler 1989). Lending institutions that broker small loans for larger banks, such as the Grameen Bank of Bangladesh, can take on these 'difficult' tasks. They provide an example of how credit can work for small rural producers (Caron and Da Silva 1992). By processing loan applications, providing technical assistance for new production activities, these 'banks' have had a significant measure of success where they have been implemented. Because the lending institution works closely with the borrowers, it is able to assess borrowers' ability to repay, independent of collateral and credit history information. The lenders insure repayment by setting up borrowers' groups mutually to enforce repayment among members. Group members only benefit if previous group loans are repaid, thus creating strong social pressure against default.

The alternative credit schemes, however, are not without their problems. One significant issue is the time required for borrowers. The 'solidarity' borrowing group must work cooperatively, or at minimum monitor each other's repayments. This can be a time-consuming activity. People who are excluded from traditional lending institutions also tend to be quite poor. They spend nearly all their time in subsistence activities, and are hardly able to afford this 'extra' time (Boviniv 1986). These programs have been difficult to replicate and expand (Biggs *et al.* 1990). Much of their success depends on the direct face-to-face contact between the loan broker and the borrower to establish a basis of trust and security that the loan will indeed be repaid. This relationship takes time to develop, or local residents must be discovered who can fill this role. Support for income diversification into small-scale enterprises can also serve simply to 'diversify subsistence' without increasing people's standard of living. The proliferation of similar micro-enterprises increases horizontal competition, reduces profits, and increases labor exploitation (Biggs *et al.* 1990).

Further, credit is not always the key bottleneck to developing a commercial activity. Often lack of access to markets, inputs and technical training prevents people from starting small enterprises. If these obstacles are not overcome, the chance of default is high (Kilby 1979; Schmitz 1982; Tendler 1989). Policies must therefore be designed with all of these considerations in mind. Research shows that diversifying income generating activities into small-scale enterprises works best when they are located in an agglomeration of complementary firms. The backward and forward linkages among small firms help insure access to inputs and markets, and enable the smaller firms to achieve economies of scale and investment jumps in new technologies that each firm on its own could not manage (Kilby 1979; Peattie 1979; Chen 1986; Schmitz 1990; Storper 1991).

A number of policy interventions emerge from the above discussion. The first involves finding the bottleneck, or missing piece in an otherwise thriving environment of firms within a larger agglomeration of firms providing related goods and services (Kilby 1979; Chen 1986; Tendler 1989). For rural semi-arid regions, this means activities that are tied to the dynamic portions of the economy, typically the non-farm sector (World Bank 1990). Credit is the most common form that the 'missing piece' strategy takes, though technical assistance, marketing and input provision are other examples. Ideally, policy interventions should link services or assist the flow of

Box 5. (*cont.*)

inputs and products among existing local firms, allowing idle capacity to be brought into use, rather than trying to create new skills and activities (Kilby 1979). Interventions that permit workers in small-scale enterprises to engage in multiple tasks – whether various income-earning activities, or a combination of income-earning and household activities – allows the enterprise activity to fit into the beneficiaries' multiple needs.

even outside the semi-arid regions, is one way to enable people to rise above their bare subsistence condition and to reduce pressures on the land (see, for example, Santibáñez 1992:41). Unless there are income-earning opportunities waiting for them elsewhere, however, there is little hope for such a strategy. It must therefore be linked to deliberate efforts to create new jobs and income-earning activities in semi-arid regions, and to foster the growth of alternative activities such as marketing, intermediary goods production and services. Directing credit for these activities, providing subsidies for start-up enterprises, and creating physical and financial infrastructure will facilitate their emergence.

Emergency responses

There will always be a need for emergency responses to climate events in semi-arid regions (see Wilhite, this volume). No matter how well adapted we are to climate variations, there will always be events which exceed adaptive structures. There are, however, ways to reduce the likelihood that we will be caught by surprise by climate events, or that when severe events occur we are completely unprepared to respond (Wang'ati, this volume). Significant advances have already been made in developing forecasting and early-warning mechanisms (Downing 1992). The task at this point is to increase the link between institutions that have forecasting capabilities and local agencies responsible for responding to emerging crises (Servain *et al.* 1992; Cochonneau and Sechet 1992; Soares *et al.* 1992). Gomes, *et al.* (1992) argue, for example, that the lack of coordination and communication among institutions within the Brazilian semi-arid region leads to ineffectual responses to crisis. This situation must be addressed. While much of the large-scale early-warning information is international in scope, there must be well-established links to the regional and local levels. In this way, not only will semi-arid regions be more prepared to deal with severe climatic events, but scientists and policy makers will learn more about the interrelationships between climate and environment.

Conclusion

This discussion is a cursory review of strategies and approaches that can foster adaptive strategies to the severe climate variability of semi-arid regions. It has not been an exhaustive discussion, but rather an indication of the kind of analytical orientation that is needed in order to address the multifaceted problems facing policy makers at the national, regional and local levels in semi-arid regions. Like any adaptive strategy, policy approaches will themselves evolve as we learn more about the interrelationships between climate and environment, and among the multiple spheres of society – economics, politics, technology, environment and culture. Each region and country must find those strategies that are most suited to its own particular conditions, limitations and capabilities. None of the strategies discussed here are panaceas for the triple burden of underdevelopment, marginalization and climate variation. Instead, they attempt to point to a more hopeful future for these regions, which will only come about through significant effort by policy makers, local entities and the local population.

Technological responses in agriculture

Introduction

Trying to respond to the natural fragility of semi-arid areas by applying unidimensional technical fixes without considering the socioeconomic and cultural context within which they are applied can often lead to disastrous results (Glantz 1989:63). The challenge to policy makers is to show that they are able to develop technical responses to climate variability and change that are sensitive to the social context in which they are to be applied. Fortunately, there is ample reason to believe this can be done. In this section we investigate some of the dominant technological responses that have been applied in response to climate variability in semi-arid areas. Each has strengths as well as limitations, opportunities as well as pitfalls. The difference between understanding or ignoring these is often the difference between success and failure.

Technology has many faces. It ranges from the newest inputs and the most 'high technology' practices, to traditional methods of cultivation. The objective of modern, high technology systems is to maximize profit or yield, using improved crop varieties and livestock breeds, along with fertilizers, herbicides, pesticides and mechanization. The aim of many traditional systems is to minimize year-to-year variation in productivity and, especially, to minimize the risk of total loss (Scott 1976; Popkin 1979; Hyden 1980). The price of this stability is often foregone potential yield. The price of modern, high-yield systems is the lack of a safety net, should the crop fail. Before any technological response can be introduced a thorough understanding of the existing systems, and their internal interactions and dynamics, is necessary. Equally, while estimation of risk levels is an essential component of agriculture analysis, the level of 'risk acceptance' and 'risk affordability' must also be taken into account (Nix 1985:107). Policy makers can learn from traditional coping strategies used by indigenous communities in the search for appropriate technological responses to climate variability.

Below we discuss soil and crop management, water management, high-input agriculture and pastoralism. This is neither an exhaustive list nor an exhaustive critique of the available technological options. The aim is to lay out a broad spectrum of major issues and discuss their relation to climate variability and change, particularly the latter as projected by major general circulation models. In general, any response is only as good as its compatibility with the context – physical, climatological, socioeconomic and cultural – to which it is applied. Its viability depends not on the technology alone, but on how it is managed and where it is used.

Soil and crop management

Soil degradation is probably the most significant threat to sustainable agriculture. Attempts to extend agriculture by expanding agriculture onto marginal soils accelerates the process. Soil erosion, deterioration of soil structure, loss of nutrients or nutrient holding capacity, build-up of salts and toxic elements, waterlogging, acidification, etc., remain constant threats to cultivated tracts in the semi-arid regions. Soil erosion is particularly disturbing due to its high replacement costs.

Soil degradation is largely a function of poor crop management. Yet, even on poor soils (like those often found in semi-arid areas) it can be brought under control. For example, inter-cropping, crop–pasture association, using crops with different root distribution patterns, crop rotations, alley cropping, ridging, terracing, mulching, and zero or minimum tillage check soil degradation while also promoting moisture retention (Watts 1987*b*:179; Huss-Ashmore 1989:27; Swindale 1992:7). Good soil management is the key to halting dryland degradation, or desertification.

Traditional cropping strategies have evolved sophisticated management practices to maintain soil quality (Huss-Ashmore 1989:28; GOP/IUCN 1991). Increasingly, however, the ability of marginalized farmers and pastoralists to maintain traditional soil and farm management practices is being threatened. For example, the beneficial effects of soil organic matter in both improving soil quality and preventing surface degradation is well known to farmers. As access to the commons decreases or when market prices increase, competing demands for dung and crop residues can trap farmers into practices that they know are not sustainable. Dung, for example, may be burned rather than plowed into the soil as firewood supplies grow scarce or too expensive.

Since plant cover is often sparse in semi-arid regions, evaporation from the soil surface can be a significant portion of the total evapotranspiration. With climate change some models project increased rates of evaporation due to increased temperatures (Rosenberg and Crosson 1992; Cohen *et al.* 1992; Schmandt and Ward 1992; Downing 1992; O'Brien and Liverman, this volume). Increasing low-water-demand plant cover, either in the form of food and cash crops or in fodder crops and grasses, is an obvious and important response, especially since a simultaneous increase in net precipitation is also projected.

Salinity is a problem for semi-arid lands, especially under warmer climate regimes. But it can be turned to advantage through better management practices if the existing information and experience about saline agriculture is utilized. Headway is already being made in employing salt-tolerant crop and grass species. Fodder crops, in particular, can be grown on fairly poor soils with highly saline water to support livestock (GOP/IUCN 1991).

Water management

Semi-arid areas are characterized by rainfall variabilities both in quantity and in spatial and temporal distribution. Wherever more regular and abundant sources of water are available nearby or where erratic or insufficient rains merit the creation of artificial water reservoirs, irrigation has historically been seen as an ideal response to climate variability. Many irrigation systems have a long record of success; from once being considered famine-prone, the dry plains of China and India are major food producers today. Mexico, Pakistan and Egypt have been equally successful in enhancing their agricultural production through intensive irrigation (GOP/IUCN 1991).

Yet the success of many irrigation systems has not come without its economic, ecological and social price (Swindale 1992:12; Selvarajan and Sinha 1992:2). Salinity, drainage deficiencies, waterlogging, compaction and siltation are just a few of the attendant problems which, if severe enough, become the precursors of desertification. With the expansion of intensive, high-input agriculture – often on soils unprepared for the burden – the problems are compounded (see the section on High-input Agriculture below). While agricultural operations can cause salinity problems even in rainfed areas, salinity is most chronic in irrigated soils. Use of unlined canals, sinking of tube-wells into salt-bearing strata, inadequate drainage and poor water and crop management combine in irrigated tracts to reduce water and soil quality. This can substantially decrease land productivity and seriously affect the quality of drinking water (Swindale 1992:6).

Where irrigation systems or their management are divorced from local social realities they can increase, rather than reduce, vulnerability to the impacts of climatic variations and change (O'Brien and Liverman, this volume). The information in Box 6, which deals with irrigation, shows that it is not irrigation itself, but how and where it is used that aggravates soil degradation. Access and distributional issues of irrigation are germane to all technological interventions. The section on Governmental, Institutional and Policy Responses above, discusses these issues in more detail.

More emphasis and attention has now turned to smaller-scale developments such as farm ponds, 'dug outs,' siltation traps and small multi-purpose reservoirs (Parry and Carter 1990:163; Swindale 1992:9; Wang'ati, this volume) (see Box 4). The aim is to retain the precious rainfall that is so often lost in semi-arid areas due to high runoffs, while improving water-use efficiency. Many of the crop management practices discussed earlier serve the same purposes.

More effective use of groundwater can reduce risk of crop failure in uncertain climates, while also circumventing the need for large and cumbersome water distribution systems (Zhao, this volume). For example, in Mali a pilot project for high-input agriculture with water-pumps is already under way (see Box 7) (Jackelen 1992). The use of dug-wells by Indian farmers for preventing crop losses when temporary rainfall deficits occur, or to recharge soil moisture storage before planting a dry season crop, has contributed substantially to improved farm livelihoods. The use of tube-wells in irrigated plains of Pakistan has similarly given the farmer a solution to waterlogging as well as a source of demand-based water provision. In many desert areas there are vast fossil water supplies which can be exploited for agricultural use (Swindale 1992:9). Groundwater depletion is a risk where recharge rates are slow. Therefore, it is essential to use water as efficiently as possible, employing sprinkler or drip irrigation technologies, or other labor-intensive technologies that achieve the same level of efficiency (GOP/IUCN 1991).

High-input agriculture

The thrust toward intensive agriculture stems not just from technological advances in irrigation systems, fertilizers, seed varieties and hybrid development, but as much, if not more, from population and government policy pressures. With projected change and uncertainty in climatic regimes compounding the already strenuous pressures on the semi-arid zones, high-input agriculture may become a necessary measure for combating vulnerability in some areas (see, for example, Box 7).

Improved cultivars are capable of delivering bumper crops in good years. Examples of the success of high-input agriculture in comparatively well endowed (particularly irrigated) semi-arid lands provides optimism (Selvarajan and Sinha 1992). Yet the need for caution must be emphasized (GOP/IUCN 1991). High-input, mono-crop agriculture lacks the 'safety net' built into traditional systems which use multiple native varieties and rarely experience complete system failure. Further, reliable water supplies, nutrient-rich soils and high technological investments are just a few of the prerequisites for the sustained success of intensive, high-input agriculture. On the more risk-prone rainfed tracts, mounting pressures of production and increasing climate uncertainty could force farmers to adopt intensive agriculture with unsustainable, if not disastrous, results (GOP/IUCN 1991; O'Brien and Liverman, this volume).

Experience points toward homogeneity and the loss of sustainability being conspicuously and directly related. Pests and diseases will always reduce crop yields to some extent, but their effects are more devastating when mixed cropping is replaced by mono-cropping and varieties are replaced by hybrids. The technological response to this technology-driven problem is chemical control (Swindale 1992:3). While pests quickly become immune to pesticides, the latter accumulate and contaminate food and water systems. The use of integrated pest management techniques shows significant potential in resolving this problem (Swindale 1992). Some stability of crop production may be achieved by varying fertilizer applications to offset anomalous climatic conditions (Parry and Carter 1990:161). Since many semi-arid soils are deficient in organic matter and are further degraded by soil erosion, increased fertilizer application is likely to be an important response strategy.

In general, it is now being acknowledged that excessive crop specialization should be avoided, despite the short-term economic benefits it provides. Increasing environmental awareness has stimulated research into alternative agricultural practices, with particular emphasis on learning not only from past follies of intensive agriculture but also from the resilience of traditional systems. The value of crop rotation, multi-cropping, mixed farming, use of cover crops and recycling of agricultural wastes is being recognized (Richards 1985). Most importantly, it is finally being recognized that building upon traditional wisdom and grounding strategies in the realities of specific socioeconomic and natural systems can lead to increased and more stable production potentials (Huss-Ashmore 1989:28; Swindale 1992).

Pastoralism

Le Houérou (1985:155) defines pastoralism as the 'unsettled and non-commercial husbandry of domestic animals' and estimates a pastoralist population of 60 to 70 million people (in 1985), mainly in Africa and Asia. He points out that pastoralism is 'essentially – but not solely – a form of

Box 6. Irrigating semi-arid lands

Buffering farmers in the semi-arid regions from the effects of recurrent droughts and erratic rainfall patterns is crucial to achieving agricultural sustainability (Swindale 1992:10). From historic to contemporary times, irrigation has been a favored response for providing such a buffer. From 137 million hectares (Mha) in 1961, the global irrigated area has increased to 219.7 Mha in 1988 – predominantly in Asia; two-thirds in developing countries; and 91% concentrated in 30 countries. In Asia, 30% of the farms are irrigated; in Africa, the share is less than 2%, although the country with the greatest dependence on irrigation is Egypt (Nemec 1988:217).

Large-scale irrigation works have been the mainstay of drought policy in many semi-arid areas in recent decades (Parry and Carter 1990:163). Irrigation has dramatically increased crop production in many countries (notably India, Pakistan, Mexico, Egypt). Yet it is equally well established that irrigation, when managed improperly and/or when incompatible with the area's ecological, social and economic characteristics, can become a disaster for semi-arid areas and a major anthropogenic cause of desertification (Glantz 1989:66; Rodrigues *et al.* 1992:7).

Large-scale irrigation works being one of the most intense forms of human interference in the hydrological cycle, can sometimes leave deep scars. Native vegetation and fauna are often the first victims of the huge civil structures required for massive irrigation initiatives. Creation of 'irrigation refugees' (those displaced by the structures of irrigation as well as those whose small land parcels fall prey to the requirements of larger holdings for intensive irrigated agriculture) follows soon after. As denudation and mono-culture result in vermin and pest invasions the immediate use of pesticides accelerates. Mismanaged irrigation works can also lead to a whole host of technical problems pertaining to drainage, water-logging, loss of water quality, siltation, compaction and salinization. In addition, there are the socioeconomic problems that may arise from subsidized water pricing, unfair access to and control of the resource, marginalization of smallholders, inequities in distribution of benefits, and proliferation of water-borne diseases (Horowitz 1991; Rodrigues *et al.* 1992:7–9).

Valdemar Rodrigues *et al.* (1992:9) reports that in the Brazilian Northeast a target of bringing 600 000 ha of semi-arid lands under irrigation (from 261 000 ha in 1980) is now under way in the expectation that irrigated agriculture will provide 20 times the yield of dryland cultivation. However, he quotes the department of drought relief works as reporting that 20% of the area already irrigated is facing problems of salinization, compaction or flooding. J. C. Silva (1988, quoted in Rodrigues *et al.* 1992:6) estimates this figure to be 30%, reaching 50% in certain areas. As Rodrigues puts it, profits originating from irrigation correspond to the losses from salinization; however, while the profits are whisked away to outside markets, the losses accumulate on the land.

Yet, by balancing these problems, there have been large increases in production of staples such as rice and wheat that have been crucial to reducing food deficits in many developing countries (often in the semi-arid zones) since the early 1970s. In large part, these increases are derived from technological improvements in irrigated agriculture. This has directly reduced vulnerability in the face of drought. The argument, then, is not so much against irrigation, as against the mismanagement of large and/or incompatible irrigation systems (Swindale 1992:12).

This realization, coupled with an increasing acknowledgment of the long-term economic and ecological costs of extensive irrigation works, has already set in; after a peak in the 1970s there is now a marked decrease in the expansion of large irrigation networks (Nemec 1988:218; Swindale 1992:8). The same realization has spurred the need for a renewed emphasis on efforts to improve the efficiency of existing schemes through reduction in seepage and other losses; control of salinization, waterlogging and siltation; improved management of watersheds, water distribution and water use; and greater involvement of farmers and end-users for more equitable and efficient management of systems (Swindale 1992:12).

Fortunately, effective research programs are already under way in several developing countries with dry climates, including India, Pakistan and Egypt (Swindale 1992:8). Substantial information exists on issues such as saline agriculture, groundwater utilization, salt-tolerant species, drainage and no-tillage agriculture. This information promises to lead toward better utilization of existing systems as well as development of more efficient, site-appropriate irrigation technologies for the future.

A recent report on recommendations for drylands research (UCAR 1991:13) points out that although irrigation does reduce the susceptibility of agriculture to the vagaries of climate, in the longer run, irrigated agriculture is limited by the physical environment. Technological advances have not changed these limitations dramatically. In 1878, at the start of scientific management of arid lands, it was reported that less than 3% of Utah (USA) was suitable for irrigation. A 1954 study stated, 'Nobody has corrected that notably since; in 1945 the cultivated area of the state, including dry farms, was 3%' (UCAR 1992:13).

It is in acknowledging and respecting the limitations of the physical, climatological and social environments – and of technological frontiers – that the future and success of irrigation in semi-arid areas depends.

Box 7. Financing pumped irrigation along the Upper Niger River

Located in the Sahel, Mali is one of the poorest countries in the world, with a per capita income of US$ 185 per annum (1988). The Timbuktu region in Northern Mali is characterized by desert and semi-arid terrain, food deficiency, and poor means of transport and communication. Here, along the floodplain of the Upper Niger River where the rural settlements are concentrated, a unique variety of 'floating' rice has been the traditional staple crop; one which has provided predominantly subsistence communities with the ability to cope with their harsh environment.

Sown prior to the flood season, using broadcast methods, this remarkable variety grows with the rising flood tides and is harvested on small boats after the stalks are between 2 to 3 meters high. With yields of between 0.50 and 0.75 tonnes per hectare the indigenous variety does not compare well with other rice species that can produce 4–6 tonnes per hectare in the same area. However, this is more than compensated for by the fact that floating rice requires little labor, no inputs and is grown on extensive floodplains, where land supply is not a constraint.

With the average rainfall decreasing by nearly a third from 215 millimeters (1950–1967) to 145 millimeters (1968–1985), the risk to the system increased as droughts intensified, triggering population dislocations and famine conditions during the late 1970s and 1980s. In his paper 'Economic interventions in the changing environment of a semi-arid zone' Jackelen (1992) describes one approach taken to mitigate the situation.

While the floods were still reliable enough to justify the continued planting of traditional varieties, the decrease in their level from historic averages and the increasing infrequency of the humid surfaces required for planting and seed germination constituted an emergency situation requiring an immediately applicable solution. The United Nations Capital Development Fund (UNCDF) considered that the introduction of small pumps (2–5 horsepower) and sprinkler systems to maintain the use of the floodplain for growing traditional varieties was too untried, complex and cost-ineffective a solution. Instead they decided to intervene by encouraging land- and capital-intensive agriculture using 25 horsepower motor pumps for small-scale (20 hectares) irrigated perimeters and introducing high-input rice varieties.

The choice was based primarily on the known successes of the technology and the fact the enhanced productivity (8–10 times the normal yield) would allow for carrying recurrent costs (both inputs and amortization of pumps) at 20–30% of total production. However, it was recognized that the communities – characterized by low education, stark poverty, hierarchical social structures and little experience in land intensive cultivation – would require adaptation to high-input agriculture; technical upkeep of motor pumps; financial management for procuring diesel, oil, phosphate, urea and seeds from season to season (amounting in cash and stocks totalling US$ 20000–40000) and amortizing the cost of motor pumps (US$ 20000) over their working life of eight seasons; successfully marketing considerable quantities of paddy; and ensuring a high level of social cooperation, management and participation.

Between 1983 and 1985 eight communities constituting some 2000 families (total population approximately 14000) were targeted. Intensive negotiations resulted in the creation of informal but functional Village Associations in each community, with elected Executive Committees entrusted with all financial and management responsibilities. On average, each community was required to organize and provide a work force of 400–500 workers for 3–4 days a week during the period of 4 months. Thus, for the overall project, 250000 work-days were mobilized, two-thirds paid in food from the World Food Program and one-third voluntary.

With all eight communities having had 5 or more years of production, technical assessments indicate that despite the harsh environment, minimal government support and low maintenance facilities (for motor pumps), the introduced technology and practices proved appropriate to the needs and capacities of the communities. The target yield for the project was set at 4 tonnes per hectare to allow all recurring costs to be covered with less than 30% of production. In 1990, only two of the eight communities failed to achieve this target (3.1 and 3.5 tonnes per hectare), two produced substantially above it (6.1 and 5.3 tonnes per hectare), while the remaining four produced around the target (5.0, 4.7, 4.3 and 4.0 tonnes per hectare).

The management of revolving funds by the community has, however, produced mixed results, with half the communities in a poor position to amortize the motor pump costs. Even though inputs for the first 2 years were included in the project cost, the relative magnitude of cash and stocks to be replenished and managed yearly (up to US$ 40000) was itself a significant factor. In addition, each season required US$ 2500 per motor pump to be placed aside for future replacement (a pro rata calculation per household reveals that the amortizement is roughly equivalent to 125 kilograms of paddy per season). While the communities demonstrated an appreciable understanding of the need to replenish inputs each season, the complex mechanisms for calculation and recovery of the motor pump amortization resulted in an understandable reticence on the part of the members to deliver.

As its most valuable lesson the project highlighted the importance of a simplified, easily understood and easily

Box 7. *(cont.)*

operable system for the management of community finances. While affordability was not the only factor in the lack of repayment, it is noted that since production does not represent commercial surpluses and requires a deduction of 20–30% each year, an alternative to straight repayments could be envisioned in the form of loan repayments. This highlights the criticality of focusing on credit financing activities, which could range from handicrafts or livestock forming the basis of micro-lending programs to use of small pumps for traditional agriculture or replacement of motor pumps through credit schemes. Communities that have demonstrated strong social structures for managing and honoring their financial commitments are, in effect, self-selected candidates for becoming the nucleus of 'community banking' on which to base more complex activities for upgrading social infrastructure and diversifying production.

In addition, it is still unclear whether this type of scheme increases or decreases subsistence vulnerability, since these interventions create dependence on external sources (markets and state agencies) for seed, fertilizer, equipment and fuel. The supply of such inputs is particularly precarious in remote regions, and their affordability can easily be affected by fluctuating prices of either inputs or the resulting crops, while their availability can be disrupted by state policies, conflicts or other events.

adaptation of human societies to hazards and hardships induced, and imposed on them, by climatic constraints.'

Recent famines in the Sahel and the subsequent plight of the pastoralists have focused attention on pastoralism, particularly in the context of projected climate change. The present state of crisis is often attributed to anthropogenic impacts such as overstocking, wood-cutting, bush-fires, 'wild' water development, and expansion of intensive cultivation. Le Houérou (1985:173) and Watts (1987*a*:295), however, describe how herders in Africa utilize complex social relationships as insurance against drought and point out that it is in the strangulation of these social relationships, and not just in the vagaries of climate and population pressures, that the present crisis needs to be understood.

Traditionally, pastoralists have combated the high variability in primary production of rangelands by relying on sturdy drought-resistant breeds, by the mix of livestock held, a sophisticated ethno-scientific understanding of local ranges, and by various sociocultural relationships in addition to the basic nomadic movement (Le Houérou 1985; Watts 1987*b*). Increasingly, the options to exercise these strategies are being severely curtailed by policies that encourage farm encroachment on pastoral lands, settlement programs and blockages in nomadic routes (Wang'ati, this volume). Even those who simplistically blame overgrazing and overpopulation as the culprits, and feel that de-stocking and resettlement of people is the most viable solution, acknowledge that issues of property rights, access to common property and efficacy of human institutions will frame the success, or failure, of any biological or physical 'fix' to these problems (Swindale 1992:14).

Sedentary pastoralism with particular focus on agropastoral systems provides one response to realizing the production potential of semi-arid areas, providing sustainable livelihoods and reducing the need for periodic drought and famine relief (Swindale 1992:15). Such systems would need to integrate traditional knowledge about adaptation of stocking rates, livestock mix and grazing patterns with the introduction of suitable fodder crops, trees and shrubs (including saline-tolerant varieties) and improved techniques such as ripping, subsoiling, scarifying, pitting, contour benching and water spreading (Le Houérou 1985:169; Swindale 1992:15). The viability of such programs would, however, be dependent upon policy changes that support the development of local infrastructure and institutions, and community involvement in projects with particular focus on the displaced nomadic pastoralists.

International responses

Introduction

The global interest accorded to the Brundtland Commission (WCED 1987) and the Intergovernmental Panel on Climate Change (IPCC 1990) testify to the new wave of international concern for the global environment. The expectations surrounding the United Nations Conference on Environment and Development (UNCED) reflect not just the twentieth anniversary of the Stockholm Conference, but more importantly the arrival of environmental issues – particularly global climate change – on the international agenda.

In this section we look briefly at the international concerns for climate change, and what expectations are being associated with the UNCED process. We then discuss why it is important to give priority to the semi-arid regions in international discussions and actions regarding global climate change. We then outline some major facets of required international responses. Finally, we discuss why restructuring international economic interventions is of concern.

International cooperation

The global nature of climate change has triggered global interest and global fears. It has even initiated some fledgling efforts toward global response initiatives; these, however, have been far from satisfactory. Whereas verbal consensus on the need for international response strategies exists, the severe distributional disparities, both in causes and in effects of climate change have made any such effort politically charged. While the overwhelming bulk of additions to the greenhouse gas flux results from the wasteful practices in the North, the countries most vulnerable to global climate change are in the South (Agarwal and Narain 1991). The debate is being framed by the North, for Northern interests, yet the South is more vulnerable, and the North is better able to cope with climate-change impacts. Not only will the South have to bear the effects of climate change, increased climate variability and a sea level rise, and pay part of the price of mitigating effects largely of the North's making (e.g. preserving forests, foregoing CFC use and paying higher energy prices) but there is a real danger of ignoring the North's wasteful consumption habits while placing the blame on the South's population (see Agarwal and Narain 1991).

Global networks and institutions

Despite the pressures for action generated by UNCED, meaningful international agreements to reduce greenhouse gas emissions are still a long way off. There have, however, been a number of important international landmarks in this direction. The Montreal Protocol of 1987 to stop the production of chemicals implicated in stratospheric ozone depletion marked one such landmark – even if limited in scope and coming after a protracted, and somewhat painful, process requiring 'long and difficult negotiations and substantial compromise [on] goals' (Harris 1991:112).

More specifically, no major international policy initiative exists to address the problems of the semi-arid areas in the light of the projected climate change. The need for such an initiative seems obvious. But given the inherent diversity between and within semi-arid regions it must emerge from, and build upon, regional networks. Although institutions such as UNEP or the Food and Agriculture Organization (FAO) have larger mandates, their particular interest in the semi-arid zones can be a potential asset. The Inter-governmental Committee for the Fight Against Drought in the Sahel (Comité Inter-Etat pour la Lutte contre la Sécheresse au Sahel; CILSS) and the Inter-Governmental Authority on Drought and Development (IGADD) in the Sudano-Sahelian region and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) are a few examples of institutions focused on issues of semi-arid lands (Swindale 1992; Wang'ati, this volume).

Such global and regional networks can provide a forum for evaluating the vulnerability of populations in semi-arid regions facing climate variability and change, exchanging successful development strategies, and sharing information on climate trends and early-warning techniques. Given the lack of funds and facilities in many semi-arid regions, such networks and institutions have a major responsibility for long-term research at the regional and local levels, with particular focus on forecasting, early-warning, and control or mitigation strategies.

The need for networks also stems as much from the fact that semi-arid regions often encompass many nations – the Sahel spans 22 countries – as it does from the importance of sharing and learning from each other's experiences. At the same time, the need to communicate between the regional and local levels requires a cadre of local experts who understand local as well as regional and international issues and needs. Educating and training a cadre of experts and decision makers may best be accomplished by regional and international networks and institutions.

International economic interventions

International trade imbalances, foreign debt constraints, international commodity markets and pricing structures, the nature of foreign loans and assistance, and the nature and level of investments by multi-national corporations (MNCs) all help shape the internal policies of developing nations. Such influences can often outweigh attempts at environmental and resource management, regardless of how much 'political will' a government has (O'Brien and Liverman, this volume). The era since the Second World War has seen the internationalization of production, finance and services. This often defines policy and policy implications at local, and even village, levels (Watts 1987*a*:292). Glantz (this volume) points out that international pressures can force countries to shift from food crops to export crops, sometimes causing hunger even where there is no drought.

In response to mounting public concern for the environment, some progress has been made. Efforts to restructure 'assistance' criteria, environmental impact assessments and natural-resource accounting in cost-benefit analysis are a few examples (Meredith 1992*a*). While all these initiatives are yet too new or untried for a meaningful assessment to be made, their potential merits attention.

Balanced inclusion in the international economy is of particular relevance for the destiny of the developing world and of the semi-arid regions within them. The relative position of weakness *vis-à-vis* MNC investments, international terms of trade and price structures can often force developing countries into decisions to exploit resources. Passed on from the international to the local stage through national policy, such decisions (e.g. growing groundnut for export rather than food crops for domestic use) force the pace of degradation and deprivation on the semi-arid lands.

Why focus on semi-arid lands?

In addressing the threats of global climate change, international attention has, until now, been focused on the issues of coastal and island settlements and on tropical forests. The first (such as the Maldives and Bangladesh) have received attention because they are at great risk of total inundation by rising sea level, the latter because forest management can both reduce the problem and contribute to its solution.[9] Semi-arid tropics deserve more international attention for these same reasons.

Like coastal and island settlements, the semi-arid tropics are at extreme risk in the face of projected global climate change. Rather than inundation by the sea, semi-arid lands risk inundation from increased rains, and desiccation from warming.[10] It is no mistake that the semi-arid southern edge of the Sahara desert is called the Sahel, from the Arabic word for shore or coastline, for the Sahel is the tidal zone between the desert and the humid forests to the south. Here exaggerating or shifting rainfall patterns could make these regions uninhabitable. Increasing desiccation drives the northern limit of cultivation southward, as has happened with past and current droughts, taking vast farming and pastoral regions out of cultivation and pasture, and dislocating the populations who depend on these lands.

In general, the ecosystems in semi-arid regions tend to have poor soils, problematic groundwater resources, and depend heavily on already scant and erratic rainfall; in addition, the spatial marginality of their populations is often compounded by chronic poverty and underdevelopment. This combination makes them extremely vulnerable to the negative outcomes associated with climate change. The semi-arid tropics are in real danger of severe and widespread human and environmental catastrophe (famine, desertification, etc.), and the need for action is urgent.

Degradation of the resource base not only jeopardizes the livelihoods of a region's inhabitants, but the resulting deprivation results in 'spillover' of dislocated populations onto other, often equally fragile, ecosystems. The dislocation of 'ecological refugees' is not a concept unique to Africa. A case in point is the relationship between the Brazilian Northeast and the Amazon, with more than 51% of those migrating into the Amazon reported to originate from the semi-arid Northeast (Bitoun *et al.*, this volume). The emerging pattern is clear: degradation and deprivation in one area can translate into increased pressures on others.

Semi-arid regions are among the least developed regions of the world. Consequently, they are also the most vulnerable to the current consequences of climate variability and the potential consequences of climate change. While mitigation strategies applied to the forest and energy sectors will reduce the potential for future aggravation of an already precarious situation, actions to reduce current vulnerability in semi-arid lands will do the same. Indeed, the object is to reduce or avert human suffering while upgrading productivity from the natural-resource base. Balanced development in these areas has the potential to do both. Equitable development can reduce local and migration-triggered environmental deterioration, as well as vulnerability to hunger, famine and dislocation, by providing the resources necessary to invest in maintenance and improvement of the land while providing jobs to prevent migration into other fragile regions. Clearly, we do not have to look to the future to find risk or need. Development in semi-arid regions will help meet these needs and reduce both current and future vulnerability.

There are opportunities in these regions. These opportunities serve not only development aims, but environmental aims as well. Not only do they stop the exploitative 'mining' of the most marginal lands by the most exploited and marginalized populations, but they also reduce pressure on other regions by reducing outmigration or by encouraging migration into more productive (agricultural and non-agricultural) regions and activities. But most importantly, development measures in these most marginal lands increase the wellbeing and security of those who are chronically exposed to the risk of hunger, famine and loss.

CONCLUSION

It is ironic that we must look into the future, to a time distant enough to be free of commitment to immediate action or change, just to discuss the tragedy taking place before us. We project future climate change and future vulnerability to dislocation, hunger and famine, while vulnerability and crisis are already chronic and widespread. Today, future scenarios allow us to discuss these (otherwise too politically charged) development, environment and equity issues in a public forum. Indeed, they have brought these 'future' issues to the center of international attention. But we must use this opportunity to slide back down the projection lines and point to the crisis at hand.

As illustrated in this chapter, and in the chapters that follow, the semi-arid regions of the world are currently experiencing the insecurity and disruptions that climate-change impact analyses indicate could become more widespread. Addressing the current problems in the semi-arid tropics will diminish the future vulnerability that climate change may exacerbate. Clearly, the long-term future of these and other regions of the world depends on today's quality of life and the sustainability of current practices and social relations within these regions. While it is important to look to the future, it is much more important to act today on what we already know from direct and repeated experience. It is critical to begin investing in the future today, by investing in social changes that can support equitable and ecologically sound development.

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ENDNOTES

1. Heathcote (1983:16) cites P. Meigs' estimate that semi-arid lands make up approximately 15.8% of the world's land area and the United Nations estimates that these lands cover 13.3% of the world's land. The Meigs estimate is based on those areas in which the ratio of precipitation to evapotranspiration falls between −20 and −40. This corresponds, according to Meigs (published in 1953), approximately to the lands falling between the 200 and 500 millimeter isohyets. The basis of the UN estimate (published in 1977) is not explained. It should be noted that the first estimate might be considered conservative since some definitions currently in use correspond to the lands falling between 200 and 800 millimeter isohyets (Rasmusson 1987). For further discussion of the problems of defining semi-arid regions, see the section on semi-arid regions. The population of semi-arid areas derived from Heathcote's (1983:20–1) figures is approximately 11.25% of the world's total. Heathcote (1983:21) also presents a UN figure (published in 1977) of 10.1% of the world's population living in these regions. The figures for the land areas, and hence the proportion of the world's population living in these areas, are subject to uncertainty and definitional dispute. The figures presented here, given the conservative rainfall range, are probably therefore underestimated.
2. Marginality is a fact, marginalization a process. While the fact of marginality can lead to environmental decline, the process of marginalization should be identified as the cause. Marginality is the result of this process. The consequences of marginality are therefore the consequences of the marginalization process. It is this process that should be examined if marginality and its consequences are to be understood and redressed.
3. The uncertainty range is 0.2–0.5 °C per decade.
4. Emphasis added.
5. The highest-resolution climate GCMs specify the state of the atmosphere at the intersections of a three-dimensional grid. Each grid is divided into sections that are approximately 250 miles on a side and about a mile thick (Stone 1992:37).
6. For an excellent evaluation of the multiple causes of soil erosion see Blaikie (1985) and Blaikie and Brookfield (1987). For a similar analysis of the causes of deforestation see Schmink (1992).
7. Gasques *et al.* (1992:38), for example, argue that in Brazil's Northeast, 'basic food production is concentrated in areas of extreme vulnerability where reduced production from climatic variations is not just an economic question, of reduced output, but rather a question of survival' (translated from the Portuguese by the authors).
8. The analyst, in the authors' opinion, must be thought of as including not only the expert adviser or policy maker, but also the populations being analyzed. Participation and participatory research are discussed in the introduction of the section on Responses.
9. Saving the tropical forests would reduce the release of greenhouse gases (through reduced burning and decay) as well as provide a sink for CO_2 (through forest planting and growth) from other sources, particularly energy.
10. This is not an either/or proposition, but, if rains remain unevenly distributed and drying is intensified, alternating floods and drought could be the mode.

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