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The case scenario approach to climate related impact analysis

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This paper is concerned with how well society might be prepared for changes in climate variability and climate extremes as a result of the carbon dioxide/trace-gases-induced global warming. It presents the use and potential value of the "case scenarios" approach in identifying the ability of decisionmakers at various levels of society to respond to environmental changes at the regional level. This approach represents yet another way to assess the preparedness of societies to climate-related stress. Case scenarios are based on assessments of appropriate contemporary historical responses to climate-related environmental changes as analogues or surrogates for what might plausibly happen if a global warming occurs. Several case scenarios are briefly described. A detailed case study is presented based on the societal and environmental impacts of a set of four freeze events in a five-year period in the first half of the 1980s. This case scenario identifies societal strengths and weaknesses in the citrus growing region of the southeastern United States in coping with such unanticipated extreme meteorological events. This study also shows how adverse climate impacts in one country can change the country's ability to compete economically in the market place. It is hoped that the case scenario approach to climate impact assessments will be useful in other sectors and in other countries as well.

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„Eset-szcenárió" megközelítés éghajlati vonatkozású hatásvizsgálatokhoz. A dolgozat célja annak elemzése, milyen jól tud a társadalom felkészülni a szén-dioxid és más nyomgázok okozta globális felmelegedés következtében létrejövő éghajlat-változásokra, ill. -szélsőségekre. Bemutatja az „eset-szcenárió" megközelítés használatát és potenciális értékét a döntéshozók tevékenységében a társadalom különböző szféráiban, hogy választ tudjanak adni a regionális méretű környezeti változásokra. E megközelítés mindenképpen új utat jelent annak felmérésére, mennyire készült fel a társadalom az éghajlat okozta stresszre. Az eset-szcenáriók lényege annak felderítése, hogy milyen megfelelő társadalmi visszahatások születtek a közelmúltban az éghajlati vonatkozású környezeti változásokra; ezeket analógiáknak tekintjük arra vonatkozóan, hogy valószínűleg mi történhetne, ha globális felmelegedés következne be. Részletes esettanulmányt mutatunk be, amely a 80-as évek első felében öt évből négyben előfordult fagykár társadalmi és környezeti hatásaival foglalkozik. Ez a tanulmány feltárja az USA délkeleti részének citrustermelő régióiban a társadalmi válasz erős és gyenge pontjait, amikor ilyen előre nem látott meteorológiai események fordulnak elő. A tanulmány azt is bemutatja, hogy az ártalmas éghajlati hatások milyen mértékben tudják megváltoztatni egy ország piacon való maradási képességét. Reméljük, hogy az éghajlati hatások felmérésére az ilyen eset-szcenárió megközelítések más ágazatokban és más országokban is hasznosnak bizonyulnak.

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Introduction

The purpose of this paper is twofold. First it is to discuss the use and potential value of what we call "case-scenarios" to identify the ability of societies (from the local to the international levels) to respond to low-grade, long-term environmental changes. We are most concerned with how well society might be prepared for changes in climate variability and climate extremes as a result of the CO_2/trace gas-induced global warming. The case-scenarios approach represents an attempt to develop yet another way to assess the preparedness of societies to climate-related stress. As opposed to the development of scenarios from atmospheric general circulation models (the development of societal impacts scenarios from the top down), the case-scenario approach is an attempt to develop such scenarios by using appropriate contemporary historical responses to climate-related problems as surrogates or analogues for what might feasibly happen in a warmer world (the development of societal impacts scenarios from the bottom up).

The second purpose of this paper (not necessarily unrelated to the first) is to present a multidisciplinary case study of the impacts of a set of freeze events on citrus production in the State of Florida (USA). This will serve to exemplify the kind of information that might be obtained in a typical climate impacts assessment. It is a shortened version of a longer more in-depth study on how climate can affect the economic competitiveness of a particular industry (*Miller* and *Glantz*, 1987). This case study also serves as yet another example of a case-scenario for the global warming section of the paper. The unusual repeated freezes in Florida in the early 1980s represent a plausible scenario of changes in frequency and intensity of extreme meteorological events that might accompany a CO_2/trace gas atmospheric warming.

The Carbon Dioxide issue and regional scenarios

There is a large collection of literature on the effects of carbon dioxide and other trace gases on global temperatures and ecosystems (e. g., *Bolin et al.*, 1986; *DOE*, 1985 a, b, c, d, 1986; *EPA*, 1983 a, b, 1984). Much of this work has been funded in the US by the Department of Energy (DOE). Originally, the DOE was charged with responsibility for societal impacts of CO_2-induced global warming but with a change in political administrations in the US in 1980, the DOE dropped its support for research into the societal aspects of CO_2 impacts. However, today there is a strong desire to focus attention on the societal and economic impacts of a global warming. Presently it is the US Environmental Protection Agency (EPA) that has the responsibility for assessing the societal impacts and policy aspects of a trace gases-induced global warming and the implications of those impacts for policy making. The problem is that there are still many uncertainties about the CO_2-induced warming that make studies of societal impacts of such a warming questionable. What, for example, does an average global warming mean to climate on a regional and local scale?

There has been considerable dependence in the past on scenario construction using General Circulation Models (GCMs) to determine regional-scale physical impacts. Yet, GCMs have not proven very reliable modeling precipitation and even temperature at the regional level. How useful to policymakers might such scenarios be for long-range planning purposes? While they may have some credibility (but not reliability) in scientific circles, they surely lack credibility in political circles because the policymakers do not have any experience in dealing with the kind of future worlds that the models suggest. Can this be remedied?

To complement the work of GCMs, we have undertaken an assessment of "case scenarios" that can be used as analogues of possible societal responses to the impacts of a trace gas-induced global warming. These cases contain actual societal responses to environmental changes that might provide us with some idea about how societies might respond to regional climatic changes. In a sense

Fig. 1.

these cases can serve as societal sensitivity studies that will show how well society is prepared to respond today to climate-related environmental problems. We look at two kinds of problems: long-term, low-grade but cumulative changes (e. g., sea level rise) and recurrent climate-related environmental changes (e. g., droughts). With regard to the latter at least two important concerns come to mind: changes in the frequency of occurrence of recurrent problems (i. e., increasing or decreasing) and changes in extremes (i. e., new records being set according to some standard, usually the historical record, or the lifetime of a structure such as a dam or reservoir).

It is important to note that how societies responded in the past may or may not provide a reliable guide as to how society might respond in the future to recurrent climate anomalies. For this reason, this approach may lack a degree of scientific credibility. Yet, they may have some credibility in political circles because they are based on recent experiences and policymakers will be able to relate to them, having had some experience, for example, dealing with the impacts of rising (or falling) lake levels on coastal communities, or dealing with the economic impacts of repeated freezes on citrus grove owners. In addition, such case scenarios could expose current strengths and weaknesses of existing institutions and processes in dealing with either long-term, low-grade cumulative environmental changes or with recurrent climate-related environmental changes, and thus can offer an opportunity for society to take into consideration appropriate adjustments.

For an assessment of case scenarios for North America, we have chosen to look at the following situations: metropolitan water supply (Northern Virginia) and drought, orange production (Florida) and freezes, the Mississippi River system and the impacts of high and low flow on navigation, coastal subsidence and sea level rise (Southern Louisiana), declining aquifers and agricultural adjustment (U. S. Great Plains), the rise in the level of the Great Lakes, the rise in the level of the Great Salt Lake (Utah), water supply management and drought (northern California) and the impact of an erroneous streamflow forecast on irrigated agriculture (Yakima, Washington). Only a few of these cases will be discussed here. Each case has its own contribution to make to our understanding of society's response to environmental change. The case studies are now in progress and the research findings (as well as the case-scenario's contributions to our understanding) are yet to be fully identified.

Specific Case-Scenarios: A few examples

Increasing levels of the North American Great Lakes. In the past few years levels of several of the North American Great Lakes *(Fig. 1.)* have been at or above record historical levels (*Cohen*, 1987; *Quinn*, 1985). There is no indication oen way or another whether this increase in levels will continue.

Previous extremely high lake levels were reached in 1974 and those have been matched or surpassed in the mid-1980s. Attention was drawn to the Great Lakes situation as a result of national media coverage of the damage that has resulted to communities bordering some of the lakes. In addition, Chicago's shorefront property had been damaged by high water as well as by wind-driven blocks of ice hurled into shorefront condominiums.

There has been considerable speculation recently about whether the increase in lake levels might be linked to the "greenhouse effect" resulting from the increase in the atmospheric content of the trace gases. This particular environmental change will be the focus of attention of the EPA's report to the US Congress early next year on the policy aspects of a carbon dioxide warming. If the CO_2 warming is taken seriously as a cause of increasing lake levels then it is assumed that these levels will remain high. In fact, with regard to a CO_2-induced warming it is believed that the level of the Great Lakes will go down, not up as they have been in the recent decades. Thus certain responses might be expected from organizations, agencies and political units (e. g., states, provinces, local communities, international commissions). A CO_2-induced warming will be a long-term, gradual but cumulative process. Several questions need to be explored. What kind of response should these various groups involved with different aspects of the Great Lakes system take? What kinds of preventive measures might be warranted, given that there is still considerable uncertainty about what such a warming might do to Great Lakes levels? Should those organizations allow the gradual changes to occur, and simply respond in an adaptive fashion to changes in lake level and associated problems such as coastal flooding or more severe storm surges? The Great Lakes are high now and have been high at previous times. Several questions might be investigated. How have societies bordering the Great Lakes dealt with sharp changes in lake levels in the past fifteen years? How have they responded in the past five years? Can we learn from such responses how societies in similar situations might respond to such climate-related environmental problems in the future? What does it tell us about how societies deal with incremental, low-grade cumulative environmental changes?

Rise in the Great Salt Lake. The U. S. Great Salt Lake is situated entirely within the State of Utah and is approximately 3,500 km². *(Fig. 2)*

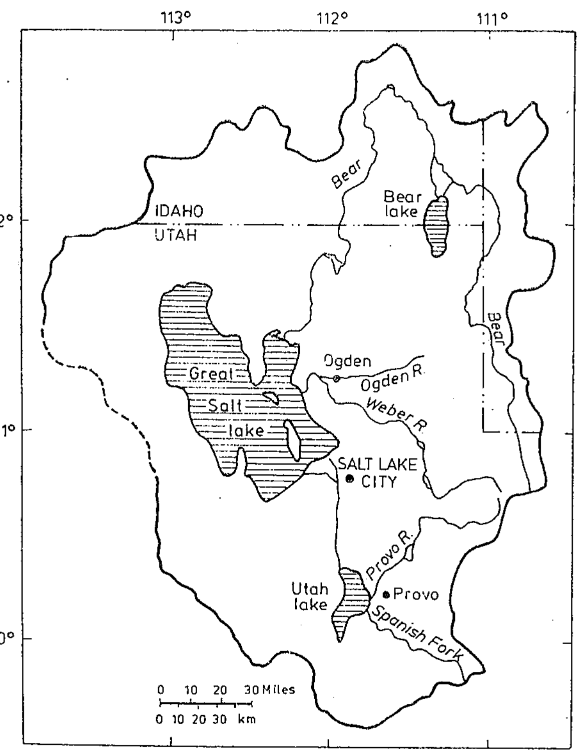


Fig. 2.

As of 1982, the level of the Great Salt Lake had reached its historic long-term average (1281) m), having rebounded from its historic low level in 1963 (1278 m). From the historic low of 1962 the levels continued to slowly rise until the early 1980s. Between September 1982 and June 1983, however, the level of the Great Salt Lake rose about 1.5 meters. The following year it had risen another 1.5 meters. There was little change in 1985. By 1986 it had risen yet another 1.2 meters, surpassing the previous historic high record set in 1873. The lake rose rapidly between 1982 and 1986, as a result of heavy precipitation in the fall and spring seasons. In June 1986 it had risen to its highest level ever recorded. Thre is uncertainty today about what direction the lake level will go in the near future.

Amidst all the speculation about why the lake level had risen as well as what society might do about it, political decisionmakers were prompted to action as a result of actual damages that resulted from the rising waters. The total damages have thus far been estimated to be over $300 million. Damage includes adverse impacts on industrial and mining activities along the lakeshore, destruction of agricultural land as well as wildlife refuges, railroad track beddings, highways, residential homes, employment prospects and so on. For example, rail lines had to be raised repeatedly in the mid-1980s in order to accomodate higher lake levels. In some areas the tracks can be raised no higher because the elevated beds cannot withstand the weight of the trains. In addition, the interstate highway (I – 80) was also raised in this period but, for the same reasons, it cannot be further elevated. If the lake continues to rise, rail service to some parts of Utah will end. Also, some of the mining companies already adversely affected by rising lake levels have already closed down their lakefront operations and terminated the jobs of hundreds of employees.

According to *Morrisette* (1987), the State's response to the rising lake levels has been to "implement a set of incremental adjustments with each step being taken as a previous step became overwhelmed by the continuing rise of the lake level" (p. 94). The reason for the inability to cope with the impacts on the lake of a variable climate regime were related to two major causes: perceptions about the upper limits of the lake level (human time scales being different from natural time scales); rigidity in institutional arrangements for dealing with the levels of the Great Salt Lake. The State of Utah opted for building a pumping station at a cost of tens of millions of dollars to keep the lake level "safe" on the short-term. This solution was supported by some and opposed by others.

It appears that two views about future lake level rise were in competition with each other for support of decisionmakers: one view was that the lake had reached its highest level and therefore had to recede, the other view was that the past record provided little insight into the future. If climate was indeed changing, then there would be little value in placing a heavy reliance on the historical record. A controversy developed over how high could lake levels go and what lake level would be acceptable for planning for development around the lake. Contingencies were developed identifying what was believed to be the most likely high lake level (1283 m by the year 2025), the most likely low lake level (1278 m by 2010), and the more extreme but still possible high lake level (1284 m by 1998). More importantly, a planning level of 1286 m was identified as the most plausible high level (extreme event).

When lake levels in 1985 did not rise, some observers felt that the problem was over. This appear to be a common response to recurrent severe climate-related phenomena. It may be no more than wishful thinking; hoping that the problem will resolve itself. Also, decisionmakers do not want to put themselves in a position whereby they have authorized some costly mitigation measures, only to have the reasons for the measures evaporate. No one knows what the future holds in store for the Great Salt Lake.

What this case study tells us is how State decisionmakers have perceived lake levels and how they perceive future climate changes and their possible effects on lake levels. Current scientific speculation suggests that with a global warming the lake levels will decline, not increase. Perhaps this belief has reinforced Utah decisionmakers to opt for a short-term solution to rising lake levels and to hope that they made the right decision.

The Ogallala Aquifer Depletion in the US Great Plains. The Great Plains is considered to be part of the heartland for agricultural production in the United States. The aquifer underlies parts of eight states, from South Dakota to Texas *(Fig. 3.)*.

It is of variable saturated thickness with the thickest part being in Nebraska and the thinnest part being in the High Plains of Texas. Agriculture in the region is heavily dependent on the use of aquifer water for irrigation purposes.

The region itself produces principally corn, wheat, cotton and feed grains (sorghum). The region is drought prone with speculation about the periodicity of those droughts somehow being linked to 22-year sunspot cycles. Whether, such a relationship is found to exist, beyond a doubt, a myth has developed that a major drought hits the Great Plains every 20 years or so . . . and now we look and wait for them.

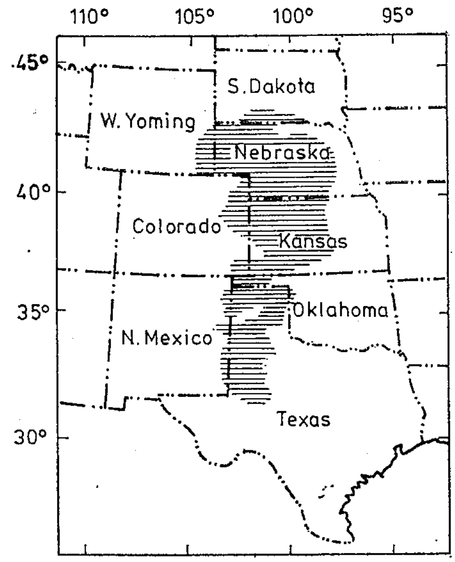


Fig. 3.

Droughts do return to the western part of the United States every so often and they have been of varying magnitude and impact. The droughts in the 1890s caused a great number of settlers to abandon their land in search of areas with less harsh climatic conditions. The worst of these droughts in intensity and in societal and environmental impacts took place in the mid-1930s, an era that is commonly referred to as the "dust bowl" days.

The spectre of a return of such prolonged and intense drought conditions is driving policymakers to take seriously scientific arguments about the regional effects of a global warming. Several models of a potential global warming suggest that the American Great Plains will become drier and soil moisture will become reduced. The models include output from general circulation models, historical and paleoecological reconstructions of the environment (regional climate and ecology) during the last warm epoch (the Altithermal about 4000 – 8000 years ago), and a reconstruction of midlatitude climate during the ten warmest Arctic summers this century (it is assumed that a one degree warming in the midlatitudes would mean a 3 – 4 degree warming in the polar region). There have even been scenarios constructed that "play out" the impacts of a 1930s type drought on a 1980s type economy in that region (*Bernard*, 1980; *Warrick*, 1984).

As the historical records show, each of the major droughts in the region has prompted decisionmakers from farmers to state governments to look for ways to buffer agricultural and other activities from the vagaries of climate, especially drought. Thus, during and following major droughts, there is a sharp increase in the number of wells constructed to tap the ground water. There seems to be little control over the exploitation of the aquifer. In fact, one could argue that for a long time the aquifer was seen as an unlimited resource. Yet the aquifer is not of homogeneous thickness or depth from the surface and is also more vulnerable to exploitation in some places than in others.

Driving the exploitation of the aquifer were favorable prices for agricultural production, cheap energy, available technology and, last but not least, recurrent droughts and dry spells throughout the region. However, some regions where the aquifer is thinnest (the High Plains of Texas) began to experience reduced availability of groundwater. The level of the aquifer had dropped to such an extent that it became more and more expensive to sink wells and required more energy to pump it out. With the depletion of the aquifer and with higher energy costs some farmers have reverted to dryland farming practices, shifted to crops with a lower dependence on water, or abandoned their land.

To take a look at the problem of a declining groundwater level, the US Congress authorized an $11 million study of the geology of the aquifer and the impacts of its depletion. Projections were made to the year 2020. In this report the climate of the region for the next 40 years was considered to be the same as the climate of the past several decades; that is, extremely favorable for agricultural production in the region. Such a view, of course, ignored all of the scientific discussion that has been taking place about the likely global warming as well as speculation about the regional impacts on the Great Plains of such a warming. The High Plains study looked at baseline projections (that is, the continuation of current policies and trends at all levels) and proposed five alternative water management strategies, two of which included intrastate and interstate water transportation. The proposal of extrapolating current policies and trends received much criticism when the study was evaluated (*NCAR*, 1985).

These two environmental problems – the actual, real problem of the drawdown of the Ogallala aquifer and the hypothesized, projected regional impacts of a global warming – should be looked at together rather than separately. Those studying each of these problems can learn from the research findings of the other. For example, how farmers in the Texas High Plains have responded to dwindling ground water supplies may shed light on how farmers in that region might respond to a change (perhaps associated with a trace gas-induced warming) in the frequency and intensity of droughts. How governments at all levels of society have responded to the long-term, low-grade but cumulative decline in ground water supply may present ideas on how best to deal with the long-term, low-grade but cumulative global warming associated with the burning of fossil fuels, the release of other trace gases, and deforestation. We have experience in dealing (or not dealing) with the aquifer's depletion, whereas we have little experience in dealing with an analogous (in several respects) problem of changes in precipitation in the American Great Plains. We can learn from societal responses to the depletion of the aquifer about how we might cope with an "atmospheric drying out" of the American Great Plains.

The aquifer depletion continues in many parts of the region and it is projected that after 2020 a groundwater "crisis" will emerge throughout the region. The global warming, if it continues, will become heightened by the early decades of the 21st century. These two adverse impacts on the water balance in the region (one actual and one potential) will converge, making a bad situation even worse.

As noted in the introduction, the following section represents both a case-scenario for the climate change issue discussed in the preceding section and a study of extreme events and societal responses to them.

The Florida Citrus Case Study. As a result of climatic factors, only a small portion of the world's agricultural land is suitable for the commercial production of high quality citrus. An even smaller portion is suitable for the profitable production of oranges intended for processing into frozen concentrated orange juice. The climate characteristics of the State of Florida were conducive for the state to become a major producer of oranges during the 19th century and the world's first major producer of frozen concentrated orange juice (FCOJ) in the mid-twentieth century. Citrus production in Florida has become a multibillion dollar industry.

The annual climatic patterns have allowed for profitable citrus production mainly in the central portion of the state. The geographic location of commercial citrus production has been limited in the southern part of the state by poorly drained soils and in the north by relatively high freeze probabilities. Even within the main citrus growing areas recurrent freezes can impose significant costs.

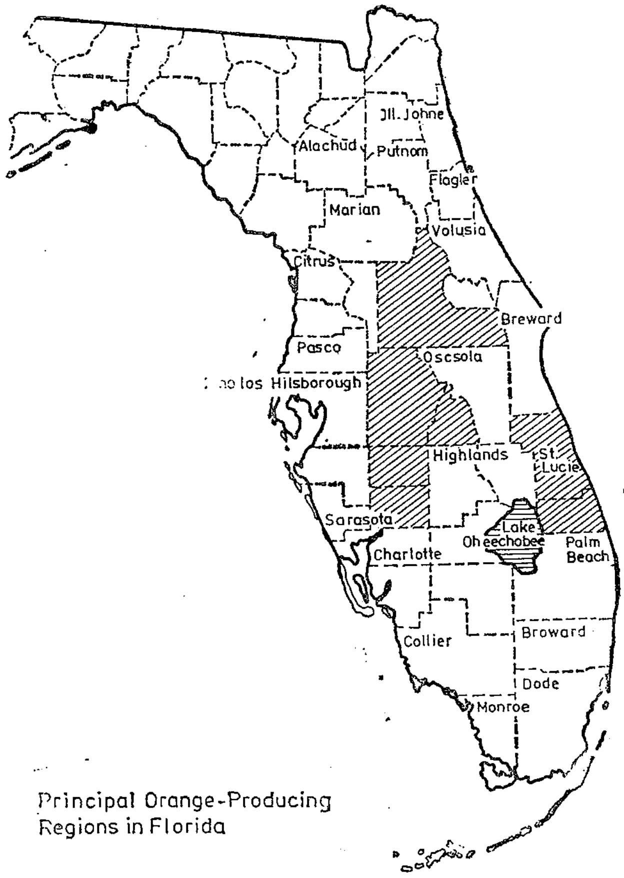
Between September 1980 and January 1986 the Florida citrus industry has suffered four major freezes. The most serious of these freezes (the third and fourth in the sequence) occurred in December 1983 and January 1985. Together, these two freezes are estimated to have killed approximately 40 percent of Florida's commercial citrus trees.

While Florida's citrus growers may have adjusted to the periodic occurrence of freeze damage, the set of freezes that began in 1980, as well as the devastating intensity of the 1983 and 1985 freezes, caught them by surprise. Such severe freeze damage had not been experienced for nearly a century.

The recent anomalous set of freezes has reinforced speculation about climate change. More than one writer has suggested that climate change is at the root of Florida's recent freezes. Chen, for example, reports that an apparent cooling trend can be discerned in Florida's minimum temperature records (*Chen*, 1984, 1985). Some observers questioned whether the citrus industry in Florida could recover. Moreover, if it recovers, what can it expect with regard to future climate variability and future climate extremes? Those who suggest a climate change, of course, represent only one view about why Florida's citrus region has been plagued by the recent series of damaging freezes. It is possible that freeze probabilities in Florida's orange growing areas *(Fig. 4a)* are high enough that this anomalous series of cold temperature events could have occurred even in the absence of a real climate change. In other situations, it has been shown that runs of extreme weather events can occur by chance with no change having necessarily occurred in the underlying probability distribution (*Glantz* and *Katz*, 1985).

Regardless of the underlying cause or causes of this recent set of seemingly anomalous freeze events, the experience may have been sufficiently costly to convince many Florida citrus growers that freeze probabilities are significantly higher than they had previously assumed and may cavuse them to seek to minimize their risk of loss by resorting to one of a variety of measures. They may expand citrus planting into southern Florida. Citrus production has traditionally been limited in Florida's southern counties because the poorly drained soils in that region are in general unfavorable to citrus production. Such soils mean higher

a)



Principal Orange-Producing Regions in Florida

Fig. 4a.

land preparation costs, greater risks of disease and relatively lower yields. As another alternative they convert their land to other less risky uses. In many parts of Florida there is considerable enticement for orange grove owners to turn their land over to other uses. For example, Florida has one of the fastest growing populations in the nation, and groves could be converted by land developers into new communities. Other potential competing uses for land in Florida's traditional citrus growing areas include conversion into forest or pasture or into land suitable for the production of other fruits, nuts, or vegetables. These other investment alternatives might become more attractive following periods of severe freezes.

As long as the trees in a grove are alive and producing, its value in citrus production is likely to exceed its value in many alternative uses. Once the trees are dead, however, the value of that parcel of land falls dramatically, and the owner is faced with a radical change in the relative value of his land inalternative uses. It has been estimated that as much as 1/3 of the frozen-out citrus acreage will be put to other uses. At least 1/3, however, will be replanted. Those growers who do replant are generally following new practices including closer

Stipple = Major Orange-Producing Region in Brazil *Fig. 4b.*

spacings, the installation of microsprinklers for cold protection, and the use of tree-wraps to protect the young trees from freeze damage. These practices provide greater cold protection for the young trees. Growers also hedge against freeze risks by planting a mix of early and late maturing varieties. While the early varieties face less risk of frost, they bring lower prices.

Until this decade, Florida growers were less vulnerable to financial losses from freezes, because when freezes adversely affected orange juice production, the resulting increase in price could compensate affected growers for some if not all of their loss. In addition, before 1962, Florida had virtually no competition as a supplier of FCOJ. Since the 1960s, Florida's output has been supplemented by a steadily increasing Brazilian FCOJ production. Today, the increased availability of Brazilian exports of FCOJ provides a ready substitute for shortfalls in Florida's production, thus the price of FCOJ has become fairly stable. Florida citrus growers can no longer count on sharp increases in prices for their oranges following a citrus-damaging freeze event.

The climate of Sao Paulo state in Brazil is especially suitable for the production of high quality oranges. *(Fig. 4b)* When in 1962 a severe tree-killing freeze occurred in Florida, the resulting rise in prices for oranges and especially for FCOJ caught the attention of entrepreneurs in Sao Paulo and stimulated the establishment of new orange groves and the development of modern, quality-controlled juice production techniques. Brazilian production has continued to expand since the 1960s. In fact, some American and multinational corporations involved in orange juice production have developed groves in Brazil as well in an attempt to minimize their financial vulnerability to the vagaries of climate.

Despite the stimulus that the 1962 freeze in Florida provided to Brazil to enter into the FCOJ industry, the role of subsequent Florida freezes in determining the rate of expansion of Brazilian FCOJ output is less clear. Steady growth in world demand, coupled with cost-saving technological innovations appear to have been the long-run driving forces behind this expansion. While there does appear to be a tendency for exports to increase in response to higher freeze-year prices, the strong underlying upward trend in output and exports suggests that the Brazilian FCOJ industry would have grown rapidly even in the absence of Florida's freezes. Although Brazilian producers have profited significantly from Florida's recent freezes, these windfall gains do not appear to have been the primary force (but a force none the less) behind the expansion of their citrus industry.

This does not mean that Florida's climate characteristics have not had an important role in its ability to compete economically with the Brazilian FCOJ industry. The pronenes of Florida's growing areas to freeze damage severely limits the ability of Florida's output to expand in response to growing world demand, while the possibility of freeze shocks results in potential windfall gains for other producers. The climate-induced instability of Florida's supply and the growing world demand have thus contributed to the creation of profitable opportunities for expanded Brazilian FCOJ production.

As for Florida's ability to continue and perhaps expand its key role in the global citrus economy, the recent freezes do not appear to have eliminated it. Rather, those freezes have reawakened Florida's citrus producers to the fact that they are involved in a climate-sensitive industry and have reminded them that the potential for freeze-related problems is never far away. This has sparked interest in developing hardier citrus varieties, more effective freeze protection methods, and better ways to hedge economically against freeze impacts to the industry.

Conclusion

There has been a sharp increase in interest in climate impact assessment in the United States, in Canada, in Germany, in Brazil and other nations in the past year or so. This has in large measure been due to growing concern among policymakers about the carbon dioxide issue. Their interest has also been reinforced by the attention that the impacts of the 1982–83 El Nino event (an atmospheric-oceanic phenomenon) had worldwide. Questions about how well society might be prepared for the yet unknown regional and local effects of a global warming have stimulated research into what might be called "prior" questions, that is, questions about how well today's societies are coping with long-term, low-grade cumulative environmental changes and with extreme meteorological events. Multidisciplinary climate impact assessments can provide useful knowledge to researchers as well as to policymakers about how societies might best deal with climate-related socioeconomic and environmental impacts. They can also provide information about which climate-related impacts people are most concerned.

REFERENCES

Bernard, H.W. Jr., 1980: *The Greenhouse Effect.* Ballinger Publishing Co., Cambridge, Massachusetts, USA.

Bolin, B., Döös, R. B., Jager, J. and *Warrick R. A.* (eds.), 1986: *The Greenhouse Effect, Climatic Change, and Ecosystems.* SCOPE 29. John Wiley & Sons., Chichester, England.

Chen, E., 1984: Long term climate trend. In *Cold Protection Guide,* Lake-Orange Extension Service, Central Florida Freeze Recovery Task Force, pp. 140 – 143. Institute of Food and Agricultural Sciences, Univesity of Florida, Gainesville, Florida, USA.

Chen, E., 1985: Minimum temperature change and freeze probabilities in Florida: 1925 – 1984. In *Cold Protection Guide,* 1985 Revision. Lake-Orange Extension Service, Central Florida Freeze Recovery Task Force, pp. S1 – S5. Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA.

Cohen, S. J., 1987: Influences of past and future climates on the Great Lakes region of North America. Submitted to *Water International.*

DOE (US Department of Energy), 1985a: *Carbon Dioxide and Climate: Summaries of Research in FY 1985.* DOE/ER – 0202/1. US Department of Energy, Washington, DC, USA.

DOE, 1985b: *Characterization of Information Requirements for Studies of CO_2. Effects: Water Resources, Agriculture, Fisheries, Forests and Human Health.* DOE/ER – 0236. US Department of Energy, Washington, DC, USA.

DOE, 1985c: *The Potential Climatic Effects of Increasing Carbon Dioxide.* DOE/ER – 0237. US Department of Energy, Washington, DC, USA.

DOE, 1985d: *Direct Effects of Increasing Carbon Dioxide on Vegetation.* DOE/ER – 0238. US Department of Energy, Washington, DC, USA.

DOE, 1986: *Carbon Dioxide and Climate: Summaries of Research in FY 1986.* DOE/ER – 0202/1. US Department of Energy, Washington, DC, USA.

EPA (*US* Environmental Protection Agency), 1983a: *Can We Delay a Greenhouse Warming?* Office of Policy Analysis, Office of Policy and Resources Management, Washington, DC, USA.

EPA, 1983b: *Projecting Future Sea Level Rise.* Office of Policy Analysis, Office of Policy and Resources Management, Washington, DC, USA.

EPA, 1984: *Potential Climatic Impacts of Increasing Atmospheric CO_2 with Emphasis on Water Availability and Hydrology in the United States.* Office of Policy Analysis, Office of Policy and Resources Management, Washington, DC, USA.

Glantz, M. H. and *Katz, R. W.*, 1985: Drought as a constraint in sub-Saharan Africa, *Ambio 14,* 334 – 339.

Miller, K. A. and *Glantz, M. H*, 1988: Climate and economic competitiveness: Florida freezes and the global citrus proscessing industry. *Clim. Change 12,* 135 – 164.

Morrisette, P., 1987: *Perception, Public Policy, and Societal Adjustment to Fluctuations in Climate: A Case of the Rising Level of the Great Salt Lake.* PhD Dissertation, University of Colorado, Boulder, Colorado, USA.

NCAR (National Center for Atmospheric Research), 1985: *Report of the Networkshop.* (Workshop organized by the Environmental and Societal Impacts Group, May 6 – 8, 1985. NCAR, Boulder, Colorado, USA).

Quinn, F., 1985: *Great Lake water levels.* Briefing conducted by the International Joint Commission. U. S. Army Corps of Engineers, North Central Division, Chicago, Illinois, USA, 1 – 24.

Warrick, R. A., 1984: The possible impacts on wheat production of a recurrence of the 1930s drought in the U. S. Great Plains. *Clim. Change 6,* No. 11, 5 – 26.