Climate Change Workshop
Potsdam, Germany
25-30 October 1994

Impact of climate change in tropical forests: research at the Center for Tropical Forest Science

(overhead with title and names: Peter Ashton, Steve Hubbell, Robin Foster, Elizabeth Losos, Ira Rubinoff, Richard Condit)

I wrangled 20 minutes out of the organizers in order to give myself your attention for long enough to describe our interest at the CTFS in climate change research. Of course, our interest is in how climates affect tropical forests, and I am just going to try to get across to you our general viewpoint on the subject. I felt 20 minutes was a good time period for this, clearly not leaving enough to present detailed research findings, which was fine by me and possibly by you as well. I brought a few copies of relevant articles. Not enough for everyone here (I couldn't have carried it all), but I can always mail copies if these are exhausted. [introductory slides?] {OVERHEAD title]

I'm going to introduce by using as a foil a study of the impact of climate change on forest distribution in Costa Rica done by P.N. Halpin (OVERHEAD taken from the project). Using future climate scenarios from one of those major league climate simulators, Halpin predicted how far the Holdridge life zones would end up shifting. This is an important prediction for many reasons, but I'm using it here to illustrate what those of us at CTFS consider important, and for this I ask you to consider for a moment how individual species' ranges will be affected by these shifts in life zones. This straightforward question truly boggles my mind. These are very diverse forests, and predicting how even some of the species will respond requires a great deal of information about the ecology of individual species -- ranges, densities on different soils under various climates, and demographic data. For this reason, making predictions about diverse communities like these is a fascinating problem for me, and it is central to our research agenda at CTFS.

There are two major reasons for understanding how individual species will respond to climate change, or I could say, two reasons for approaching studies of community change by looking at individual species. One reason is that the species themselves are intrinsically important, and predictions about where species will be threatened, extinction rates, etc., hinge on knowing details about the species within a community.

The second major reason for a species approach gets at what I sense this meeting is about -- understanding ecosystem level responses and feedbacks to climate change; that is, understanding how plant communities as a whole respond. From this predicted life zone map in Costa Rica, we could predict changes in community-level features: productivity, carbon storage, gas exchange, etc., all probably can be predicted fairly well from a holistic look at the forests. So why know about individual species? In a nutshell, I will assert that the prediction laid out in this map will be greatly augmented by modeling responses of species. For example, the prediction here is one of instantaneous change -- a 10% increase in rainfall will cause this shift in life zones. But changes in tree communities will take centuries, as has been amply demonstrated by modeling studies in temperate forests. In addition, future environments are more complex than being just 10% wetter -- there will be more CO_2, there will be less forest cover -- and predicting how communities will respond to unprecedented scenarios requires good understanding of individual species.

The CTFS emphasizes studies of individual species in the tropics, and our goal has been to rapidly acquire basic demographic on a large number of species in a network of forests selected to span important climatic gradients, and to initiate long-term inventories of species composition in each of these forests. [world map and describe sites] Our effort is unprecedented in its scope and is a response to the high diversity of tropical trees and the relatively meager effort expended by the world to understand it. In order to realize this effort, CTFS has developed collaborations with scientists throughout the tropics, all willing to utilize a reasonably standardized methodology to generate a global database.

The projects began 14 years ago when Steve Hubbell and Robin Foster set out to map 50 ha of forest at Barro Colorado, counting and identifying every stem above 1 cm diameter [OVERHEAD few plot maps]. Although the original goal was not related to climate change, it readily became apparent that the work was evolving in that direction. We identified a diversity gradient in the BCI plot that follows a moisture gradient [OVERHEAD -- is this relevant?] We then discovered an important increase in mortality after an unusually severe El Niño drought in 1983, and the 50 ha plot provided an ample and ideal dataset to document it. Afterwards, I looked closely at population responses to the drought and to a longer dry period in central Panama [OVERHEAD of population changes], and again found that our 313 species dataset easily showed impacts of climate change (something that small plots could not have done). This leads me to predict that diversity will fall and that about 25-35 species will go extinct if the current rainfall regime holds for 40-50 more years. We thus realized that we have a monitoring system which will document how 12 tropical forest communities in very different settings will change through time -- at the species level.

The network of plots also will provide demographic data on > 2000 tree species, and we are keen to use these in developing models to simulate community dynamics, much as has been done in temperate communities with FORET-type models. This effort involves a variety of research projects overlain on the 50 ha plots -- growth responses in different light environments, germination studies, etc. Recently, Catherine Potvin and Steve Hubbell expanded these to include studies of elevated CO_2. Our immediate goal is to document the range in variation in a large number of species to high CO_2 [OVERHEAD from Catherine], and later to use these in building an understanding of how a community might respond over the longer term.

Currently, Jianguo Lui at Harvard, Sean O'Brien and Steve Hubbell at Princeton, and myself have begun working with forest simulators based on data from 50 ha plots in Malaysia and Panama. I am not taking any time to delve into these models at all, but rather I want to examine our goals and consider how they relate to the purpose of this workshop. In general, we want to understand and predict species composition. We will take as a given how many trees there are and a total biomass (or more likely basal area), and divy this up between species. We want to know what controls populations of individual species [could illustrate OVERHEAD Trichilia model here], and we want to know if the forest is currently a stable mixture, or if it is undergoing changes [mention Steve's model]. And we are interested in knowing what future changes might bring, given our knowledge of how species respond to drought, to CO_2, etc. I believe, and I think we all do, that it is crucial that we develop ways to group species in guilds (functional groups?) that still allow good predictions of forest composition -- we know we can't study every species. But data from a large number of species will allow us to test models which collapse species into a manageable number of guilds.

It is not currently our goal to predict ecosystem level changes at these plots -- for example, changes in biomass, productivity. That is currently not our interest, not our approach. Having laid this out, my question is how do we fit into other global change studies and what is being discussed here. I would like to find out how to make our efforts useful to others, and to learn how other approaches could help our modeling efforts. Perhaps our goals and products can be adjusted to become more useful to global scale projects. Perhaps we can collaborate with others who could take advantage of our research sites and background of information to develop models that explicitly address the global change questions.

Thanks. [final slide?]

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My interest is demographics, particularly of tropical forest trees [few SLIDES]. I work at STRI in Panama, and I am involved with Peter Ashton, Steve Hubbell, Robin Foster, and Elizabeth Losos in the Center for Tropical Forest Science. The Center coordinates a network that now includes 11 permanent forest plots in 10 different tropical countries [OVERHEAD], each site with all stems $\geq$ 1 cm dbh marked and identified over 16-50 ha. Eventually we will be able to examine the demography of $\geq$ 3000 tree species and several million plants, and analyze the dynamics of forest communities at the level of the species. These data are pertinent to PFT's for tropical forest trees and for the evaluation of impacts of climatic change on tree communities.

I. For example, data from BCI on population change and climate change [OVERHEAD]; changes probably not relevant from the GCM perspective, because the species being lost are no different -- to the climate -- than the ones not lost

II. For example, responses of individual species to elevated CO_2 [OVERHEAD]; perhaps elevated CO_2 will lead to major shifts in species composition, but again, GCM's might ignore it

III. Models we are working on are species-specific (Steve Hubbell, Jianguo Liu, and I), but we recognize the need for grouping species into "guilds" (as I would have called them before this meeting). For example, I have analyzed data on the relationship between mortality rate and regeneration characteristics, and on growth rate at small size vs. growth rate at large size. If I combine these, I expect to be able to define a continuum of species limited to a certain growth-mortality tradeoff, but which I can test with forests from 3 continents [NEW OVERHEAD]

IV. For the benefit of the current topic on PFT's, I decided last night to go through a brief exercise in evaluating ropical forest types and climate change. Current climate models belittle tropical forest [OVERHEAD global map]. Anyone with only minimal experience in the tropics could document the variation in forest cover that is encompassed within two forest types on this map, from say Central American semideciduous forests down through the Choco in Colombia where it rains 15 m per year, up through low montane forest, <u>Quercus</u> forest, timber line forest, the p_ramo, then down into the foothills east of the Andes where forests have more tree species per km^2 then all of Europe, out through nutrient poor forests of the northern Amazon, through central Amazonia and eventually out the mangroves of the coast. As I tried to explain yesterday in our group, dividing northern forests into conifer-broad-leaved is a result of our bias toward an obvious difference that we readily recognize -- if there are real differences in gas exchange between conifers and broadleaved trees in the north, how many differences might we expect across the gradient I just described?

A. Having said this, though, I will make you happy to report that I buy into the PFT approach, and the simplified approach ideas that group 1 put forward yesterday ought to be appropriate for the current generation of GCM's; I am interested in individual species shifts and the dynamics of a range of tree species' guilds in the tropics, but you people don't need to be

B. But I point out the variation within tropical broadleaved forests because this meeting has an obvious bias toward the northern/Australian regions, and that most of you are not thinking about what tropical forests involve

C. And this is why I thought the exercise of evaluating major forest types in the tropics might be useful. Based on what I have heard about PFT's, vegetation in the tropics might be collapsed into these types [OVERHEAD of main forest types].

1. These might be explicable by the sorts of biogeochemical/climate models we have discussed.
2. As climate changes, the most important transitions in natural vegetation would be from wet evergreen to moist semideciduous. This process will involve mostly -- over a time scale of 100 years or so -- simply death of species that need more water (such as I have seen at BCI). The reverse process, moist deciduous to evergreen, can probably not happen within 100 years, since it requires invasion of tree species (drought resistant species will probably not suddenly die off if rain increases). Within the framework of PFT's we have discussed, the shift toward a drier climate ought to favor species toward the pioneer end of the guild continuum, and species which are deciduous [back to previous OVERHEAD; pretty hypothetical. I recommend that modelers think through these processes for the tropics (and many other communities) to evaluate whether the fundamentals are captured.
3. The most important conversion process will be deforestation to grassland and reconversion to forest. It's more complex, strongly climate-dependent, and requires consideration of fast-growing ruderal trees, fire, loss of soil nutrients, changes in hydrology, and the possibility that grasses can outcompete trees. It probably does not require consideration of tree dispersal.
4. At the GCM level, I think that fairly simple PFT processes -- with demography incorporated, can describe these changes. I am interested in the shift in abundance of every species, which will require more detail, but you don't need to worry about that.

V. That's all I have time for (final slide). All I would like to make you all do is think about the nature (and complexity) of the issues relevant to changes in tropical forests.

Community Responses to Elevated CO2:
Instantaneous Photosynthetic Rate Changes

(Ellis, Potvin, Hubbell 1994. In prep.)

Tree Species	Photosynthesis Ambient CO2	Photosynthesis High CO2	% Change
Cecropia insignis	~~2.76~~	~~5.99~~	217%
Trema micrantha	~~2.57~~	~~6.39~~	248%
Ochroma pyramidale	~~2.83~~	~~9.23~~	326%
Miconia argentea	~~2.48~~	~~5.42~~	223%
Luehea seemannii	~~3.27~~	~~6.25~~	191%

μmole $CO_2/m^2/sec$

ambient	high	
17.9	28.6	Cecin
10.5	9.6	Och
8.6	22.9	Trem
12.3	12.1	Mic
5.5	11.5	Lueh

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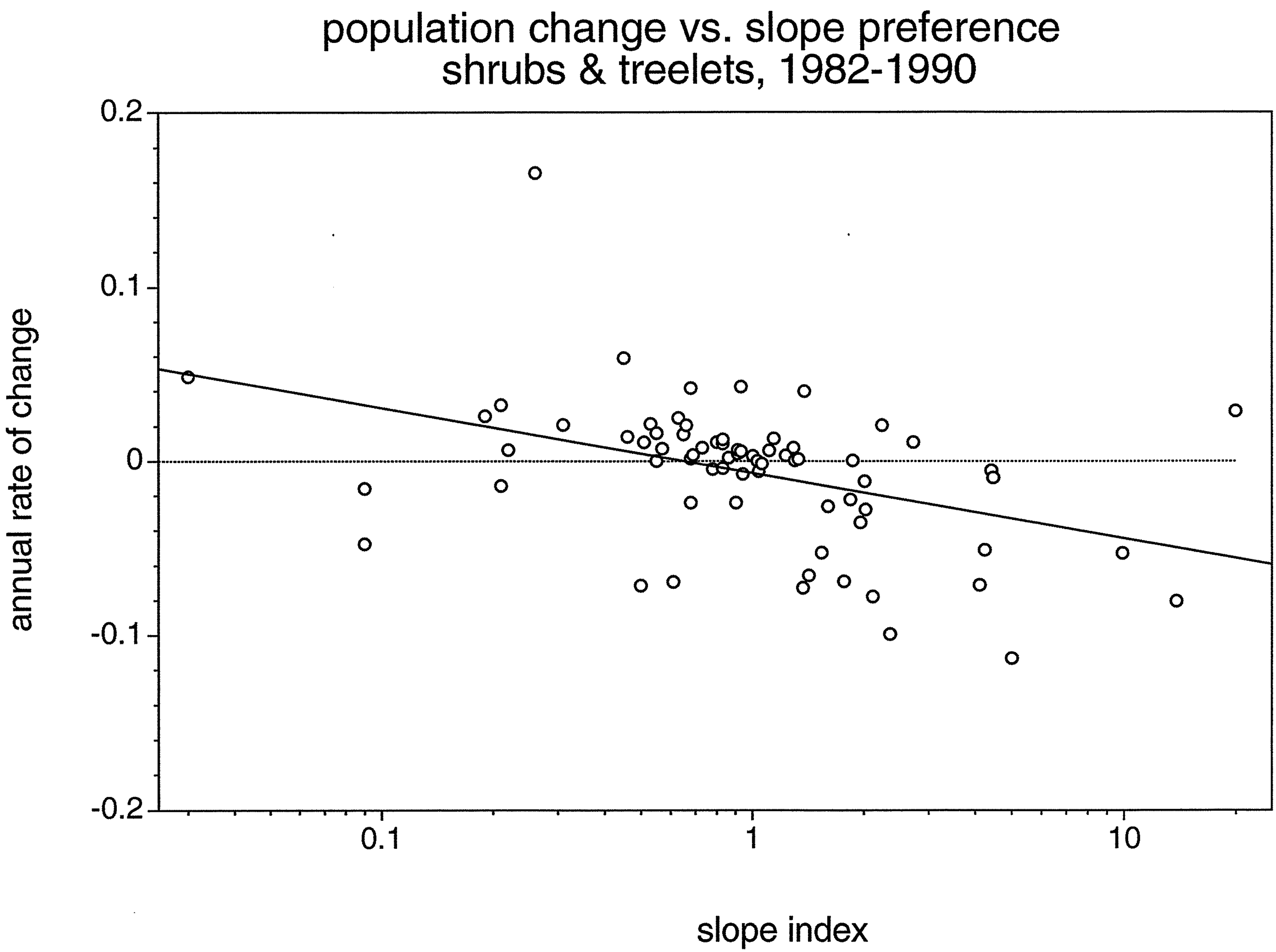
population change vs. slope preference
shrubs & treelets, 1982-1990
annual rate of change
0.2
0.1
0
-0.1
-0.2
0.1
1
10
slope index

population change vs. slope preference
large and medium-sized trees, 1982-1990