

CLIMATE IMPACTS OF LAND DEGRADATION IN THE WORLD'S DRYLANDS

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Summary

Drylands throughout the world have always undergone periods of degradation due to naturally-occurring fluctuations in climate. However, over the past century, the human population in drylands has grown exponentially and the resulting pressures on the landscape have exacerbated various desertification processes, particularly in Africa. The degradation of drylands has led to changes in local, regional, and even global climate. In the driest areas, increased albedo associated with degradation leads to cooling which can stabilize the atmosphere and reduce precipitation. In other drylands, desertification reduces soil moisture, and this change in surface hydrology leads to a warming that accelerates evapotranspiration and further reduces soil moisture levels. The nations of the world recognize the severity of the desertification issue, and most have ratified the "United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa".

1. Introduction

Even before a time of any human activity, drylands of the world were degraded periodically due to natural causes, and interactions occurred between desertification and climate. However, with literally one billion people now living in drylands, the effects of human-induced desertification are more pronounced today than at any time in the Earth's history. More of the world's drylands are being degraded more than ever before, and we are now witnessing a complicated set of feedbacks between dryland surface conditions and the local, regional and global atmosphere. While a great deal of attention is being placed on how anthropogenic climate changes (e.g. enhanced greenhouse effect) may alter dryland areas, the ongoing land degradation in the drylands is having a profound impact on local and regional climate conditions. The nations of the world

clearly recognize the overarching importance of the desertification issue, including its direct link to climate change, and they recently adopted a convention to combat desertification.

The focus of the scientific community on desertification and climate can be traced, in substantial part, to a fluctuation in climate that occurred this century in Sahelian Africa. For nearly five decades, precipitation levels in this region remained relatively high, allowing local inhabitants to sustain or even increase crop yields, cattle herds, and human population levels. However, in the early 1960s, the precipitation levels fell in the region (Figure 1), and by the early 1970s, the human and ecological tragedy of the Sahel was a serious matter receiving considerable attention worldwide.

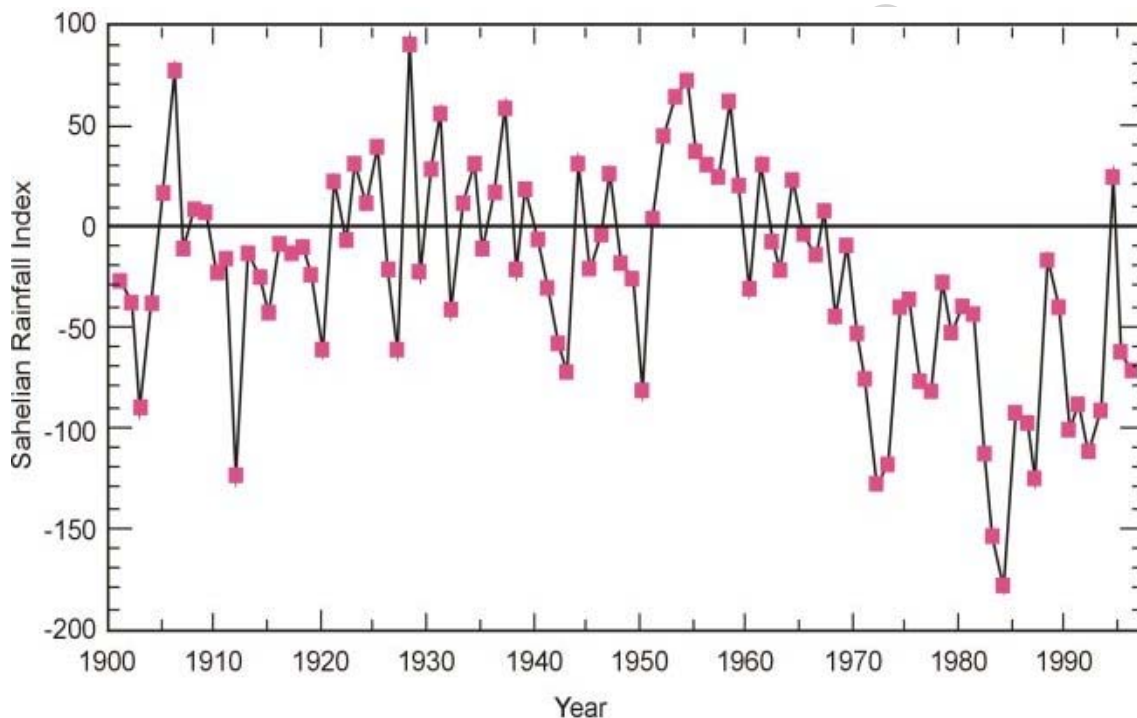


Figure 1: The precipitation levels fell in the region

In one of the first attempts to explain the climate “failure” in the Sahel, noted climatologist Reid Bryson proposed that pollution in the Northern Hemisphere was creating a “human volcano,” causing a cooling at a hemispheric level. In Bryson’s view, that cooling was causing a southerly migration of the northern circumpolar vortex (the jet stream), as well as a southerly migration of the subtropical high-pressure belt. This pattern would restrict the ability of the rain-producing intertropical convergence zone to move northward into the Sahel, and lower precipitation levels during the summertime rainy season would result. Bryson’s argument placed the blame for the tragic Sahelian drought on industrial activity in the developed nations of the Northern Hemisphere.

Shortly afterwards, others began presenting the argument that overgrazing in the Sahel could increase both the surface albedo (reflectivity) and the soil compaction leading to an increase in surface runoff and a reduction in available soil moisture. The “expanding Sahara” could be the result of local activities and not the industrialization of the mid-

latitudes of the Northern Hemisphere. Others argued that overgrazing in dryland areas could increase albedo, reduce surface temperatures and near-surface air temperatures, stabilize the atmosphere, and reduce local rainfall levels. Although supporting measurements for this claim came from Sinai, the arguments seemed transferable to the Sahel.

A landmark article was published in 1975 by Jule Charney in which he presented a complex biogeophysical feedback model of desertification in the Sahel. The work received considerable attention in the popular press and scientific community, and the basic ideas put forth in this and related articles became known as the “Charney hypothesis.” Charney and his associates developed a physically-based numerical representation of a biogeophysical feedback mechanism that could initiate and/or reinforce drought in sub-Saharan Africa as a result of vegetation depletion. In their numerical model, the degradation of vegetation by natural or anthropogenic causes would increase the surface albedo, decrease the net shortwave radiation, decrease the surface temperature, and increase the relative emission on longwave radiation due to a slight increase in the emissivity of the surface. These processes would reduce the net radiation at the surface, leaving less energy for warming the surface and the overlying atmosphere. Changes in heat transfer would stabilize the lower layers of the atmosphere and suppress local convection. The reduction in local rainfall would further stress the remaining vegetation, thereby, initiating a positive biogeophysical feedback.

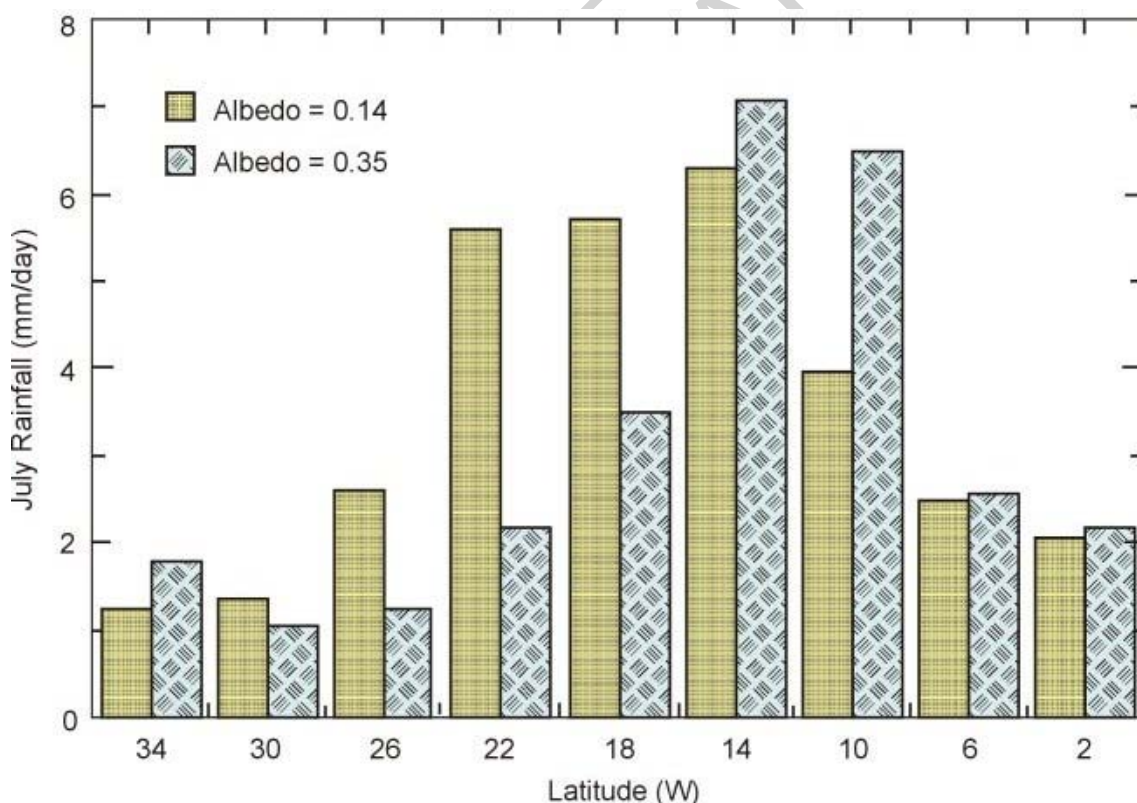


Figure 2: Albedo effect

When Charney and his colleagues increased Sahelian albedo from 0.14 to 0.35, their

model showed a southerly shift of the Intertropical Convergence Zone of several degrees of latitude in the Sahel during the normally rainy summer season. In some latitudinal bands, rainfall decreased by more than 50 percent due to this albedo effect (Figure 2). Within a few years, similar results were being reported by other investigators and for other dryland areas of the world.

However, despite the support from a variety of modeling studies, the Charney hypothesis was challenged immediately on theoretical and empirical grounds. Some scientists argued that removal of vegetation in drylands would lower soil moisture levels, decrease radiant energy used to evaporate and transpire water, and increase surface and near-surface temperatures. In areas where vegetation was reduced, the local surface and near-surface temperatures would increase, not decrease as proposed in the Charney hypothesis. Hydrological processes, not albedo effects, would dominate the surface energy balance changes associated with vegetation removal in most dryland environments.

The debate surrounding the Charney hypothesis continues to this day, but fundamentally, several important interrelated questions may be raised concerning climate change and desertification. Firstly, there is the question of whether desertification in drylands actually changes the local climate. As we see in the Charney debate, desertification may produce feedbacks that lead to warming or cooling of the surface and the near-surface air. Secondly, there is a question regarding whether desertification in drylands impacts regional, hemispheric, or even global climatic conditions? While the literature is dominated by research on how the buildup of greenhouse gases may alter future climates, including those of dryland areas, there remains a substantial literature on how land degradation in drylands has an impact on the climate system. And while the greenhouse issue is certainly an important one, understanding the impact of desertification on climate is essential in determining future climate change in dryland areas of the world.

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Biographical Sketch

Dr. Robert C. Balling, Jr. is currently the Director of the Office of Climatology and Professor in the Department of Geography at Arizona State University. He received a Ph.D. in geography from the University of Oklahoma in 1979. Prior to accepting a position in Arizona, he was a faculty member in the climatology program at the University of Nebraska. Throughout the 1990s, Dr. Balling has been involved in a variety of interrelated climatological issues. He has published 100 articles in the professional scientific literature, received over \$3 000 000 in research grants, presented lectures throughout the United States and more than a dozen foreign countries, and appeared in a number of scientific documentaries and news features. In 1996, Dr. Balling co-authored a book entitled *Interactions of Desertification and Climate* published by the United Nations Environment Program and the World Meteorological Organization.