Desertification: Its Nature, Extent and Impact and the Interaction with Global Climate Change

Victor R. Squires

Adelaide, Australia
E-mail: dryland@senet.com.au

Abstract: Desertification is a major human tragedy, affecting the daily lives of about 1 billion people. It is this aspect of desertification that deserves further consideration. As a humanitarian effort it is an opportunity, and an obligation, for the industrialized nations to transfer financial support and technical assistance to those countries worst affected by land degradation in all its forms.

Desertification is a key component of global environmental change but knowledge of its extent and links with global climate change is poor. Studies of both phenomena are hindered by difficulties in separating long-term trends from short-term variations. Greater convergence between research in the two fields would improve understanding of vegetation degradation, soil degradation, land surface-atmosphere interactions and the social dimension of global environmental change. It is also indispensable for effective global climate change mitigation.

While the need to realize synergies between the three "Rio conventions" on climate change, biodiversity and desertification is recognized, progress has been slow, both bilaterally (between conventions) and multilaterally (through the Global Environment Facility). One reason for this is lack of scientific knowledge of the linkages between them, yet slow institutional convergence is hindering research convergence that would help to fill this gap. The most pragmatic solution to this problem seems to be to give desertification a higher profile within the IPCC. These issues are explored through a series of 10 Propositions.
Keywords: land, research convergence, institutional cooperation, science policy

1 The convention to combat desertification

Proposition 1. The Convention to Combat Desertification (CCD)[(1)] was designed to facilitate participation of the population and take measures of real importance at the grass roots level.

More than 1 billion people live in the world's drylands that occur on most continents (Squires, 2002). Many live under poor conditions on land badly affected by desertification. The CCD is aimed at focussing the world's interest on this situation. Various measures are needed to improve the land productivity and enhance human livelihoods. The mechanism for all this would be the national action programs of each country (the strategic plan) and the national desertification funds (the financing). Financial support and technical assistance from the international community also have a role to play.

The CCD has yet to prove its full potential, but it is an essential part in the framework of legally-binding documents aimed at giving substance to the notion of sustainable development together with the sister Conventions on the ozone layer, on climate change and on biological diversity (UNCED, 1992).

Proposition 2 Desertification is a product of complex interactions between the social and economic systems (disease, poverty, hunger and an unreliable economy) and natural factors (drought, water erosion, soil salinization, degradation and loss of vegetation cover).

---

(1) The Convention to Combat Desertification came into force in December 1996 after its ratification by the 50th country. It has now been ratified by over 170 nations. Desertification is defined as land degradation in drylands caused by climatic variations and human factors

2 Land surface- atmosphere interactions

Proposition 3: The fundamentals in combating desertification come down to three items-land, plants and people.

But whereas climate is to a large extent dealing with central aspects of modern development such as energy and transport, the CCD is about the traditional fundamentals: land, plants, and people. The land surface is at the "front line" of concerns about global climate change. People live on the land surface; it is where we grow food, build our homes and collect our drinking water. The land surface climate is vital for our survival. The many relationships between the land surface and the global climate are very complex. There are many ways in which the biosphere is of importance in the climate system. These include transfer of moisture from the soil into the atmosphere, modification of the albedo which changes the amount of radiation absorbed by the climate system, responsibility for the exchange of carbon and other chemicals and modification of the surface roughness which alters the exchange of momentum.

Soil degradation, the first main component, is often taken to be synonymous with desertification, but the full implication of soil damage or loss is still poorly understood. This is particularly true of the contribution made by soil carbon degradation to greenhouse gas emissions (Squires, 1998). At the global level soil carbon stocks may be half as much again as stocks in above-ground biomass, but in dry areas the ratio may be as high as 20 to 1. The potential to sequester carbon by controlling desertification could be as high as 40% of the annual rise in atmospheric carbon dioxide concentration (Lal *et al*., 1999).

The second main component of desertification, vegetation degradation, involves a temporary or permanent reduction in the density, structure, species composition or productivity of vegetation cover and is an essential element of global climate change research too. A lot has been learned in the last 20 years about the contribution made to global climate change by carbon emissions from tropical deforestation, but much less is known about vegetation degradation in dry areas (Williams and Balling, 1996).

New techniques to monitor it could therefore be devised as part of a wider program to improve our understanding of the role of vegetation degradation in global climate change and global environmental change as a whole. The Global Environment Facility has emphasized the generic importance of land degradation by devising an operational framework that includes both desertification and deforestation (GEF, 1996).

Desertification and climate change

Proposition 4: Desertification is linked with climate change through the catalytic role of drought. But we still know little about other links, e.g. how changes in land cover can modify regional climate.

Desertification is known to change thermal processes, e.g. by affecting the albedo. One possible explanation for the prolonged drought in the Sahel in the 1970s and 1980s, for example, was biogeophysical feedback, in which drought led to reduced vegetation cover, prompting overexploitation by humans and animals, which fed back to reduce rainfall, leading in turn to increased exploitation etc.(Rasmussen, 1999, Charney *et al*., 1975). Much more remains to be learned about land surface-atmosphere interactions in dry areas and so the results of future research should lead to better global climate models.

The global climate is obviously very sensitive to land surface changes that includes greenhouse gas emissions, creation of aerosols (particulates and droplets; surface reflectivity (albedo) and emissivity disturbances; and impacts on the surface roughness, and surface hydrology. Replacing the forests with pastures, and clearing woody plants from more and more arid regions for fuelwood or fodder can lead to three primary types of change at the land surface. These are: higher albedos, less evaporation, and lower surface roughness.

Exploitation of large areas of the continents for current societal needs is causing massive disturbances that are contributing to, and are impacted by, global change. Land clearance and land-use change are now recognised as having the potential to affect and be impacted by local, regional and global climate characteristics.

3 Land cover change

Proposition 5: Land cover can change in two principal ways in response to two very different driving forces. These are climate and humans.

Throughout history humans have changed the landcover of this planet, mostly to enhance our own survival. The nature and extent of human-induced landcover changes are determined by two factors: the total population pressure and the technological capacity of that population. These factors are multiplicative in ways that are not easily appreciated. The key question to ask is "how and why does landcover change?"

The land cover of the Earth is constantly changing. At the local scale (over seasons) land cover functioning is influenced only by weather events such as droughts and severe storms. Consequently, the influence of climate on land cover can be described across all scales. For the purposes of this discussion we can safely ignore changes over geological time and concentrate on time scales that are more meaningful in terms of a human life span – i.e. a year to a decade.

On an annual time scale, climate most strongly influences the functioning of land cover rather than its floristic composition. This physiological change in landcover is impressive. Driven by the changes in precipitation and temperature, the vegetation cover changes through the seasons, waxing and waning in greenness and vigor. So great is the annual cycle of plant activity that its signal of extraction and release shows in carbon dioxide concentration in the atmosphere.

Unlike seasonal changes in land cover activity, human-induced change occurs rapidly and asymmetrically in time and is unnaturally patchy in space. Agricultural use converts forests and woodlands into croplands and pastures. Plantation forestry can convert diverse forests into monocultures and thus reduce biodiversity. Animal husbandry can convert rangelands into deserts.

Proposition 6: Accelerated land cover change is one the most serious environmental threats facing humans today

People are beginning to make regional-scale changes to the character of the Earth's surface; the most important of which are desertification, re- and de-forestation and urbanisation. The sparse vegetation natural to arid and semi arid areas is easily removed or destroyed by the direct impact of human activity such as overgrazing, or poor agricultural practices (including inappropriate land conversion) and as a result of relatively minor changes in the climate. Removal of the vegetation and exposure of bare soil decreases soil water storage and capacity, increases run off, and increases the albedo. Less moisture available at the surface means a decreased latent heat flux, leading to an increase in surface temperatures.

On the other hand, the increased albedo produces a net radiative loss. In climate model calculations, the latter effect appears to dominate in arid and semi-arid regions and the radiation deficit causes large-scale subsidence and drier conditions. In the descending air mass, cloud and precipitation formation would be very difficult and aridity would tend to increase. There is therefore a positive feed back loop tending to further augment a detrimental human impact on climate (Henderson Sellers and Gormitz, 1984).

4 Scientific linkages among global environmental problems

Proposition 7: Scientific linkages among global environmental problems are needed so that the solution of one can be seen to be part of the solution to the others, enhancing the value of taking action.

Desertification research could easily be regarded as a special case of three major categories of global climate change research: land cover change; land surface-atmosphere interactions; and mitigation studies. There are many benefits to be gained from several types of convergence between disciplines when dealing with global environmental problems that, by their nature, are not simple (Grainger *et al*., 2000).

Proposition 8: Global environmental change (including desertification and climate change) is so complex that it can only be properly understood by interdisciplinary research of the highest order, and many scientists have simply not been trained for that.

The slow development in the last decade of global environmental change science, and of our understanding of the mechanisms of global change, can be blamed on the constraints imposed by the tightly defined sub-disciplinary compartments in which scientists tend to work today. This research was

long dominated by physical environmental scientists, and by atmospheric scientists in particular; although global climate change is largely anthropogenic, it was some time before social science research was properly funded. The gap between social and environmental sciences still remains. The gap certainly constrains studies of desertification.

4.1 Developing interdisciplinary studies

Proposition 9: There is a need to develop powerful foci for global environmental work, whilst always keeping the issue of scaling up to the global level in mind. But it is also essential to identify some topics around which genuine interdisciplinary studies can evolve; some of these should include social dimensions.

Three possible focus areas spring to mind.

(1) Carbon sequestration. One such topic could be that of carbon sequestration. Drylands generally lack the massive carbon stores of the humid tropics, but have long been regarded as having potential for afforestation and other forms of revegetation that can sequester carbon from the atmosphere (Squires, Glenn and Ayoub, 1997). Social, economic and political constraints must be overcome before attempting to control desertification.

(2) Climatic variation also has a major catalytic role in desertification and is expected to intensify as global climate changes. The responsiveness of different regions and social institutions to the changes in variability in climate and other resource factors is not well understood. There is a need to look at how certain social institutions cope with different levels of resource variability. With major changes in land tenure systems occurring in areas such as southern Africa and Mongolia, such studies are urgently needed to match social institutions to environments.

(3) Vegetation degradation. This is a third possible focus. The reduction in vegetation cover and vegetation quality (eg. through changes in species composition) in dry areas is an essential element of desertification. To model global climate change in a comprehensive way embracing both the atmosphere and the land surface we must take full account of spatio-temporal trends in vegetation cover and land use as modified by human impact and climate change. The results will lead to a better assessment of the economic linkages between land degradation, its impacts on global climate, biodiversity, food production and human welfare, so that governments can make a more realistic cost-benefit analysis of future actions to combat desertification.

The implications of vegetation degradation, in the drylands and elsewhere, remains so poorly studied that it is a major source of uncertainty in our knowledge of the global carbon cycle and the links between desertification and climate change (Williams and Balling, 1995). Naturally, the questions of what the underlying social driving forces for vegetation degradation are, and what the resulting impacts are on rural livelihoods, are essential points of convergence between disciplines.

5 Research on desertification processes and impacts: where is it?

Proposition 9: The lack of scientific knowledge of the linkages between desertification and global climate change is still a major constraint on cooperation between the two major international conventions.

Desertification research today is still limited in scope. But things could change very quickly. At the moment, cooperation between these institutions is constrained by a lack of scientific knowledge on significance of the linkages between the different components of global environmental change. This, in turn, is hampering research that could help to fill this gap in our knowledge (Glenn, Stafford Smith and Squires, 1998). Greater convergence between research into desertification and global climate change could break this scientific and institutional logjam, improve our knowledge of desertification and its links with global climate change, and help the UNCED institutions to work more smoothly together for the benefit of all (Grainger *et al*., 2000).

5.1 Capitalizing on synergies between the rio conventions

In principle, therefore, research into both desertification and global climate change would benefit from greater convergence between the two fields. The key question is how to stimulate this. One

approach is to rely on institutional convergence between the three global environmental regimes that emerged from the UN Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. Both the Framework Convention on Climate Change (FCCC) and the Convention on Biodiversity (CBD) mention the importance of desertification. Possible synergies identified by the CCD secretariat include links between scientific bodies associated with the conventions:

- common approaches in education and capacity building;
- information management; national systems for
- reporting progress in implementing conventions;
- legal and other procedures;
- sharing resources;
- coordinating the planning of meetings
- improving financial mechanisms, particularly in liaison with the GEF (SCCD, 1998).

Work on the conventions can be linked by two main mechanisms.

- Bilateral links can be established when one of the Conference of Parties (COP) instructs its secretariat to cooperate with another, usually formalizing this with a memorandum of understanding.
- Multilateral mechanisms are another possibility. The CCD differs from the other two regimes in lacking a specific multilateral fund for its implementation. Instead, it has a Global Mechanism, coordinated by the International Fund for Agricultural Development (IFAD), based in Rome, to improve management of existing funds. How successful this will be is open to question, given the remarkable lack of funds (Grainger *et al*., 2000).

Multilateral funding can also be channelled through the Global Environment Facility (GEF), which finances projects that make a genuinely global contribution to implementing international regimes (GEF, 1996). The lack of scientific knowledge of the linkages between desertification and global climate change is still a major constraint on cooperation between the two regimes (SCCD, 1999). Unfortunately, this risks creating a vicious circle, because without better cooperation there is unlikely to be strong institutional support for closer integration between research into desertification and global climate change.

5.2 Extending scientific cooperation under the auspices of the IPCC

Proposition 10: Closer links between desertification and global climate change research under the auspices of the IPCC would be mutually beneficial. For even if desertification as such is not given prominence at the moment within the IPCC, the processes that characterize it are.

Better networking between scientists and science funding agencies, for example within the supportive institutional framework provided by the IPCC might lead to faster and better outcomes. But there are difficulties that reflect the current gulf between desertification and global climate change research. The IPCC must also now function within constraints imposed on it by the Kyoto Protocol (Grainger *et al*., 2000). One way to promote greater convergence would be to give desertification greater prominence in the IPCC e.g. by identifying a set of priorities for collaborative research that will improve our knowledge of desertification and its links with global climate change.

6 Conclusions

Scientists in a hundred years time will look back in disbelief at our failure to grapple with phenomena like desertification that involve both environmental and social factors, which we have either been ignored or treated in a one-sided manner. Whether desertification is caused by over exploitation or climatic variability, it is still a real problem affecting real people. There is no doubt that lessons learned in trying to control desertification could be of great help to policy makers keen to mitigate or accommodate to other global issues such as climate change. One of the clear lessons is the need to take full account of local social, economic and political concerns.

Desertification has much in common with global climate change from the point of view of policy. Climate change will cause significant shifts in climate zones that affect the suitability of land for agricultural and other uses. But that is exactly what has happened in Africa, and elsewhere, as a result of

prolonged drought. Lands became less suitable for traditional uses but the responses were not planned and the result was over exploitation and land degradation. Unless appropriate planning takes place-which may only involve the removal of constraints-the same experience could be replicated throughout the world as climate zones shift. Thus there are enormous opportunities to learn about the future by understanding how societies have reacted in the past.

Closer links between combating desertification and mitigating global climate change are also desirable, for three main reasons. First, any fall in the rate of desertification should reduce the rate of depletion of vegetation and soil carbon stocks and hence cut greenhouse gas emissions. Improving the sustainability of land management should also increase the annual rate of net carbon sequestration.

Second, revegetating areas of degraded lands would sequester surplus carbon from the atmosphere (Squires, Glenn and Ayoub, 1997). Trading carbon emission credits within the framework established by the Kyoto Protocol to the Framework Convention on Climate Change could provide funds to revegetate and sustainably manage degraded dry areas.

Third, better knowledge of desertification processes will also improve our responses to global climate change. Whether desertification is unique, or just another form of environmental degradation (Thomas, 1993), the lessons learned in controlling it could help in the formulation of policies to mitigate or accommodate to global climate change. For the problems that are likely to arise as climate zones shift and people are slow to respond to the changing circumstances will be very similar to those confronted in Africa when prolonged drought made lands less suited to agriculture and desertification accelerated.

Acknowledgements

Many of the ideas in this paper arose from discussions with Dr Alan Grainger, Leeds University, Dr. Mark Stafford Smith, CSIRO, Australia and Dr Ed. Glenn, University of Arizona and from involvement with specialists in UNEP and in the Global Mechanism of the CCD, Rome.

References

Charney, J.,P.H.Stone, W.J.Quirk. 1975. Drought in the Sahara: a biogeographical feedback mechanism, *Science* 187: 434-5.

GEF 1996. *A Framework of GEF Activities Concerning Land Degradation*. Global Environment Facility, Washington D.C.

Glenn, E.P., M. Stafford Smith, V.R. Squires. 1998. On our failure to control desertification: implications for global change issues, and a research agenda for the future. *Environmental Science and Policy* 1:71-78.

Grainger, A. M., Stafford Smith, V.R. Squires, E.P. Glenn. 2000. Desertification and climate change: the case for greater convergence. *Mitigation and Adaptation Strategies for Global Change* 5: 361-377.

Henderson Sellars, A. and V. Gomitz. 1984. Possible climatic impacts of land cover transformations with an emphasis on tropical deforestation. *Climatic Change* 6: 231-258.

Lal, R., H.M. Hassan, J. Dumanski .1999. Desertification control to sequester carbon and mitigate the greenhouse effect IN: N. J. Rosenberg, R.C. Izaurralde and E.L. Malone (eds), Carbon sequestration in Soils: Science, Monitoring and Beyond. Batelle Press, Columbus , Ohio 83-136.

Rasmussen, K. 1999. Land Degradation in the Sahel-Sudan: the conceptual basis. *Danish J. of Geography* Special Issue 2: 151-159.

SCCD 1998. Promoting and strengthening of relationships with other relevant conventions. Collaboration and synergies among Rio conventions for the implementation of the UNCCD Conference of the Parties, Second Session Dakar November 30- December 11 1998. Item 6 of the Provisional Agenda ICCD/COP (2/7) Secretariat of the UN Convention to Combat Desertification, Geneva (www.unccd.ch).

Squires, V.R. 1998. Dryland soils: their potential as a sink for carbon and as an agent for mitigating climate change. Advances in GeoEcology 31:209-215.

Squires,V.R., E.P. Glenn, A.T. Ayoub (eds) . 1997. Combatting global climate change by combatting land degradation. UNEP, Nairobi.

Squires, V.R. 2002. Global extent of desertification. *Encyclopedia of Soil Science* (in press).

Stafford Smith, M. B. Campbell, S. Archer, D. Ojima, W. Steffen, 1995. GCTE Focus 3 pastures and rangelands task: an implementation plan. Global Change and Terrestrial Ecosystems Report No.3. CSIRO, Collingwood.

Thomas, D. S.G.1993. Sandstorm in teacup? Understanding desertification. Geograph.J. 159:318-331.

UNCED 1992. Earth Summit Agenda 21: Programme of Action for sustainable development. United Nations Department of Public Information, New York.

Williams, M.A.J., R.C. Balling. 1996. Interactions of desertification and climate. Wiley, New York.