Press release – 14 February 2020

Climate change and global drylands: Identifying three ecosystem response thresholds

Climate change does not simply involve an increase in temperatures but also drastic changes to both the way ecosystems function and the landscapes around us. This was revealed in a study published in the journal Science on 14 February 2020 by an international researcher consortium in which INRAE plays an active role. The study describes how an increase in our planet's overall aridity - as forecast by the current context of climate change[1] - leads to abrupt changes in the functioning of dryland ecosystems worldwide, limiting their ability to sustain life and provide essential ecosystem services to the human communities that depend on them. The study identified three transition thresholds. Some 20% of the Earth's land surface area could be affected by the year 2100.

Aridity - the balance between precipitation and evapotranspiration - seriously hampers ecosystems' production capacities. Currently drylands cover 41% of the planet[2] and are home to one out of every three of its inhabitants. Climate change scenarios predict a significant increase in aridity across the globe, which will exacerbate the water deficit in those areas and extend their influence to other ecosystems that are not yet subject to such conditions. Up to now, scientists have theorised that a steady ongoing increase in aridity would gradually make ecosystems less green and fertile and landscapes more barren. This study revealed a more worrisome scenario, i.e. increasing aridity could affect ecosystems in rapid and abrupt ways when certain aridity thresholds are crossed. Such threshold effects lead to an irreversible decrease in ecosystem functions such as a decline in soil fertility, increased erosion and a drop in food and biomass production.

These conclusions were reached after an international team of researchers coordinated by the University of Alicante in Spain created the most comprehensive compilation of empirical data on global drylands to date, as part of the European ERC-BIODESERT project. The team evaluated how certain vital structural and functional ecosystem characteristics change along wide aridity gradients. The data covered some 20 attributes such as *in situ* and satellite-estimated productivity measurements, vegetation data (composition and species abundance), information on how plants adapt to drought and their ability to fix atmospheric carbon dioxide through photosynthesis, and data on soil fertility and microbial biodiversity. They then analysed all the data and tested to see whether each attribute’s response to spatial variations in aridity was linear and continuous or if, in contrast, aridity led to abrupt responses.

---

[1] According to the 2100 aridity levels predicted by the IPCC RCP8.5 scenario (i.e. based on a continued increase in CO^2 emissions at current rates)

[2] Drylands are defined as as tropical and temperate areas with an aridity index greater than 0.6. They include sub-humid, semi-arid, arid and hyper-arid ecosystems such as Mediterranean scrub, the Eurasian Steppe, savannah and deserts.

The results showed that all the variables studied responded in a non-linear way to increases in aridity. For the first time, these researchers mapped out three major ecosystem transition points that speed up ecosystems' responses to climate change. The first transition was a phase of sharp reduction in plant productivity. In order to adapt to drought, plants produce progressively smaller leaves to maximise water use for photosynthesis. Once a certain of aridity has been reached, that strategy runs into a physiological limit and existing species begin to be hampered by the lack of water. This is the transition between Mediterranean-type vegetation (Downy or pubescent oak forests and scrubland, photo 1a) to more arid types of vegetation such as those found in southern Spain or in the landscapes of the North African steppes. The second transition revealed itself through many sudden changes to several soil variables, indicating a decrease in soil fertility. During that phase, the soil loses its structure and becomes increasingly vulnerable to erosion. Soil organisms that play a vital role in maintaining nutrient cycling are also radically affected with an increase in the number of pathogenic agents observed to the detriment of organisms that are more beneficial for plants such as mycorrhizae. The plants that survive beyond this aridity level are mainly shrubs, which can find water in deep soil layers (photo 1b). The final transition led to an abrupt loss in diversity and plant cover. At this extreme level of aridity, the system collapses and become a desert (photo 1c). Most plants cannot thrive under such conditions and only those rare types capable of taking advantage of scarce and unpredictable rainfall through dormancy strategies can survive.

Photo 1. According to a new study published in Science, the green landscapes of the southern half of France could change into barren mountains by 2100 (photo Nicolas Gross - INRAE)

According to climate projections based on the "business as usual" scenario, due to climate change, more than 20% of the Earth's land surface area could cross one or more of the thresholds identified by the study by 2100 (see map below). Life will not disappear from drylands but these results suggest that our planet's ecosystems will experience abrupt changes that will directly affect more than 2 billion people currently living in dryland areas, but also people outside them. The study showed that the Mediterranean Basin, including the southern half of France, could be adversely affected by such events, radically changing the landscapes we know.

The study's results should make it possible to better anticipate the impacts climate change has on land ecosystems and, in that way, help develop relevant adaptation and mitigation measures.

Inset 1: Map of dryland vulnerability to climate change. Drylands are defined as tropical and temperate areas with an aridity index greater than 0.6. They include sub-humid, semi-arid, arid and hyper-arid ecosystems such as Mediterranean scrub, the Eurasian Steppe, savannah and deserts. This map covers those areas that could cross one or more of the described thresholds based on the aridity levels forecast for 2100 by IPPC RCP8.5, i.e. assuming that CO^2 emissions continue to rise.

References

Berdugo, M., M. Delgado-Baquerizo, S. Soliveres, R. Hernández-Clemente, Y. Zhao, J. J. Gaitán, N. Gross, H. Saiz, V. Maire, A. Lehman, M. C. Rillig, R. V. Solé & F. T. Maestre. 2020. Global ecosystem thresholds driven by aridity. Science

Scientific contact:

Nicolas Gross - nicolas.gross@inrae.fr

"Prairie Ecosystem"

ECOFA Scientific Department

INRAE Clermont-Auvergne-Rhône-Alpes Centre

Fernando Maestre - ft.maestre@gmail.com
Dryland Ecology and Global Change Lab
University of Alicante
Spain