CASCADE

Catastrophic shifts in drylands:
How can we prevent ecosystem degradation?

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http://www.cascade-project.eu/

Reporting on our recent Plenary meeting in Chania, Crete

Photo by N Geeson

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Knowledge needed to understand and predict thresholds for catastrophic shifts in dryland ecosystems of Europe is still limited. The challenge is to improve the understanding of the underlying processes in soil-water-plant systems, as well as of socio-economic drivers and land use management. We are establishing what might move dryland ecosystems towards thresholds, to be able to define threshold values for tipping points and to find ways to prevent such shifts from occurring.

When tipping points are likely to be approached, urgent action is needed to avoid catastrophic shifts in the dryland ecosystem. We aim to create decision-making tools to find suitable management options that help prevent shifts and promote sustainable land management. We hope that these tools, along with predictions for tipping points, can be used by policymakers and land users for more sustainable management of drylands worldwide.

In the CASCADE Project, researchers are carrying out experiments in study sites in parts of dryland Portugal, Spain, Italy, Crete and Cyprus to find a better understanding of discontinuous shifts, or tipping points, in ecosystems.

Historical evolution of dryland ecosystems

(*See Deliverable 2.1* [*http://www.cascade-project.eu/index.php/downloads/project-deliverables*](http://www.cascade-project.eu/index.php/downloads/project-deliverables))

In the European drylands, four ''broad'' dryland biomes - desert, grassland, Mediterranean (mainly scrubland) and forest (mainly woodland), successively replace each other along the aridity gradient, with increasing aridity leading to an expected decrease in plant cover. Within the biomes, biological species respond to various environmental variables, such as soils and geomorphological and landscape features, as well as the overall moisture deficit.

A typical Cretan landscape

In most Mediterranean basin drylands, the downward spiral of land productivity towards desertification is driven by the degree of aridity along with fluctuations in land exploitation or land abandonment, peaks of overgrazing, forest clearing for agriculture, forest over-exploitation for firewood, charcoal production, wildfire damage, and logging. In Southern Europe, fire has always been a major factor in shaping rural landscapes, causing degradation of vegetation, the reduction of forest surface, the degradation of soil quality, and the increase of soil erosion and risk of flooding.

The main causes of degradation for each CASCADE Study Site are different, but they are always relevant to the accumulated impact of a driver: forest fires, marginal agriculture, grazing and wood-gathering activities, and long-term poor land management that is difficult to reverse. Less often, the causes are related to climate, which nevertheless serves as a catalyst.

This accumulated impact may be associated with sudden ecosystem shifts beyond thresholds that prevent successful restoration of the desirable ecosystem properties and services. Sudden transitions have been shown to occur under continuous external stress, such as decreased water availability or increased grazing .

In cases where external pressure is discontinuous, sudden shifts can also occur. After numerous fires, some restored Mediterranean forests have lost resilience and subsequent restoration may never conclude, as some maintenance is always required. Strong feedbacks between biotic factors and the physical environment can signify the existence of localized thresholds. These thresholds can either depict a "point of no return" or a "resilience against restoration" owing to constrains or in the vegetation-soil system at landscape level.

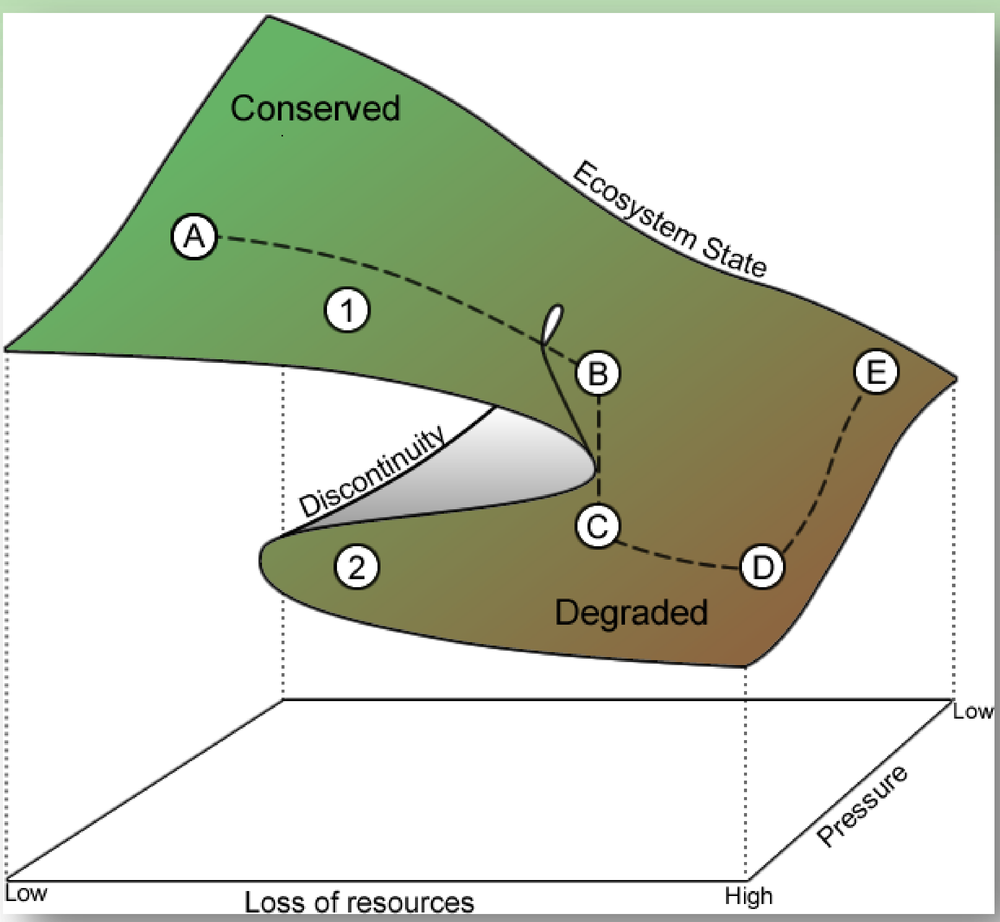
CASCADE researchers discuss rainfall exclusion experiments in the Messara Valley, Crete

A conceptual framework for catastrophic shifts

See CASCADE Deliverable 1.2 http://www.cascade-project.eu/index.php/downloads/project-deliverables

Catastrophic shifts can be described in terms of a simple "fold" diagram. The maximum disturbance that can be absorbed by the system is considered to be the system resilience. As long as the disturbance stays within the resilience, the system has the capacity to assume its previous conserved state when external conditions become favourable. When system resilience is exceeded, then the system falls to a new state through a discontinuous change. This degraded state is also stable in the sense that it also presents a new resilience against external conditions.

While this model describes a one dimensional external input well, ecosystems are usually driven by more than one variable and behave in more complex ways. Especially for dryland systems, buffering mechanisms that keep them within certain boundaries are also considered, e.g. the absence or abundance of a resource may prevent transition to a conserved or a degraded state respectively. Dependence of ecosystem stability on more than one variable or system state can be depicted with the use of the cusp catastrophe diagram (see next page).



Framework of catastrophic shifts in land degradation due to an anthropogenic pressure (e.g. grazing, fire frequency) and the variability of resources (I. Tsanis and I. Daliakopoulos)

In the Figure above**, A** represents an area where a driver is causing pressure to the ecosystem which nevertheless retains a good status and high resources. Here the system is in stable state **1**, and can maintain this state regardless of the grazing pressure due to its resilience. As resources become depleted the system reaches the tipping point (**B**) where two alternative stable states (**1** and **2**) can co-exist. The transition between **B** to **C** is very quick as processes reinforce each other. An example is a grazing system where the rate of consumption becomes significantly higher than the rate of biomass production leading to collapse. If resources are depleted further (**D**), transitioning back to **C** may require effort and to **B** may be nearly impossible, especially when drivers are human induced. More importantly, eliminating the exerted pressure will drive the system to an alternative state **E** rather than back to its pristine condition. Therefore it is possible that the system becomes "trapped" in this alternative state, especially if resources at hand are non-renewable (e.g. soil) and their loss cannot be amended within a reasonable timeframe (e.g. the human lifespan). Recovery from **E** may be more gradual as resources are recovered provided pressures are controlled. The cusp catastrophe concept and variations can be adopted for different ecosystems or selected ecosystem health indicators.

While the connection of vegetation with climate and water stress is well established on an annual basis, analyses have shown that in several cases (e.g. Randi Forest and Messara), drought can have a creeping effect over several years. This behaviour implies the existence of resources buffers that once depleted, can cause system resilience to be reduced and can potentially lead to a different stable system, as predicted by the cusp catastrophe concept.

Climate change can be expected to undermine the resilience of pastoralism ecosystems, especially under marginal management conditions. The expected consequences relate to variables such as the land's carrying capacity, the plant growth coefficient, the yield response factor and the biomass consumption coefficient. These parameters are strongly related to soil quality, which is under severe stress in arid areas.

Quantification of some features of the human and natural driver interaction with the state and rate of land degradation still poses a challenge as feedbacks and interactions are often ambiguous. However, features of the cusp catastrophe model can be identified in all the CASCADE Study Sites. The transition from the degraded state to the conserved one is hindered to the extent that resources depletion and climate cannot be reversed, thus rendering the conserved state inaccessible.

A shepherd tends his flock in a degraded part of the Messara Valley, Crete

In degraded areas the long leaves of Urginea maritima are common. Both the bulb and the leaves are poisonous

Management practices for natural resources

(*See Deliverable 7.1 http://www.cascade-project.eu/index.php/downloads/project-deliverables*)

Management practices may be used to reverse losses of resources, relieve pressure, improve resilience, improve ecosystem state and, ultimately to prevent or reverse shifts. Before inventing new natural resource management measures it is worthwhile identifying existing practices which are already affecting ecosystem shifts. Effective and sustainable natural resource management depends on suitable technologies and associated implementation approaches, and on flexibility and responsiveness to changing complex ecological and socio-economic environments. Therefore, these existing management practices were identified, documented and assessed using the standard WOCAT format. (See https://www.wocat.net/en/knowledge-base.html)

In order to maintain (or enhance) the natural resource base and sustain productivity and biodiversity, the vital ecosystem functions, (including resilience to climate change, disasters and other threats and risks) must also be maintained. The assessment of sustainable land management practices therefore includes impacts on ecosystem functions and services, following the Framework provided by the Millennium Ecosystem Assessment, which distinguishes provisioning, regulating, cultural and supporting services of ecosystems. The assessment includes information on costs and benefits of land management practices, and on their appreciation by stakeholders concerned. Rehabilitation, implementation and maintenance measures are also included, with prevention and mitigation measures chosen for their potential to reverse catastrophic shifts.

In the CASCADE Study Sites land managers were identified and consulted. Overall, they have shown a lot of interest in sustainable land management, and in the exchange of knowledge among different types of expert, some from different study sites or countries. For example, in the context of forest fires, experience was exchanged between firemen and forest workers. In general the more proficient stakeholders/land users were, the more they were willing to contribute and use a tool like WOCAT. Among the land management practices already implemented by land users there are several that seem to be effective in increasing the provision of services while improving the ability of the system to withstand disturbances. While land users do not always have the means to implement conservation measures alone, they have found ways to integrate their use of the land and the maintenance of the environment functionality and resilience. Only a few land users have directly expressed the need for more information or technical knowledge, so it is not yet possible to say how the land users and other stakeholders will be using the results of this SLM practices inventory.

Researchers and stakeholders discuss sustainable land management in the Randi Forest area of Cyprus


Photo by HP Liniger

Existing technologies being used in the CASCADE study sites were collected and described. The documentation and evaluation was done using the basic WOCAT questionnaires on Sustainable Land Management (SLM) technologies and approaches, which are available on the WOCAT website (www.wocat.net). These are accompanied by an online database system. The questionnaires are available in some of the CASCADE study site languages, such as Portuguese and Spanish.

Study site	**Code**	**Technology in use for sustainable land management**
Portugal	T_POR001en	Primary strip network system for fuel management (fire breaks)
Portugal	T_POR003en	Post-fire Forest Residue Mulch
Albatera, Spain	T_SPA013en	Multi-specific plantation of woody species
Albatera, Spain	T_SPA014en	Aleppo pine plantation on terraces
Albatera, Spain	T_SPA015en	Spatially diverse multispecific plantation
Ayora, Spain	T_SPA009en	Cleared strip network for fire prevention (firebreaks)
Ayora, Spain	T_SPA010en	Selective forest clearing to prevent large forest fires
Ayora, Spain	T_SPA011en	Selective clearing and planting experiment to promote shrubland fire resilience
Ayora, Spain	T_SPA012en	Afforestation with Pinus Halepensis after the fire of 1979 (La Molinera)
Castelsaraceno, Italy	T_ITA003en	Pasture manuring (application of manure from shelter)
Castelsaraceno, Italy	T_ITA004en	Ploughing and seeding of fodder species to recover degraded grazing areas
Castelsaraceno, Italy	T_ITA005en	Metallic fences to prevent damages to pastures from wild boars
Castelsaraceno, Italy	T_ITA006en	Cutting of ferns
Castelsaraceno, Italy	T_ITA007en	Unvegetated strips to reduce fire expansion
Castelsaraceno, Italy	T_ITA008en	Selective cutting
Crete, Greece	T_GRE008en	Graze land forestation with Ceratonia siliqua (carob trees) in the Mediterranean
Crete, Greece	T_GRE009en	Cypress afforestation by state
Crete, Greece	T_GRE010en	Integrated water-harvesting and livestock water-point system
Randi, Cyprus	T_CYP001en	Fodder provision to goats and sheep to reduce grazing pressure on natural vegetation
Randi, Cyprus	T_CYP002en	Planting carob and olive trees

Photos by N Geeson

As more CASCADE Deliverables are completed, they will be made available for download on the CASCADE website http://www.cascade-project.eu/index.php/downloads/project-deliverables and be described in the information system CASCADiS http://www.cascadis-project.eu/sudden-ecosystem-shifts

Read more about the general aims and work plan in the CASCADE flyer, (downloadable from http://www.cascade-project.eu/index.php/downloads/category/1-public-documents in 5 languages)

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