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Biodiversity and Ecosystem Function

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their function. Hence, these *SWEET* genes are genetically redundant, which likely explains why earlier genetic screens failed to identify the efflux step. Collectively, the data demonstrate that the *AtSWEET11* and *12* genes encode the missing link in sucrose phloem loading, the sucrose effluxer.

The identification of SWEET proteins as sucrose facilitators raises a number of questions. Are the regulation and localization of SWEETs and sucrose transporters coordinated to maximize phloem loading efficiency and minimize any potential loss of sucrose to the apoplast (and thereby to pathogens)? Additionally, *AtSWEET11* and *12* are expressed in most *Arabidopsis* tissues; what other roles beyond phloem loading might they play? One possibility is that they may function in sucrose efflux to seeds (*13*). Another is that during long-distance transport, SWEETs may facilitate the "leakage" of sucrose from the phloem to nourish adjacent stem tissues (*14*). If so, manipulating *SWEET* expression could enhance carbohydrate delivery to developing seeds to increase yield, or it could increase the sucrose concentration in the storage cells of sugarcane or sweet sorghum stems to improve biofuel production.

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ECOLOGY

Biodiversity and Ecosystem Function

A study of drylands across the world highlights the importance of species richness for ecosystem function.

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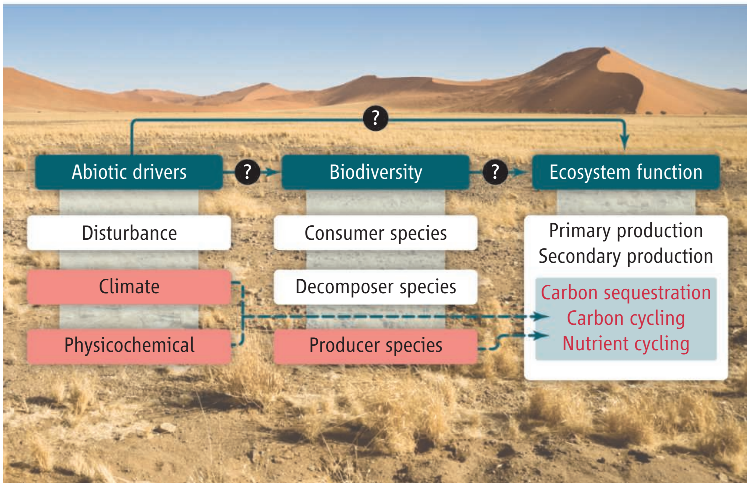
How is the biodiversity within an ecosystem related to the ecosystem's function? Quantifying and understanding this relationship—the biodiversity-ecosystem function (BEF) (*1*)—is important because socio-economic development is almost always accompanied by the loss of natural habitat and species (*2*). Short-term economic gains may thus trump longer-term benefits for human society, creating vulnerabilities that could be avoided or corrected with enough knowledge about the role of biodiversity. Erosion of biodiversity at local and regional scales may also reduce resilience at larger spatial scales as a result of degradation of ecosystem function (*3*). On page 214 of this issue, Maestre *et al.* (*4*) report an important step toward extending our understanding of BEF to globally important ecosystems.



A framework for testing the BEF. Biodiversity and abiotic drivers determine ecosystem function individually and in concert (blue boxes). How they do so cannot be fully answered without assessing the roles of multiple elements within these categories (indicative elements elaborated below blue boxes). The elements included in Maestre *et al.*'s test of the BEF are shown in red; dashed blue lines and arrows denote the relationships tested by the authors.

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Concern about the loss of biodiversity and its consequences is motivating the development of an Intergovernmental Platform on Biodiversity and Ecosystem Services (*5*), which aims to address the gaps in the science–policy interface on biodiversity and ecosystem services. Yet despite this level of attention, understanding of the BEF is far from complete (*5*), and is biased toward a small number of ecosystems amenable to experimental manipulation (*6*). Far-reaching preliminary conclusions about the critical importance of biodiversity thus rest on a small and unrepresentative knowledge base.

Maestre *et al.* ask whether the plant species richness in semi-arid ecosystems (drylands) enhances their multifunctionality (the ability of ecosystems to maintain multiple functions, such as carbon gain, carbon storage, and nutrient cycling). The authors employ a natural experiment approach, which uses quantifiable variables measured under field conditions as explanatory and response variables, to assess 14 functions in the carbon, nitrogen, and phosphorus cycles in the soil. In a massive global effort, they collected data on these functions by analyzing the soils of 224 dryland ecosystems sampled from all continents except Antarctica. From this they evaluated how biodiversity (quantified as the species richness of perennial vascular plants growing in those soils) relates to ecosystem multifunctionality across dryland ecosystems globally. This is a useful new angle and a particularly stringent test of the BEF hypothesis, according to which increasing biodiversity enhances ecosystem function. Most previous

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work assessed functions individually and did not address dryland systems, which, as Maestre *et al*. point out, cover 41% of Earth's land surface and support over 38% of the global human population.

Human society needs ecosystems to provide multiple services effectively, especially as we increase pressure on ecosystems from local impacts such as extractive harvesting to global impacts such as climate change (*4*). In drylands, critical ecosystem services include the conversion of solar energy, atmospheric CO_2, and water to plant biomass (net primary productivity), carbon storage, and provision of nutrient pools. This suite of services is vital for arresting desertification trends and sequestering carbon.

Maestre *et al*.'s test of the BEF hypothesis is stringent because they test for a relationship between species richness of primary producer species (perennial plants) and ecosystem functions expressed in soils. Soil functions are subject both to abiotic drivers and many biotic effects other than those due to perennial plants. Confirmation of the BEF hypothesis under these constraints would therefore imply robust general support for it. They also did not shy away from the confounding influence of human management impacts, given that their field sites around the world represent a wide range of intensity of human use, barring major soil disturbances such as farming or mining.

Maestre *et al*. report that perennial plant species richness is a statistically significant explanatory variable for ecosystem multifunctionality both on its own and when considered together with several abiotic explanatory variables. Indeed, only two abiotic variables, mean annual temperature and soil sand content, were more important than plant species richness in explaining ecosystem multifunctionality (hotter, more sandy sites had lower multifunctionality), in a set of variables that included mean annual rainfall.

Maestre *et al*. find that the relationship between species richness and ecosystem multifunctionality rises steeply with fewer than five species and then increases incrementally with the addition of more species. This implies that ecosystem multifunctionality as defined by Maestre *et al*. is well established by relatively few species in these dryland ecosystems, in contrast with results from temperate grasslands (*5*). However, the large spread in Maestre *et al*.'s data suggests that, apart from uncontrolled effects such as land-use history mentioned above, there may be important individual species effects (including keystone species effects) that are not quantified in this natural experimental approach. That is, the stringency and generality of their test have the unfortunate consequence of obscuring important details that seem better revealed by the experimental approaches followed in the temperate grassland studies (*6*).

Given the acknowledged limitations of the experimental design used by Maestre *et al*., future work should focus on teasing out how much variation is explained by plant species richness when potentially powerful factors such as land-use history and intensity of herbivory are controlled for. This will be important in assessing the value of biodiversity in real-world settings and may suggest how rapidly ecosystem multifunctionality could be enhanced under different land management practices aimed at ecosystem restoration.

All considered, Maestre *et al*.'s conclusion that perennial plant species richness matters for ecosystem function in dryland systems is robust. This answer has global relevance, and is especially valuable for many developing and least-developed countries facing desertification trends. Neither Maestre *et al*.'s approach nor the experimental approaches undertaken in temperate grasslands or earlier experimental work (*7*) have yet fully addressed the multilayered question of how biodiversity across trophic levels, in conjunction with abiotic drivers, determines ecosystem function (see the figure).

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ASTRONOMY

Gamma-Ray Binaries Revealed

The Fermi Large Area Telescope is unveiling a large population of otherwise hidden sources of gamma rays.

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Recent ground- and space-based telescopes that detect high-energy photons from a few up to hundreds of gigaelectron volts (GeV) have opened a new window on the universe. However, because of the relatively poor angular resolution of these telescopes, a large fraction of the thousands of sources of gamma rays observed remains unknown. Compact astrophysical objects are among those high-energy sources, and in the Milky Way there is a particular class called gamma-ray binaries. These are neutron stars or black holes orbiting around massive stars (*1*). On page 189 of this issue, the Fermi Large Area Telescope Collaboration (*2*) use the correlated orbital modulation at gamma-ray, x-ray, and radio-wave wavelengths to show that the source 1FGL J1018.6–5856 is a new gamma-ray binary, demonstrating the potential of searches for periodic modulation at gamma rays and other wavelengths to unveil new populations of gamma-ray binaries.

This area of high-energy astronomy presents several challenges: identifying the gamma-ray source with a source observed at other wavelengths; determining the properties of the binary system; and understanding the physical mechanisms by which gamma-rays are produced. In the Milky Way, only a handful of binaries radiating at gamma rays have been unambiguously identified (Cygnus X-3; PSR B1259–63; LSI +61° 303; LS 5039; HESS J0632+057). However, models of the evolution of massive stellar binaries suggest a much larger population of gamma-ray binaries.

The Large Area Telescope (LAT) on board the Fermi satellite has cataloged more than 1400 high-energy sources. Many of them are in the Milky Way, but because of the uncertain positions in the sky provided by the gamma-ray telescope (typically a few arc-min), and the complexity of the star-formation regions where gamma-ray binaries are usually located, the association of these high-energy sources with objects observed at other wavelengths is usually uncertain. The observation of correlated

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