

請閱讀以下 4 篇論文之後，摘要寫出每篇內容之主旨(不超過 250 字)。請勿逐字翻譯。

- 1) (25%) Nature conservation literature and policy instruments mainly focus on the impacts of human development and the benefits of nature conservation for oceans and aboveground terrestrial organisms (e.g., birds and plants) and processes (e.g., food production), but these efforts almost completely ignore the majority of terrestrial biodiversity that is unseen and living in the soil (1). Little is known about the conservation status of most soil organisms and the effects of nature conservation policies on soil systems. Yet like “canaries in the coal mine,” when soil organisms begin to disappear, ecosystems will soon start to underperform, potentially hindering their vital functions for humankind. Soil biodiversity and its ecosystem functions thus require explicit consideration when establishing nature protection priorities and policies and when designing new conservation areas. To inform such efforts, we lay out a global soil biodiversity and ecosystem function monitoring framework to be considered in the context of the post-2020 discussions of the Convention on Biological Diversity (CBD). To support this framework, we suggest a suite of soil ecological indicators based on essential biodiversity variables (EBVs) (2) (see the figure and table S3) that directly link to current global targets such as the ones established under the CBD, the Sustainable Development Goals (SDGs), and the Paris Agreement (table S1).

Soils not only are a main repository of terrestrial biodiversity, harboring roughly one-quarter of all species on Earth, but also provide a wide variety of functions (e.g., nutrient cycling, waste decomposition) and benefits (e.g., climate regulation, pathogen resistance); they regulate the diversity and functioning of aboveground systems, including their contributions to human well-being (3). If we do not protect soils for the next generations, future aboveground biodiversity and food production cannot be guaranteed. Nonetheless, recent calls to expand nature protection (4), as well as many other initiatives aimed to shape future environmental policies (5), do not consider the specific requirements of soil biodiversity and associated ecosystem functions (6, 7).

Discussions and data concerning soils and their sustainability have long focused on either their vulnerability to physical impacts (e.g., soil erosion) or

improvements to their food production potential (e.g., through fertilization). These narrow perspectives, often missing tangible indicators and disconnected from environmental monitoring, limit a wider discussion on the ecological importance of soil biodiversity and its role in maintaining ecosystem functioning beyond food production systems. The prevailing emphasis has also prevented soils from becoming a more mainstream nature conservation priority. Although initiatives to provide a more holistic representation of soils as ecosystem services providers exist [e.g., (8)], standardized and timely information to track policy targets related to soils is missing, particularly at global scales. These information gaps have precluded the delivery of a robust scientific message supporting the importance of soil biodiversity and have delayed the inclusion of soil biodiversity in nature conservation debates.

Linking soil biodiversity to policy

Links between global soil essential biodiversity variables (EBVs) (outer ring) are prioritized by the Soil Biodiversity Observation Network (SoilBON) and policy sectors (center) through the use of soil ecological indicators (inner ring; table S3). Thin lines correspond to links between EBVs and soil indicators; thicker lines refer to links between each soil indicator and specific policy sectors. The EBVs for soil systems are proposed as a holistic system approach (table S2), where soil organisms are intertwined with relevant soil chemical, physical, and functional properties, contributing to overall societal well-being. See table S1 for further information on links to specific policy targets and policies. See table S2 for details of the EBVs.

2) (25%) Photosystem II (PSII) is an oxidoreductase found in the thylakoid membrane of organisms that perform oxygenic photosynthesis. The fully assembled PSII complex consists of approximately 20 protein subunits and multiple redox-active cofactors that allow PSII to function as a catalyst for the light-driven oxidation of water and concomitant reduction of plastoquinone (1–4). This conversion of sunlight to chemical energy initiates the photosynthetic electron transport chain and sustains nearly all life on Earth.

The active site for water oxidation, a Mn_4CaO_5 cluster (henceforth Mn cluster), is buried within the PSII complex near the lumen-membrane interface (5). This buried position limits water access to the active site, a key feature that promotes the reaction. When PSII is modified to allow an unrestricted flow of water to the active site, incomplete water oxidation occurs, forming hydrogen peroxide (H_2O_2) that is

reduced to the harmful hydroxyl radical ($\text{HO}\cdot$) (6–9). The buried active site minimizes, but does not completely prevent, such a side reaction pathway, allowing some reactive oxygen species (ROS) to be produced under physiological conditions (10, 11). ROS-induced damage to PSII is the major mechanism believed to be responsible for the frequent PSII turnover that occurs in cells (2, 12), and oxidative modifications of PSII residues near the Mn cluster have been detected (11, 13–17).

Although PSII is the only known enzyme capable of complete water oxidation, it is not the only enzyme for which water is more than just a solvent. Aquaporins transport water across membranes; cytochrome c oxidases produce water as a by-product while pumping protons; and the haloalkane dehalogenases use specific interactions with carefully placed internal water molecules to achieve catalysis. For these and many other enzymes, it is becoming increasingly clear that water dynamics is exquisitely tuned by the protein scaffold to fit the enzyme's function. For example, specific channels regulate the accessibility, geometrical positioning, and flow rate of water molecules within the abovementioned enzymes and in many others (18–21).

Water transport within PSII is of prime interest, given water's unprecedented role as substrate and the problems associated with unrestricted water access to the active site. A number of computational studies have searched for water channels by examining cavities within the static PSII crystal structure (22–24) or by performing molecular dynamics (MD) simulations (25–30). Pathways for removal of the reaction products, dioxygen and protons, have also been considered (22–24, 27, 28, 30) because the extended presence of dioxygen can lead to protein damage (from conversion to singlet dioxygen) (31), and of protons, to inhibition of catalysis (due to improper redox leveling) (32, 33). These computational studies have identified several putative channel systems within PSII.

Here, we took an experimental approach to identify oxidized residues on the luminal side of PSII from the cyanobacterium *Synechocystis* sp. PCC 6803 (henceforth *Synechocystis*) by using high-resolution tandem mass spectrometry (MS). We reasoned that after generation near the Mn cluster, ROS would diffuse through putative channels that lead away from the cluster and modify most readily the residues that line the walls of these channels. The approach is related to a typical hydroxyl radical footprinting experiment, in which hydroxyl radicals are generated from solvent water molecules by an x-ray or laser pulse (34–37) or via a metal-catalyzed reaction (36, 38–40) and then modify nearby residues. The modified residues, detected by MS, leave a trail of oxidative damage that, when identified, can

illuminate structural aspects of the system being studied. Hence, the ROS produced at the Mn cluster serve as a built-in footprinting reagent. Using this approach, we identified three nearly continuous formations of oxidized residues that are centered at the Mn cluster and radiate outward all the way to the bulk solvent. Hydrogen peroxide and the hydroxyl radical are the two major ROS known to be produced at the Mn cluster (6, 11). The hydroxyl radical, by far the more reactive species, is short-lived but can diffuse several tens of angstroms after generation at a protein site (38, 41, 42). Given the similar size and hydrophilicity of HO• and water (43), an HO• diffusion pathway is likely to be favorable for water as well. We conclude that the three ROS channels identified in our study represent three possible water channels in PSII. We discuss the implications of our results for the delivery of water to the site of its oxidation in PSII.

3) (25%) Early in mammalian development, sleep predominates over wakefulness, with both non-rapid eye movement (NREM) and rapid eye movement (REM) sleep at their lifetime maximums. This period of life corresponds to a time of rapid cortical changes and has led to the hypothesis that the endogenous neural activation characteristic of REM sleep in particular may be critical for normal maturation of the central nervous system (1–4).

Sleep deprivation studies in both young felines and juvenile rodents have identified core functions of sleep in the early development of the visual system (3, 5–7), motor systems (8–10), refinement of sensorimotor integration (11), and organization of spinal reflexes (12). Early-life sleep may also be necessary for the maturation of the neurobiological systems that underlie complex social behaviors (13): Previous works in both *Drosophila* (13, 14) and rats (15–17) suggest that early-life sleep disruption (ELSD) results in long-lasting changes in species-specific sociosexual behavior (e.g., courting and mating). However, the role of early-life sleep in the development of specific brain circuits that underlie complex social behaviors such as pair bond formation and expression remains largely unexplored.

In mice and rats, inhibitory GABAergic synapses within the barrel fields of the primary somatosensory (S1) cortex undergo marked remodeling in the second and third postnatal weeks (18, 19), with normal whisking behavior emerging between postnatal days (P) 12 and 15 (20). The somatosensory system is crucial for the expression of rodent social behaviors (21). Both neonatal damage to the somatosensory cortex (22) and the deprivation of sensory stimuli to the whiskers alter the development of play behavior (23), which can influence the adult expression of

social behavior (24, 25).

Proper synchronization of excitatory and inhibitory processes, essential to normal neural functioning throughout the neocortex (26), is dependent on fast-spiking parvalbumin (PV)-expressing inhibitory interneurons (27). These interneurons are involved in generating electroencephalographic (EEG) oscillations within the γ frequency band (20 to 100 Hz) (28, 29) associated with cortical activation present during wake and REM sleep (30). Direct activation of PV interneurons in the barrel cortex of mice selectively amplifies EEG oscillations within the γ frequency band (28), and aberrant EEG γ band oscillations are a feature of many neuropsychiatric disorders (31).

PV interneuron development is especially vulnerable to atypical experience during early development because of its activity-dependent postnatal maturation (32) and has been shown to be sensitive to REM sleep deprivation in kittens (5). In the rat and mouse, PV immunoreactivity (PV-ir) in the cerebral cortex develops rapidly between P12 and P21 (33, 34) and may represent a time period in rodents whereby social neural networks are sensitive to environmental insults such as ELSD. Notably, PV disruption in the cortex has been linked to abnormal social behavior in mice (35).

To investigate how sleep shapes the neural system's underlying social development, we disrupted sleep early in life in the highly social prairie vole (*Microtus ochrogaster*). Prairie voles are socially monogamous rodents that form lifelong pair bonds with opposite sex individuals. In the wild, prairie voles engage in a number of affiliative social behaviors common to humans, including biparental care (36) and extended opposite sex cohabitation (assessed in the laboratory using the partner preference test) (37). We hypothesized that REM ELSD that occurs within a sensitive period of PV development in the cortex of rodents would have long-lasting effects on PV-ir and social bonding in the prairie vole.

In this series of studies, we first validated a method of ELSD in juvenile prairie voles using a laboratory orbital shaker while undergoing chronic in vivo sleep EEG/electromyographic (EMG) recordings. EEG/EMG signals were used to determine sleep measures during ELSD compared to baseline, as well as relative EEG power during sleep stages. Prairie vole pups underwent ELSD for 1 week during their third postnatal week in development (P14 to P21), when social behaviors with littermates are starting to emerge (38) and when PV-ir is maturing in the neocortex. Brain tissue was collected from adult animals and processed for PV-ir in the S1 cortex

as a first probe into the neocortical excitation/inhibition tuning necessary for appropriate social development. Behaviorally, adult prairie voles were tested for pair bond formation, novel object recognition, and anxiety-related behavior to examine the role of early-life sleep on the development of complex behaviors known to involve the somatosensory system (i.e., sensory integration of environmental cues).

4) (25%) Atmospheric nitrogen (N) deposition is considered to be a driver of increasing carbon (C) storage in woody biomass, particularly in N-limited temperate and boreal forests in North America and Europe (1–3). However, there is still debate on the impact of N deposition on the greenhouse gas (GHG) balance of tropical forests, which have abundant available soil N and a much leakier N cycle than temperate forests (4, 5). The tree growth and C storage in woody biomass were not found to significantly respond atmospheric N deposition in temperate forests across Europe and northeastern United States (6, 7). Similar results were also observed in P-limited Hawaiian tropical forests growing on soil of 4.1 million years (8). However, Frey et al. (9) demonstrated that N addition increased soil C accumulation largely due to a suppression of organic matter decomposition rather than enhanced C inputs via litterfall and root production. These results suggest that the responses of forest C sequestration to N addition are variable depending on background limitation, changes in the nutrient use efficiency of plants and decomposers, and limitation of other nutrients such as phosphorus (P) (10, 11). Few studies on N deposition effects have focused on tropical and subtropical regions compared with boreal and temperate regions (12).

Methane (CH₄) and nitrous oxide (N₂O) are the important GHGs that contribute to more than one-quarter of anthropogenic global warming, and their emissions partly offset terrestrial CO₂ uptake at the global scale (13, 14). It has been reported that the emissions of CH₄ and N₂O from terrestrial ecosystems offset 73% of the land CO₂ sink over the North American continent (15). Forest soils are a sink for CH₄, but this sink may have decreased by 77% from 1988 to 2015 (16). Humid tropical forest soils have higher background N₂O losses than temperate forest soils and are the largest source of N₂O across natural ecosystems (12). Nitrogen addition was reported to increase CH₄ and N₂O production and inhibit CH₄ consumption in recent studies, which may shift the net GHG balance toward a source of CO₂ equivalents (CO₂eqs) and could offset 53 to 76% of increased C sequestration induced by N deposition across terrestrial ecosystems (14).

This study focuses on Moso bamboo (*Phyllostachys edulis*), a widely planted species

in East and Southeast Asia, covering 4.43 Mha in subtropical China (17). Moso bamboo has extremely fast growth rates (completing height and diameter growth within 2 months after shoot emergence) and a strong regeneration ability (alternating high and low new bamboo recruitment years). The site studied is intensively managed with one-third of the aboveground biomass being removed by thinning each 2 years, thus leaving tree cohorts younger than 4 years. The residence time of most harvested bamboo products, such as bamboo flooring and bamboo furniture, is larger than 20 years (18, 19). Management practices include fertilization, ploughing, and weeding. Therefore, Moso bamboo forests can always grow and remove CO₂ from the atmosphere; at steady state, their net ecosystem exchange is equal to harvest, and the standing biomass carbon stock remains constant. The net CO₂ sink of the system formed by bamboo forests and their wood products thus depends mainly on the lifetime and accumulation in wood products and waste. Our 5-year observation using eddy covariance measurements found that the mean annual net C sequestration in both trees and soil was 6.03 Mg C ha⁻¹ (17). Over a 30-year time period, the carbon stock of the system including plantation and its products pool is 246 metric tons (t) C ha⁻¹, higher than the 200 t C ha⁻¹ of Chinese fir (*Cunninghamia lanceolata*), another fast growing tree in China (19).

The regions where Moso bamboo mainly distributes are today subject to much higher N deposition rates of 30 kg N ha⁻¹ year⁻¹ (20) than Western European (8 to 11 kg) and United States (4 to 5 kg) (21). Moreover, N deposition is predicted to increase by 50 to 100% by 2030 relative to the year 2000 and could reach up to 50 kg N ha⁻¹ year⁻¹ by 2050 in China (22, 23). It was shown that N deposition significantly increased P uptake (24), photosynthetic capacity (25), decomposition rates of leaf litter (26) and fine roots (27), loss of dissolved organic carbon (DOC) (28), and soil microbial biomass (29) in bamboo forests. However, how N deposition affects ecosystem productivity, soil carbon storage, soil uptake of CH₄ and soil N₂O emissions, and thus the net GHG balance remains to be quantified. In this study, we performed a 4-year field experiment at three N addition levels of 30, 60, and 90 kg N ha⁻¹ year⁻¹ upon a control (N-free addition with an ambient N deposition rate of 30 kg N ha⁻¹ year⁻¹) in Moso bamboo forests composed of 1- and 3-year-old bamboo cohorts since January 2013.