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current logging practices and the importance of dipterocarps in the global timber industry. Part of the value of timber from Southeast Asia is that most comes from dipterocarps; it is light and easily worked and can be sold in large volumes under just a few wood types. One of the great tragedies of the Asian timber industry is that dipterocarp forests are amenable to selective harvesting and long-term management, but economic and political conditions favor short-term intensive harvesting and conversion to plantations.

Overall the book is well written, thoroughly researched, and packed with information on this important tropical tree family. The black-and-white figures can be tough to interpret and the author misses opportunities to make some key synthetic points. But there is a lot to like, including the thoroughness of the review and suggestions of promising directions for further research. I thought the author's approach was valuable and worthy of replication; I think similar books should be written on other large families of trees, such as legumes and oaks. This book is a valuable contribution to the tropical ecology literature.

Dipterocarp Biology, Ecology, and Conservation by Jaboury Ghazoul, Oxford University Press, 2016. US $89.95, hbk (320 pp.) ISBN 978-0-199-63965-6.

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References
1. Whitmore, T.C. (1998) *An Introduction to Tropical Rain Forests,* Oxford University Press
2. Corlett, R.T. (2014) *The Ecology of Tropical East Asia* (2nd edn), Oxford University Press
3. Ashton, P. (2015) *On the Forests of Tropical Asia: Lest the Memory Fade,* Royal Botanical Gardens
4. Corlett, R.T. and Primack, R.B. (2011) *Tropical Rain Forests: An Ecological and Biogeographical Comparison* (2nd edn), Wiley-Blackwell
5. Ghazoul, J. and Sheil, D. (2010) *Tropical Rain Forest Ecology, Diversity, and Conservation,* Oxford University Press

Letter

Future Benefits from Contemporary Evosystem Services: A Response to Rudman *et al*.

Daniel P. Faith,[1,*] Susana Magallón,[2] Andrew P. Hendry,[3] and Michael J. Donoghue[4]

The contributions of nature to people include many ecological processes within ecosystems that provide services valued by society. The value to humans of biodiversity (living variation at the gene, species, and ecosystem levels) is sometimes assumed to relate solely to its underpinning of such ecosystem services. However, biodiversity has its own long-recognised anthropocentric values, especially through the future options ('option value' [1]) provided by living variation. Therefore, biodiversity sits side-by-side with ecosystem services as a key benefit from nature [1]. Recently, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) [2] recognised the 'maintenance of options' as a distinct category of the contributions of nature to people. The IPBES conceptual framework [3] discussed these values with a reference to the concept of 'evosystem services', broadly conceived as the benefits to society stemming from evolutionary processes in the past, present, and future [4]. This definition explicitly includes contemporary evosystem services derived from rapid evolution [4]. In a recent article in *TREE*, Rudman *et al.* [5] brought further attention to these 'contemporary evosystem services', characterising them as 'the maintenance or increase of an ecosystem service resulting from evolution that occurs quickly enough to alter ecological processes'. Unfortunately, this implies that ecosystem services are the only benefits from contemporary evolution, overlooking a role for contemporary evolution in providing the 'maintenance of options' contributed by biodiversity. Here, we argue in favour of a broader interpretation of contemporary evosystem services that includes these additional benefits.

The useful overview and examples provided by Rudman *et al.* [5] expand on recent work on contemporary evosystem services in relation to ecological processes and ecosystem services (e.g., [4,6]). However, we note that other recent studies that refer to evosystem services and contemporary evolution focussed less on altering ecological processes and more on the generation of diversity and its prospective (often global) benefits. An important example is what Bellon and colleagues [7,8] described as evosystem services for global agricultural and food systems. These authors referred specifically to the 'public benefit' from the genetic diversity and evolutionary potential produced by 'on-farm conservation': the management of crops to produce and maintain diversity. Bellon *et al.* [9] make an explicit contrast with ecosystem services, referring to evosystem services from on-farm conservation as including the option values of biodiversity, such as 'options to obtain more diverse products for consumption and sale' [10].

The work of Bellon and colleagues is clearly about contemporary evolution. As they summarise: ' . . . farmers influence through their knowledge, preferences and practices, the alleles and genotypes that pass from one generation to the next and their spatial distribution – contributing to shape the traits under selection' [7]. Such conservation farms, collectively, make a global contribution to 'sustaining the capacity of agricultural and

Box 1. Evosystem Services

Evosystem services [4] encompass the contributions of nature to people [2] that result from past, present, and future evolutionary processes. In Figure I, evosystem services cover all combinations from the left column (the timescale of evolutionary processes) and the right column (the contributions of nature to people). 'Contemporary evosystem services' encompass all of the contributions of nature that result from contemporary evolutionary processes.

Rudman *et al*. [5] worried that our broad interpretation of evosystem services [4] might be 'a concept too meta-scale to measure'. However, the specific elements (combinations from the timescale and contribution columns) of our more inclusive concept of evosystem services are measurable. For example, assessments of on-farm conservation [7,10] include measurement of the option values of contemporary evosystem services (dotted blue arrow in Figure I). Likewise, the maintenance of options resulting from past evolution (broken blue arrow) has well-established measures based on 'phylogenetic diversity' [1,4].

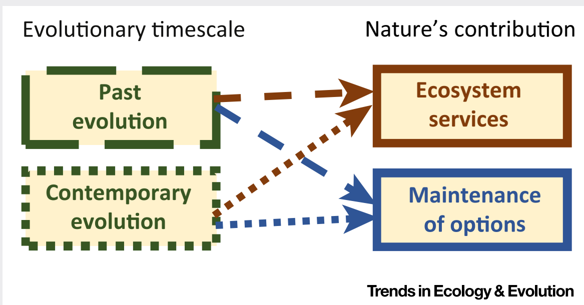

Figure I. Inclusive Interpretation of Evosystem Services. Arrows represent support or provision of the contributions of nature to people (brown for ecosystem services; blue for options) stemming from evolutionary processes taking place on a specified timescale (broken for past evolution; dotted for contemporary evolution). Other possible categories of the contributions of nature [2], and evolutionary timescales, including noncontemporary evolution, are not highlighted here.

food systems to adapt to change by maintaining crop evolution in their fields today, thus enabling humanity to continue to have the broad genetic variation needed to adapt crops to changes tomorrow' [7]. This body of work [7–10] supports our broader interpretation of 'contemporary evosystem services' as providing not only ecosystem services, but also the 'maintenance of options' insured by biodiversity (Box 1).

Rudman *et al.* [5], in accord with their focus on ecosystem services, explicitly tied 'rapid evolution' to simultaneous changes in ecological processes, affecting services derived from natural ecosystems [5]. Our interpretation of 'contemporary evolution', encompassing evolutionary changes observable over less than a few hundred years [4], includes the possible services based on the generation of diversity and options. Consequently, it does not require simultaneous change in ecological processes. Furthermore, much contemporary evolution and its services will manifest in non-natural, human-influenced evosystems, such as the agricultural systems highlighted by Bellon and colleagues (see also [11]).

These perspectives are relevant to the recent call for greater attention to evosystem services, relative to the conventional emphasis on ecological factors, when making conservation decisions [12]. As society addresses conservation challenges, it will be important to recognise that contemporary evosystem services encompass the same range of benefits as the evosystem services associated with other evolutionary timeframes (Box 1). One long-recognised challenge is to balance the global option-value benefits of biodiversity with the more-localised benefits from ecosystem services [1]. Management for contemporary evosystem services faces this same issue. The human-influenced evosystem services described by Bellon and colleagues are typically global benefits, for 'society at large' [7]. However, as Bellon *et al*. observe, opportunities now exist for 'outside interventions' (such as incentives programs) to balance or align the interests of individual farmers with the interests of society at large. The success of such emerging strategies depends on our appreciation of both the ecosystem services and the option values provided by evosystem services.

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http://dx.doi.org/10.1016/j.tree.2017.07.005

References

1. Faith, D.P. (2017) A general model for biodiversity and its value. In *The Routledge Handbook of Philosophy of Biodiversity* (Garson, J. *et al.*, eds), pp. 69–85, Routledge
2. IPBES (2017) *Update on the Classification of Nature's Contributions to People by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, IPBES
3. Díaz, S. *et al.* (2015) The IPBES Conceptual Framework – connecting nature and people. *Curr. Opin. Environ. Sustain.* 14, 1–16
4. Faith, D.P. *et al.* (2010) Evosystem services: an evolutionary perspective on the links between biodiversity and human-well-being. *Curr. Opin. Environ. Sustain.* 2, 66–74
5. Rudman, S. *et al.* (2017) Evosystem services: rapid evolution and the provision of ecosystem services. *Trends Ecol. Evol.* 32, 403–415

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6. Vonlanthen, P. *et al.* (2012) Eutrophication causes speciation reversal in whitefish adaptive radiations. *Nature* 482, 357–363
7. Bellon, M.R. *et al.* (2015) Conserving landraces and improving livelihoods: how to assess the success of on-farm conservation projects? *Int. J. Agric. Sustain.* 13, 167–182
8. Gotor, E. *et al.* (2017) Assessing the benefits of Andean crop diversity on farmers' livelihood: insights from a development programme in Bolivia and Peru. *J. Int. Dev.* Published online February 1, 2017. http://dx.doi.org/10.1002/jid.3270
9. Bellon, M.R. and van Etten, J. (2013) Climate change and on-farm conservation of crop landraces in centres of diversity. In *Plant Genetic Resources and Climate Change* (Jackson, M. *et al.*, eds), pp. 137–150, CABI
10. Bellon, M.R. *et al.* (2015) Assessing the effectiveness of projects supporting on-farm conservation of native crops: evidence from the high Andes of South America. *World Dev.* 70, 162–176
11. Hendry, A.P. *et al.* (2017) Human influences on evolution, and the ecological and societal consequences. *Phil. Trans. R. Soc. B* 372, 20160028
12. Smith, T.B. *et al.* (2014) Prescriptive evolution to conserve and manage biodiversity. *Annu. Rev. Ecol. Evol. Syst.* 45, 1–22

Letter

Contemporary Evosystem Services: A Reply to Faith *et al*.

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We thank Faith *et al.* [1] for their informative and thought-provoking reply to our recent article in *TREE* [2]. We agree with several of their comments regarding the path forward for the study of evosystem services and especially contemporary evosystem services, the topic of our article [2]. Evosystem services are 'all the uses or services to humans that are produced from the evolutionary process' [3] including benefits stemming from past, current and future evolution. In our article [2], we defined 'contemporary evosystem services' as 'the maintenance or increase of an ecosystem service resulting from evolution occurring quickly enough to alter ecological processes'. Here, we briefly discuss two areas where our opinions and working definitions differ from those of Faith *et al.* [1].

One area of discord between our view and that of Faith *et al*. [1] is that we do not see enhancements to ecosystem services stemming from evolution by artificial selection as a contemporary evosystem service. Evolution stemming from natural processes that occur on human-altered landscapes and that increase ecosystem services would fit our definition, and we provide several putative cases in our original article [2]. For example, the slowing of the evolution of pesticide resistance through gene flow between farm and refuge populations of pests is a clear contemporary evosystem service that occurs in agricultural landscapes. Faith *et al*. [1] would also include the action of farmers intentionally maintaining crop diversity in fields under their definition, but we regard this as a form of artificial disruptive selection. We fail to see the advantage of lumping artificial selection with natural selection under the same heading. If the intentional maintenance of genetic diversity is to be regarded as an evosystem service, then so should other forms of manipulation leading to changes in genetic diversity, including the selective breeding of crops and livestock, and artificial evolution achieved through allelic replacement using CRISPR and older transgenics techniques. In all of these cases, humans are driving heritable genetic changes, but the action of human engineering differs markedly in mechanism and ontology from what occurs in scenarios not deliberately controlled by humans. More importantly, these cases diverge from the main message of the ecosystem services concept, which is to focus on the contributions to human wellbeing that are outside of the market system. Farmers maintaining genetic diversity are certainly performing a service to society, but we believe that calling it a contemporary evosystem service reduces the clarity of the concept.

Faith *et al*. [1] also make the interesting point that option values (such as that provided by genetic diversity) should also be included with contemporary evosystem services. In our view, this depends on whether one regards option values as an ecosystem service or as something distinct from ecosystem services. Option values have long been included in the ecosystem services concept. Daily *et al*. [4] formally recognized them as 'a premium that people are willing to pay to preserve an environmental amenity, over and above the mean value of the use values anticipated from the amenity' ([4] pp. 34–35). The Millennium Ecosystem Assessment (MEA) [5] defined option value more broadly as: 'the value individuals place on keeping biodiversity for future generations.' The original definitions from Daily *et al*. [4] and the MEA [5] focus on how humans value maintaining the option of enjoying ecosystem services in the future. Similar to other ecosystem services, option values, as defined by Daily *et al*. [4], could be modified by contemporary evolutionary processes, and contemporary evolution could alter the value humans ascribe to maintaining options for future use. In this case, rapid evolution leading to changes to option values should be regarded as a contemporary evosystem service.

Faith [6] provides a rather different definition of option value: 'option value refers not only to the unknown future benefits from known units of biodiversity, but also to the unknown benefits from unknown units.' Using this definition, Faith *et al*. [1] focus on the importance of maintaining genetic diversity to maintain 'future options' provided by living variation. Although we agree that the maintenance of genetic diversity is important for future evolution, we would not classify these option values as contemporary