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Hydrology and Earth System Sciences Discussions

Interactive comment on "Biotic pump of atmospheric moisture as driver of the hydrological cycle on land" *by* A. M. Makarieva and V. G. Gorshkov

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In response to the comments of J. van Damme and V. Gavrilov:

In their valuable comments Dr. van Damme and Dr. Gavrilov discuss the biological bases of the biotic pump that were described in Section 4 of the paper. The main purpose of Section 4 was to illustrate the need of seeking an understanding of the studied phenomenon that would be accepted as non-contradictory within any domain of science, like geophysics and evolutionary biology.

We therefore fully agree with the view expressed in both comments that the problem of how natural selection, acting on individual organisms, might be able to produce a continent-scale environmental regulation by the biota, deserves a special investigation. And that the introduced notion of biotic sensitivity should be further elaborated in several contexts, including genetic and ecological. In fact, some work in this direction has been already performed. In particular, an attempt was made to find a quantitative genetic analogue of the ecological sensitivity of natural selection. A detailed analysis of the levels of genetic variability in mammals has shown that the observed patterns can be quantitatively explained assuming a finite sensitivity of selection to the number of mutational substitutions in individual genotypes (Gorshkov and Makar'eva, 1997; Makarieva, 2001). In other words, natural selection cannot tell apart individuals whose genomes differ by a too small number of mutations. Mutations can therefore accumulate to some average level when they start to be 'seen' by selection. This threshold, determined by the sensitivity of natural selection, determines the observed levels of genetic variability within biological species.

However, retaining the geophysical focus, here we would like to give a more general response to the issues raised in the comments.

Trees are the apparent structural units of forest ecosystems. The environment of each tree can be separated into the individual-level local and population-level global components. For example, soil nutrient composition is largely determined by functioning of the individual tree and the associated microbiota like bacteria and fungi, while the gaseous composition of air, e.g. CO_2 concentration, is shared by all trees in the forests. So, due to mixing, local concentration of carbon dioxide experienced by a particular tree, is only to a very small extent influenced by this particular tree. But if the small change of a global environmental parameter performed by each tree is sufficient to impart some competitive advantage to this tree or its associated organisms, via improvement of environmental conditions, such trees and the organisms that work in coordinated manner with them will be favored by selection. In the result, the population will consist of trees jointly performing a large-scale environmental control, which is the idea of biotic sensitivity.

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Large animals, whose home territories include many individual trees, can similarly be considered as a global, shared environmental component with respect to trees. The interactions between animals and trees is not chaotic, it is strictly determined by biological and ecological peculiarities of both sides. As is well-known, trees actively control the rate of herbivory and, hence, regulate the population numbers of forest animals. Therefore, those trees who, on the evolutionary time scale, pursue the right strategy in their interaction with animals, will benefit more (by a small but appreciable amount) from the useful functions of animals (e.g., seed dispersal or pollination) and less from their negative functions, of which the major one is the introduction of fluctuations into the standing plant biomass. Therefore, in the evolutionary result, forest will consist of only those trees and tree species which are jointly able to maintain the population numbers of large animals at an optimal level, similar to how they have evolved to jointly run the continent-scale biotic pump to maintain optimal soil moisture content.

Keeping in mind that the major disturbing factor introduced by large animals is fluctuations of plant biomass due to its consumption and that these fluctuations grow rapidly with animal body size, it is interesting to note that the forest ecosystem has apparently evolved to surpress energy consumption of the largest animals. In *natural undisturbed* forests the largest portion of primary productivity (about 90%) is consumed by the smallest organisms, bacteria and fungi. Their consumption is most regular, due to their great numbers and small size. Herbivore species of intermediate size, including insects, consume althogether about 10% of primary productivity. Finally, the largest animals (like contemporary mammals and birds) are allowed to consume no more than about one per cent of total primary productivity. This suggests, for example, that the common image of large dinosaurs having once *dominated* on our planet is not ecologically sound – one can hardly speak of dominance of organisms whose cumulative influence on biospheric processes is limited in power to less than 1%.

More detailed and quantitative elaboration of these ideas can be found elsewhere (see Gorshkov et al., 2004; Makarieva et al., 2004 and references therein). In conclusion,

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it can be noted that an integral and satisfactory understanding of the controlling biotic influence on the global environment will demand equal efforts from geophysical as well as biological sciences. Geophysicists were the first to get concerned about gaining such an understanding (see references in the paper). But, in our view, population geneticists will similarly have to verify whether their current vision of genetic phenomena is consistent with, and can yield a clue to, the established facts of large-scale regulatory environmental impacts of the biota, of which one, as we argued, is the continental forest pump of atmospheric moisture.

References

Gorshkov, V. G. and Makar'eva, A. M. Dependence of heterozygosity on body weight in mammals, Doklady Biological Sciences, 355, 384-386, 1997.

Gorshkov, V. G., Makarieva, A. M., and Gorshkov, V. V.: Revising the fundamentals of ecological knowledge: The biota-environment interaction, Ecol. Complexity, 1, 17-36, 2004.

Makarieva, A. M., Gorshkov, V. G., Makarieva, A. M., and Li, B.-L.: Body size, energy consumption and allometric scaling: a new dimension in the diversity-stability debate, Ecol. Complexity, 1, 139-175, 2004.

Makarieva, A. M.: Variance of protein heterozygosity in different species of mammals with respect to the number of loci studied, Heredity, 87, 41-51, 2001.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 3, 2621, 2006.