OPEN ACCESS

GAVIN PUBLISHERS

Current Trends in Forest Research

Godron M. Curr Trends Forest Res: CTFR-116.

Review Article

DOI: 10.29011/ 2638-0013. 100016

Three Direct Measures of Diversity for Forests

Michel Godron*

Department of Phyto-sociological and Ecological, Scientific Research National Center, Ladiss Université Paris VII, France

***Corresponding author:** Michel Godron, Department of Phyto-sociological and Ecological, Scientific Research National Center, Ladiss Université Paris VII, The Graineterie, 18410 Brinon, France. Tel: +330248585474; Email: migodron@wanadoo.fr

Citation: Godron M (2018) Three Direct Measures of Diversity for Forests. Curr Trends Forest Res: CTFR-116. DOI: 10.29011/ 2638-0013. 100016

Received Date: 14 July, 2018; **Accepted Date:** 17 August, 2018; **Published Date:** 27 August, 2018

Abstract

Brillouin's model gives a new measure of diversity related to thermodynamic neguentropy and it helps to understand the functioning of forests. For 274 stands of forest Brillouin's index was calculated for the diversity of species and also for the diversity of diameters of the trees.

The first result is that the Bravais-Pearson correlation between these two diversity indexes is 0.54 and is very highly significative. As the diversity of the species present in a stand is a guarantee of resistance to climatic change, we may be sure that improving irregularity of diameters increases the resistance to climatic change and to other disturbances as diseases.

Brillouin's formula gives also a probabilistic distance between the species frequencies observed in two different stands which is a spatial biodiversity important for landscape ecology.

If we compare the species frequencies observed in one stand along time, the tensor of probabilistic distances between these observations will show if the forest oscillates in a cybernetic attractor. That phenomenon is related to the metastability of all the biological systems: each living system is more or less stable and stays oscillating at some time scales around some medium states, until its death where all its vital regulations crashes.

At least, Brillouin's index is a precise measure of the mutual information between species and with the ecological characters of their environment.

Keywords: Biodiversity; Climate Change: Diversity of Frequencies; Ecology; Forestry; Metastability

The Biodiversity Concept

Biodiversity appeared as a prominent concept with [1], but it was perceived many years before by ecologists interested in statistics as [2,3] Some measures of biodiversity were proposed by [4,5] and now biodiversity is generally measured by the [6] created for messages transmission.

May RM [7] remarks that the Shannon's index has no biological meaning and is not a clear guide for the management of ecosystems. Moreover, that index is inferential and its statistical estimation is biased. So, we will use Brillouin's index whose signification is related to the neguentropy of the system, as shown by [8]. Considering the elements of a set of data. The idea of [9] was to measure directly the probability of the observed frequencies distribution. The number of combinations giving a frequency distribution (named "complexion") is:

$$C = N! / n1!\ n2!\ n3! \dots ns! \quad (1)$$

with N = total number of individuals, n1 = number of individuals in the first species, n2 = number of individuals in the second species, etc.

The probability of the observed complexion is:

$$P = n1!.\ n2! \dots ni! \dots ns! \ / N! = P\ ni! / N!$$

The information (= neguentropy) given by the observation of that complexion is:

$$I(E) = \log 2\ 1/ \log 2\ N! \ / P\ ni!$$

and the unit of information has been named "binon".

Application to Forest Stands

The description of a forest stand includes the number of trees of each species and their diameter. We observed these two parameters in 276 stands in Sologne forests, near Loire valley. The distribution of frequencies of the Brillouin's index for the biodiversity of species is:

Index	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Frequency	46	6	6	6	11	8	13	21	18
Index	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7
Frequency	11	16	13	12	10	13	8	11	7
Index	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	_
Frequency	11	8	3	7	3	3	2	1	_

That distribution is very far to be gaussian, but it shows that there are probably some clearly different types of forests in the sample.

In each stand, we observed also the diameters distribution of the trees, and Brillouin's formula gives the frequencies distribution:

Index	0	0.1	0.03	0.4	0.5	0.6	0.7	0.8	0.9
Frequency	45	3	3	9	6	8	12	12	13
Index	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
Frequency	10	10	11	16	14	16	13	12	10
Index	1.9	2	2.1	2.2	2.3	2.4	-	-	-
Frequency	7	14	14	8	7	1	-	-	-

Another set of 880 stands with stratified sampling [10] was also studied and gave the same type of results, but it is not related here because the stands were less representative.

The Most Important Result

The Bravais-Pearson correlation between the two diversity indexes is 0.54, and it is very highly significant. The consequence of that correlation is that if the management of the forest gives a large set of diameters it will also give generally a great number of species in each stand. As climatic change will affect differently the species present in a stand, a great diversity of the species present in a stand is a guarantee against climatic change. We could then tell to the foresters: "If you increase the irregularity of the diameters, you have a good chance to increase also the resistance and the resilience of your forests to climatic change and to other disturbances as diseases."

A Third Diversity Index

The two first indexes give an indication on the "local" diversity (or "alpha" diversity according to [11], observed in one stand. We proposed a generalization of Brillouin's ideas to get a spatial diversity index of probabilistic distance between the frequencies of the species observed in two different stands.

The principle will be explained by the example of two stands where the frequencies of three species are:

Quercus pedunculata	50	97
Carpinus betulus	50	0
Pinus silvestris	0	3
Total	100	100

The Brillouin's index for the three lines of the matrix and for the difference between the two columns are respectively 132 0 0 binons and 15 134 192 binons. Its value for the set of the two columns is 196 binons. Them, the measure of the spatial diversity is:

Quercus pedunculata	+49
Carpinus betulus	-62
Pinus silvestris	+4

The sign is + if the frequency in the second stand is greater than in the first stand, and it is - in the other case.

This result is named "probabilistic distance" and it gives a precise confirmation of the impression that:

- The frequency of Quercus pedunculata is greater in the second stand,

- The frequency of Carpinus betulus is much smaller in the second stand,

- And the frequency of Pinus sylvestris is a little greater in the second stand.

The sum of the absolute values of the three distances is 115 = 49 + 62 + 4. It is a detailed for each species measure of the "beta" diversity imagined by [11].

The Probabilistic Distance and the Stability of the System

When a stand is observed at different times, the probabilistic distance indicates temporal change for each species. That is complementary to the transition matrix [12], because it characterizes the metastability of the system. Metastability of living systems is the condition to live and to change, until the death.

This principle is directly applicable to forests: a natural forest changes by the disappearing of some old trees and the germination of seeds. The probabilistic distance of all the species between two observations oscillates proportionally to the forest metastability.

When the forest is managed, some species are favored and other disappear. Then, the probabilistic distances will increase durably till the end of the crisis when a new equilibrium will appear. This may be illustrated by the "Russian hills" model [13] of a marble moving in a box, the bottom of which is undulated (Figure 1).

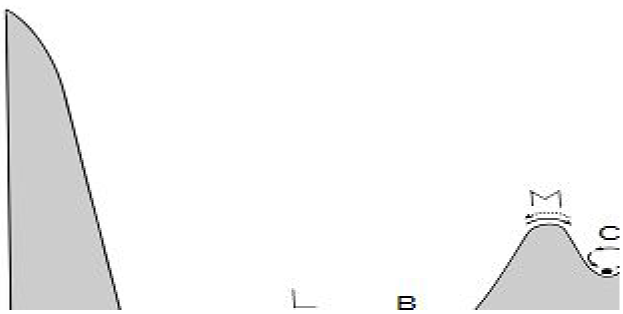

Figure 1: The "Russian hills" model of metastability for a biological system. When the box is shacked, the marble moves inside the troughs A, B, C, and D or moves from a trough to another. The summits L, M and N are unstable and have the two characters of a crisis (instability and also opportunity to find a new functioning).

The troughs of metastability A, B, C or D are named "well" or "attractor" in cybernetics, and the marble oscillates inside a well, as long as a big clash does not push it over one of the summits L, M or N. Then the system may go down in another well of metastable equilibrium. This possibility to go from an attractor to another was central in Evolution processes and in the genetic differentiation of species.

Natural forest is a deep well (for example the well D) where it stays for many centuries. The reason is that the natural regulations are well recorded in the trees' physiological memory. A managed forest is submitted to perturbations which are not foreseeable and the forest has more chances to escape out of the well and to go to a less metastable attractor.

A deep well is protected by two high summits and the system does not have many chances to come back after having escaped of it. For example, a species having the advantages of the strategy K [14] has a high metastability. If it escapes of the well where it lives because a too strong disturbance, it has a few chances to come back to the previous ecosystem.1

Mutual Information and Gradient Analysis

Brillouin's formula gives also a matrix of the mutual information between species, based on the probability for these species to live together. A cluster analysis, for example with the archipelago algorithm, shows the groups of species which live in the same ecological niche. The similarity of stands is also treated the same way.

The results are a precise complement to multivariate analysis and a help to gradient analysis. It has the great advantage to avoid any estimation bias because it is not inferential.

Conclusions

Brillouin's model is directly linked to the functioning of thermodynamic systems and gives a measure of information. For biologists, it helps to understand that life is a transmission of information regulating all vital processes. Brillouin's index is a no-bias non-inferential measure of information which is important for local and spatial biodiversity, and for a probabilistic distance which may be related to the metastability of forests.

Note: 1The economical system of European Union is also metastable, and the Brexit leaves very few chances for the United Kingdom to benefit again of the useful regulations of the European economic system.

References

1. Wilson IEO (1984) Biophilia, Cambridge : Harvard University Press.
2. Raunkiaer C (1918) Recherches statistiques sur les formations végétales. Det. KGL. Danske Vidensk Selskab. Biologische Meddeleiser 13: 11-78.
3. Raunkiaer C (1934) The life-forms of plants and statistical plant geography, Oxford.
4. Peet RK (1974) The measurement of species diversity. Ann Rev Ecol Systematics 5: 285-307.
5. Connell JH (1978) Diversity in tropical rain forests. Science 1999: 1302-1310.
6. Shannon CE, Weaver W (1949) The Mathematical Theory of Communication. Urbana.
7. May RM (1973) Stability and Complexity in Modern Ecosystems. Princeton, Princeton Univ. Press.
8. Boltzmann L (1896) Vorlesungen uber Gastheorie. Leipzig.
9. Brillouin L (1962) Science and Information. (2nd edition). New York.
10. Desabie J (1966) Théorie et pratique des sondages. Paris: Dunod.
11. Whittaker RH (1972) Evolution and Measurement of Species Diversity, Taxon 21: 213-251.
12. Godron M, Lepart J (1973) Sur la représentation de la dynamique de la végétation au moyen de matrices de succession. Sukzessionsforschung, Cramer, Vaduz: 269-287.
13. Godron M (2012a) Écologie et évolution du monde vivant (Vol. 1-La vie est une transmission d'information). Paris : Édition l' Harmattan.
14. Blondel J (1979) Biogéographie et écologie. Paris: Masson.

ISSN: 2638-0013