# 5. = HETEROTOPY REMASTERED WITH A QUANTITATIVE TOOL: THE CASE STUDY OF EUROPEAN BEECH (*FAGUS SYLVATICA* L. SUBSP. *SYLVATICA*) IN PENINSULAR ITALY AND SICILY

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The term "heterotopic" (from the Greek roots "*hetero*-" meaning "other" + "*topos*" meaning "place" = other place) was used for the first time in biology by Haeckel (1) to define a change in germ-layer origin of reproductive organs in animals. Later, it was applied to phytogeography by Jackson (2), referring to those plant populations found on soils apparently very different from those typically occurring across their distribution range. In Italy, Negri (3) was likely the first to use this term referring to European beech (*Fagus sylvatica* L. subsp. *sylvatica*) populations occurring at low altitude. Since then, most of the further Italian authors used the term "heterotopic" mainly referring to beech or other woody species (i.e. *Ilex aquifolium* L., *Quercus ilex* L.) populations occurring out of their common altitudinal range or, in a broader sense, growing out of their typical macroclimatic context. Indeed, as regards European beech populations in Italy, those occurring below 800 m a.s.l. have been generally considered as heterotopic (4), even though in many cases stands above 800 m a.s.l. were also termed as "heterotopic" (e.g. 5, 6).
Here, we highlight the need to quantify "heterotopy" and propose a standard method to test a reliable applicability of this concept. As model species, we selected the European beech in peninsular Italy and Sicily, primarily because this species is typically dominant in mountain woods in all the considered area and, historically, a number of stands have been reported as heterotopic in literature.
We checked 18 bibliographic references reporting 108 populations as heterotopic (sometimes not explicitly, but with related terms like extra-zonal). We also randomly generated 305 points falling within the polygons of natural potential vegetation (7) with *F. sylvatica*, as provided by http://www.va.minambiente.it/, and considered them as controls. Both controls and putatively heterotopic populations were georeferenced by means of a GIS software. Climatic and altitudinal data associated with the occurrence sites were extracted from the Worldclim database (www.worldclim.org). We obtained a data matrix (413 beech stands × 6 environmental variables) that was subjected to a cluster analysis applying as the distance measure the Euclidean Distance and as group linkage method the Group Average (UPGMA), following the methodology commonly used in vegetation studies.
Two main clusters were identified, with a dissimilarity index of 0.35. The first cluster is composed by all those populations (including some control points) located at an altitude ≤ 600 m a.s.l., whereas the second one includes all the remaining points. The former cluster is also characterized by those populations growing on stands with a higher mean annual temperature than the latter (t-test, difference between means = 4.09 °C, $p < 0.01$).
These results led us to define as "quantitatively heterotopic" in Italy those beech populations located at an altitude ≤ 600 m a.s.l., and with a mean annual temperature generally higher than 12 °C. They mainly occur on the Tyrrhenian side, namely in Tuscany and Lazio, marked by a high oceanicity.
Many of these populations are located outside of vegetation series with European beech and, among these, some are distant more than 20 km, so that they could be interpreted not only as heterotopic, but also as biogeographical-ecological relicts (8).
Our methodology could be applied to other species in order to quantify the level of heterotopy by defining ad hoc thresholds (if any), resulting from the multivariate analysis.

1) E. Haeckel (1866) Generelle Morphologie der Organismen. 2 vols. Berlin, Georg Reimer
2) B.D. Jackson (1900) A glossary of botanic terms, 1st edn. Duckworth, London
3) G. Negri (1928) Nuovo Giorn. Bot. Ital., n.s., 35, 298-299
4) S. Pignatti (1994) Ecologia del Paesaggio. UTET, Bologna.
5) A. Hofmann (1961) Delpinoa n.s., 3, 373-406
6) S. Sabbatini, F. Selvi, D. Viciani (2011) Forest@, 8, 88-102
7) R. Tüxen (1956) Angewandte Pflanzensoziologie, 13, 5-42
8) A. Aubréville (1970) Adansonia ser. 2, 10(4), 439-497