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# **A phytoclimatic methodology for evaluating the effects of climate change on the dynamics of *Pinus sylvestris* L. stands in the Mediterranean basin preliminary to definition of new adaptative management regimes**

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## **Abstract**

A phytoclimatic methodology was assayed to evaluate the possible effects of climate change on the composition and competitive capacity of *Pinus sylvestris* L. forests in the Mediterranean basin. The variation over time of the phytoclimatic suitability index of the main tree species present in a forest formation, and their relative values, are used to indicate the competitive hierarchy of *Pinus sylvestris* and other forest tree species, especially *Fagus sylvatica* L. The methodology is applied at a specific location: the Canfranc station, 1168m above sea level, on the south-facing slopes of the Pyrenees mountain range in the Iberian Peninsula. We have studied the evolution of the phytoclimatic suitability index over the period 1910-2008. The thermopluviometric values were calculated on the basis of 30-year mobile averages. In the period of observation at Canfranc station the increase in the average temperature was 1.4°C (from 7.9°C in the period 1910-1939 to 9.3 in the period 1979-2008). The results indicate that the situation of apparent balance between the two species studied seems to have started changing as from the 1951-1980 average, with gradual loss of competitive capacity of scots pine with respect to beech. This is indicated by the gradual fall in the phytoclimatic suitability index of the pine compared to the regularity of the values of the beech. The integrated phytoclimatic approach proposed here offers new methodological horizons for the study of the effects of climate change on stands of *Pinus sylvestris* in the mountains of the Iberian Peninsula preliminary to definition of different alternatives of forest management.

**Key words:** Biodiversity, suitability, competition

## **Introduction**

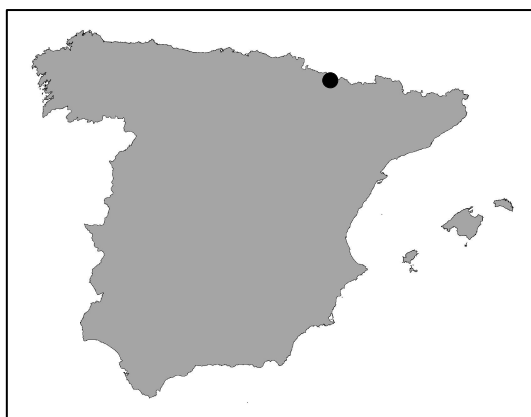
Biodiversity estimation has acquired increasing importance over the last few decades as a key tool for nature management. Aspects such as the evaluation of an area for the purpose of legal and administrative measures to protect it, assessment of the possible impacts of plans, programmes or projects, or the taking of decisions in the light of future uncertainties surrounding climate change, are all largely founded upon methodologies for the estimation of ecological diversity. Indeed, the effects of climate change on the diversity of plant covers and on internal competitive relationships among the principal species constituting those covers seems likely to be one of the priority lines of research in the future ((DAVIS *et al.*, 1998; PEARSON *et al.*, 2003; FERNÁNDEZ *et al.*, 2005). Effective conservation strategies that offset the climate change threats to species persistence will be critical in maintaining species and genetic diversity (KREMER, 2000; ARAÚJO & RAHBEK, 2006; BARNARD and THUILLER, 2008)

From a phytoclimatic standpoint the potential of an area of land to host different types of arboreal forest cover can be studied holistically using mathematical models to determine what principal species of a forest formation are compatible with that area, and also the degree of adjustment of each of these formations to the phytoclimatic environment at the station concerned (GUISAN and THUILLER, 2005).

This integrated phytoclimatic approach not only provides a means of determining the potential wealth of an area in terms of arboreal forest formations, assessed on the basis of the number of compatible principal species; in addition, by calculating numeric adjustment indicators it is possible to assess the capacity of the medium to host each forest formation, and from there to enter the complex universe of competitive relationships between species and between forest formations by comparing their relative degrees of adjustment. Plant species are limited not only by their absolute limits of survival but also through competition from other species, which might grow better in a given climate (MORIN and CHUINE, 2006; THUILLER *et al*, 2008; BASELGA and ARAÚJO, 2009). The importance of the competition factor in the distribution of plant species is such that according to some authors (WALTER, 1977), the natural limits of distribution of a species will occur where its ability to compete is so depleted by variable environmental conditions that it is supplanted by other species; generally speaking, ecological factors are only decisive at the absolute limits of distribution.

This paper reports the assay of a methodology that serves to assess the possible influence of future climate dynamics on the composition and structure of arboreal covers of *Pinus sylvestris* L. in the Mediterranean basin. The comparative variation over time of phytoclimatic suitability indices of *Pinus sylvestris* and other tree species present in forest formations serves as an indicator of the ability of these species to compete and hence of the foreseeable composition and structure of the forest mass and the vulnerability of scots pine to climate change, and is used in defining alternatives for future management of these pine stands.

The methodology has been put into practice at the Canfranc-Los Arañones weather station (AEMET nº 9198) located at an altitude of 1168 m in the Pyrenees (Huesca province), over a period stretching from 1910 to 2008. The dominant forest species is currently *Pinus sylvestris* with some *Fagus sylvatica* (figure 1).



**Figure 1: Situation of Canfranc-Los Arañones weather station**

## Material and methods

The phytoclimatic system used is based on the models of ALLUÉ-ANDRADE (1990 and 1997) as modified by GARCÍA-LÓPEZ and ALLUÉ CAMACHO (2003). This phytoclimatic system was chosen for the present study because at this time it is the only quantitative one—in other words it is possible not only to fit a station into a previously-defined phytoclimatic category in qualitative terms but also to quantify the adjustment of the station to that category or phytoclimatic type, and likewise all the other types in the system, using relative “*position coordinates*” and “*phytoclimatic distances*”, between these and relative to factorial phytoclimatic ambits.

As the principal species in the forest formation at the assay site, *Pinus sylvestris* and *Fagus sylvatica* were assigned an autecological factorial ambit based on the corresponding sampling points. According to GARCÍA-LÓPEZ and ALLUÉ CAMACHO (2003), the borderline of each ambit can be defined in very close correspondence with the cluster of points in 12-dimensional factorial hyperspace by calculating a convex envelope that will convert it to a hyperpolyhedron and can be projected on to planes formed by pairs of factors in order to perform the specific calculations for the phytoclimatic model. For reasons of space, readers are referred to [www.climatforest.com](http://www.climatforest.com) for articles explaining the theoretical basis of the models used.

By running diagnostics on a point with the autoecological phytoclimatic system constructed using the programme CLIMATFOREST 1.0 (GARCÍA-LÓPEZ and ALLUÉ CAMACHO, 2009), we can generate a diagnostic spectrum of the following type in abbreviated annotation:

$$(e_a.A; e_b.B)$$

where A and B are abbreviated codes for species whose phytoclimatic ambits, defined by the convex envelope, include the target point (*Pinus sylvestris* or *Fagus sylvatica*) and where  $e_a$  and  $e_b$  ( $\geq 0$  and  $\leq 1$ ) are scalars of the target station’s adjustment to the phytoclimatic ambit of species A and B, with  $e_a > e_b$  (GARCÍA-LÓPEZ and ALLUÉ CAMACHO, 2008). Each scalar functions as an index of relative phytoclimatic suitability of a forest species with respect to the optimum.

For the purposes of this article, “phytoclimatic suitability” (ALLUÉ CAMACHO, 1996) means the degree to which a site is suited to host certain taxa or syntaxa, principally in terms of staying power (self-regenerating capacity), ability to compete with other species and resistance to diseases.

**Table 2. Phytoclimatic factors used**

ABBREVIATION	FACTOR	UNIT
K	Intensity of aridity. Calculated on the basis of the quotient $A_s/A_h$ , where $A_h$ is the humid area of the climodiagram (Pi curve above the Ti curve, i.e., $2T_i < P_i$ ) and $A_s$ is the dry area of the climodiagram (Pi curve below the Ti curve, i.e., $2T_i > P_i$ ).	
A	Duration of aridity in the sense of GAUSSEN, that is the number of months in which the Ti curve is above the Pi curve, i.e., $2T_i > P_i$ .	months
P	Total annual precipitation	mm

<b>PE</b>	Minimum summer precipitation (June, July, August or September)	mm
<b>TMF</b>	Lowest monthly mean temperature	°C
<b>T</b>	Mean annual temperature	°C
<b>TMC</b>	Highest monthly mean temperature	°C
<b>TMMF</b>	Average of the minima of the month with the lowest mean temperature.	°C
<b>TMMC</b>	Average of the maxima of the month with the highest mean temperature.	°C
<b>HS</b>	Certainty of frost. Calculated as the number of months in which $T_i \geq 4^\circ\text{C}$	months
<b>PV</b>	Period of free plant activity, calculated as the number of months in which $T_i \geq 7.5^\circ\text{C}$ , not counting periods where $A > 0$	months
<b>OSC</b>	Thermal oscillation. Calculated as $TMC - TMF$	°C

In order to assess the phytoclimatic dynamics 30-year mobile averages were compiled following the recommendations of BRUNET *et al* (2008) to filter the natural climatic variability at the Canfranc-Los Arañones station over the period from 1910 to 2008.

**Table 2. Evolution of factorial values in 30-year mobile averages between 1910 and 2008 for the Canfranc-Los Arañones station**

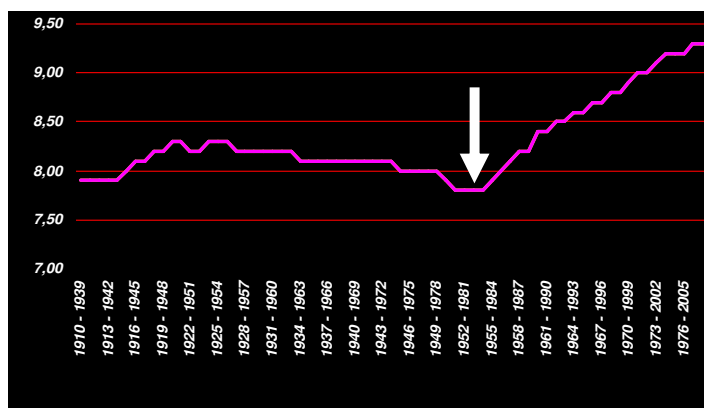
Period	K	A	P	PE	T	TMF	TMC	TMMF	TMMC	HS	PV	OSC
1910 - 1939	0.00	0.00	1698	76	7.90	1.30	16.20	-2.60	22.30	4.20	5.80	14.90
1911 - 1940	0.00	0.00	1662	74	7.90	1.20	16.30	-2.60	22.30	4.20	5.80	15.10
1912 - 1941	0.00	0.00	1646	71	7.90	1.10	16.10	-2.50	22.20	4.20	5.80	15.00
1913 - 1942	0.00	0.00	1649	70	7.90	0.90	16.30	-2.50	22.20	4.20	5.80	15.40
1914 - 1943	0.00	0.00	1630	74	7.90	1.00	16.30	-2.40	22.20	4.20	5.80	15.30
1915 - 1944	0.00	0.00	1605	72	8.00	1.20	16.50	-2.30	22.20	4.20	5.80	15.30
1916 - 1945	0.00	0.00	1571	71	8.10	1.20	16.40	-2.10	22.10	4.00	5.90	15.20
1917 - 1946	0.00	0.00	1544	69	8.10	1.00	16.40	-2.20	22.10	4.00	5.90	15.40
1918 - 1947	0.00	0.00	1552	71	8.20	1.10	16.50	-2.10	22.10	3.90	6.00	15.40
1919 - 1948	0.00	0.00	1544	71	8.20	1.20	16.50	-1.90	22.10	3.90	6.00	15.30
1920 - 1949	0.00	0.00	1504	66	8.30	1.30	16.50	-1.80	22.10	3.80	6.10	15.20
1921 - 1950	0.00	0.00	1492	67	8.30	1.30	16.60	-1.90	22.10	3.80	6.10	15.30
1922 - 1951	0.00	0.00	1515	66	8.20	1.20	16.60	-1.90	22.10	3.80	6.10	15.40
1923 - 1952	0.00	0.00	1517	69	8.20	1.10	16.60	-2.10	22.10	3.70	6.10	15.50
1924 - 1953	0.00	0.00	1490	61	8.30	1.10	16.60	-2.10	22.20	3.60	6.10	15.50
1925 - 1954	0.00	0.00	1483	62	8.30	1.00	16.70	-2.20	22.30	3.60	6.00	15.70
1926 - 1955	0.00	0.00	1495	58	8.30	1.00	16.60	-2.10	22.30	3.50	6.10	15.60
1927 - 1956	0.00	0.00	1474	61	8.20	0.90	16.50	-2.20	22.20	3.60	6.00	15.60
1928 - 1957	0.00	0.00	1460	58	8.20	0.90	16.60	-2.30	22.20	3.60	6.00	15.70
1929 - 1958	0.00	0.00	1463	59	8.20	0.80	16.50	-2.50	22.30	3.60	6.00	15.70
1930 - 1959	0.00	0.00	1464	58	8.20	0.80	16.50	-2.50	22.30	3.60	6.00	15.70
1931 - 1960	0.00	0.00	1478	62	8.20	0.70	16.50	-2.70	22.10	3.60	6.00	15.80
1932 - 1961	0.00	0.00	1484	64	8.20	0.70	16.60	-2.70	22.20	3.60	6.00	15.90
1933 - 1962	0.00	0.00	1490	60	8.20	0.70	16.60	-2.70	22.40	3.70	6.00	15.90
1934 - 1963	0.00	0.00	1533	64	8.10	0.50	16.60	-3.00	22.20	3.80	6.00	16.10
1935 - 1964	0.00	0.00	1558	66	8.10	0.50	16.60	-3.10	22.20	3.70	6.00	16.10
1936 - 1965	0.00	0.00	1580	66	8.10	0.50	16.50	-3.10	22.20	3.80	6.00	16.00
1937 - 1966	0.00	0.00	1609	65	8.10	0.50	16.50	-3.10	22.20	3.80	6.00	16.00
1938 - 1967	0.00	0.00	1591	65	8.10	0.60	16.60	-3.10	22.20	3.80	6.00	16.00
1939 - 1968	0.00	0.00	1622	67	8.10	0.60	16.60	-3.00	22.20	3.80	6.00	16.00

1940 - 1969	0.00	0.00	1661	69	8.10	0.60	16.60	-3.10	22.30	3.80	6.00	16.00
1941 - 1970	0.00	0.00	1677	69	8.10	0.70	16.70	-3.10	22.40	3.80	6.00	16.00
1942 - 1971	0.00	0.00	1699	71	8.10	0.80	16.60	-3.10	22.40	3.90	6.00	15.80
1943 - 1972	0.00	0.00	1710	72	8.10	0.80	16.60	-3.20	22.40	3.90	6.00	15.80
1944 - 1973	0.00	0.00	1715	72	8.10	0.70	16.60	-3.30	22.40	4.00	6.00	15.90
1945 - 1974	0.00	0.00	1739	73	8.00	0.60	16.60	-3.30	22.30	4.00	6.00	16.00
1946 - 1975	0.00	0.00	1750	74	8.00	0.90	16.60	-3.20	22.40	4.10	5.90	15.70
1947 - 1976	0.00	0.00	1772	78	8.00	0.90	16.60	-3.00	22.30	4.00	5.90	15.70
1948 - 1977	0.00	0.00	1780	81	8.00	1.00	16.50	-3.00	22.20	4.10	5.90	15.50
1949 - 1978	0.00	0.00	1807	82	8.00	1.00	16.60	-3.10	22.20	4.10	5.90	15.60
1950 - 1979	0.00	0.00	1862	84	7.90	0.90	16.40	-3.10	22.10	4.20	5.90	15.50
1951 - 1980	0.00	0.00	1874	82	7.80	0.80	16.40	-3.10	22.10	4.30	5.80	15.60
1952 - 1981	0.00	0.00	1890	85	7.80	0.90	16.30	-3.10	22.10	4.20	5.80	15.40
1953 - 1982	0.00	0.00	1883	86	7.80	1.00	16.30	-2.90	22.00	4.30	5.80	15.30
1954 - 1983	0.00	0.00	1900	87	7.80	1.00	16.30	-2.80	22.00	4.20	5.80	15.30
1955 - 1984	0.00	0.00	1920	86	7.90	1.00	16.40	-2.70	22.20	4.20	5.80	15.40
1956 - 1985	0.00	0.00	1915	85	8.00	1.20	16.50	-2.60	22.20	4.10	5.90	15.30
1957 - 1986	0.00	0.00	1920	82	8.10	1.50	16.60	-2.30	22.40	4.10	5.90	15.10
1958 - 1987	0.00	0.00	1944	89	8.20	1.50	16.60	-2.20	22.40	4.00	6.00	15.10
1959 - 1988	0.00	0.00	1944	88	8.20	1.50	16.70	-2.10	22.50	3.90	6.00	15.20
1960 - 1989	0.00	0.00	1930	89	8.40	1.60	16.80	-2.00	22.60	3.80	6.00	15.20
1961 - 1990	0.00	0.00	1893	85	8.40	1.90	16.90	-1.80	22.70	3.80	6.10	15.00
1962 - 1991	0.00	0.00	1876	86	8.50	1.80	16.90	-1.80	22.80	3.70	6.00	15.10
1963 - 1992	0.00	0.00	1882	86	8.50	1.90	17.00	-1.80	22.80	3.60	6.10	15.10
1964 - 1993	0.00	0.00	1849	81	8.60	2.10	17.00	-1.60	22.90	3.50	6.10	14.90
1965 - 1994	0.00	0.00	1854	79	8.60	2.10	17.10	-1.50	23.00	3.40	6.10	15.00
1966 - 1995	0.00	0.00	1845	78	8.70	2.30	17.20	-1.30	23.00	3.30	6.10	14.90
1967 - 1996	0.00	0.00	1836	80	8.70	2.20	17.30	-1.30	23.10	3.30	6.20	15.10
1968 - 1997	0.00	0.00	1852	88	8.80	2.40	17.20	-1.10	23.00	3.20	6.20	14.80
1969 - 1998	0.00	0.00	1848	86	8.80	2.50	17.30	-1.00	23.10	3.10	6.20	14.80
1970 - 1999	0.00	0.00	1850	90	8.90	2.50	17.40	-1.00	23.20	3.00	6.20	14.90
1971 - 2000	0.00	0.00	1872	91	9.00	2.50	17.40	-1.00	23.20	2.90	6.20	14.90
1972 - 2001	0.00	0.00	1868	92	9.00	2.60	17.50	-0.80	23.30	2.80	6.20	14.90
1973 - 2002	0.00	0.00	1875	92	9.10	2.70	17.50	-0.70	23.30	2.70	6.20	14.80
1974 - 2003	0.00	0.00	1897	90	9.20	2.80	17.60	-0.60	23.40	2.70	6.20	14.80
1975 - 2004	0.00	0.00	1880	90	9.20	2.80	17.70	-0.50	23.40	2.70	6.30	14.90
1976 - 2005	0.00	0.00	1877	91	9.20	2.70	17.70	-0.60	23.40	2.70	6.30	15.00
1977 - 2006	0.00	0.00	1883	91	9.30	2.60	17.60	-0.70	23.40	2.70	6.30	15.00
1978 - 2007	0.00	0.00	1876	85	9.30	2.70	17.70	-0.60	23.50	2.70	6.40	15.00
1979 - 2008	0.00	0.00	1866	85	9.30	2.90	17.80	-0.50	23.60	2.70	6.40	14.90

From table 2, which shows the evolution of factorial values in 30-year mobile averages between 1910 and 2008 for the Canfranc-Los Arañones station, we can see that precipitations are relatively stable but there is a clear increase in temperatures based on the mobile averages starting in the 1950s (figure 2).

The mean annual temperature (T) in particular increased by 1.4°C between the first (1910-1939) and the last mobile average (1979-2008), and the average of minimum temperatures (TMMF) increased by 2.1°C in the same period. Also, the duration of the period with certainty of frosts (HS) declined by 1.5 months and the period of free plant activity (PV) increased by 0.6 months.

Figure 2 shows an example of trends for the factor T (mean annual temperature).



**Figure 1: Evolution of mean annual temperature (T) in °C at Canfranc station in 30-year mobile averages between 1910 and 2008.**

## Results

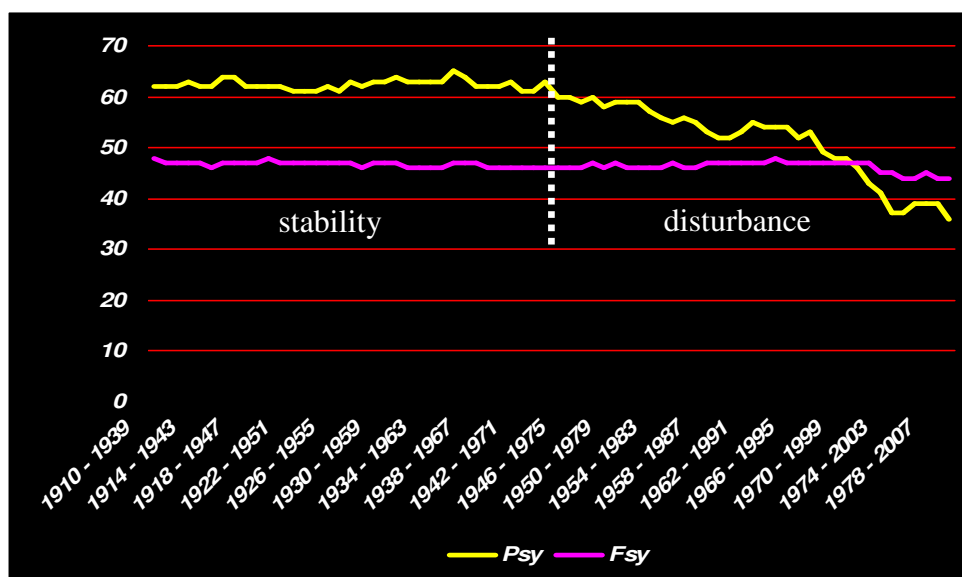
The phytoclimatic diagnostic model was applied to the set of factorial variables in table 2 to generate the diagnostic grid, which shows the scalars of adjustment of each mobile average to each of the two factorial ambits corresponding to *Pinus sylvestris* and *Fagus sylvatica* respectively (table 3).

**Table 3. Suitability indices of *Pinus sylvestris* and *Fagus sylvatica* at the Canfranc-Los Arañones station in 30-year mobile averages between 1910 and 2008**

Period	Psy	Fsy	Period	Psy	Fsy	Period	Psy	Fsy
1910 - 1939	0.62	0.48	1933 - 1962	0.63	0.46	1956 - 1985	0.56	0.46
1911 - 1940	0.62	0.47	1934 - 1963	0.63	0.46	1957 - 1986	0.55	0.46
1912 - 1941	0.62	0.47	1935 - 1964	0.63	0.46	1958 - 1987	0.53	0.47
1913 - 1942	0.63	0.47	1936 - 1965	0.65	0.47	1959 - 1988	0.52	0.47
1914 - 1943	0.62	0.47	1937 - 1966	0.64	0.47	1960 - 1989	0.52	0.47
1915 - 1944	0.62	0.46	1938 - 1967	0.62	0.47	1961 - 1990	0.53	0.47
1916 - 1945	0.64	0.47	1939 - 1968	0.62	0.46	1962 - 1991	0.55	0.47
1917 - 1946	0.64	0.47	1940 - 1969	0.62	0.46	1963 - 1992	0.54	0.47
1918 - 1947	0.62	0.47	1941 - 1970	0.63	0.46	1964 - 1993	0.54	0.48
1919 - 1948	0.62	0.47	1942 - 1971	0.61	0.46	1965 - 1994	0.54	0.47
1920 - 1949	0.62	0.48	1943 - 1972	0.61	0.46	1966 - 1995	0.52	0.47
1921 - 1950	0.62	0.47	1944 - 1973	0.63	0.46	1967 - 1996	0.53	0.47
1922 - 1951	0.61	0.47	1945 - 1974	0.60	0.46	1968 - 1997	0.49	0.47
1923 - 1952	0.61	0.47	1946 - 1975	0.60	0.46	1969 - 1998	0.48	0.47
1924 - 1953	0.61	0.47	1947 - 1976	0.59	0.46	1970 - 1999	0.48	0.47
1925 - 1954	0.62	0.47	1948 - 1977	0.60	0.47	1971 - 2000	0.46	0.47
1926 - 1955	0.61	0.47	1949 - 1978	0.58	0.46	1972 - 2001	0.43	0.47
1927 - 1956	0.63	0.47	1950 - 1979	0.59	0.47	1973 - 2002	0.41	0.45

1928 - 1957	0.62	0.46	1951 - 1980	0.59	0.46	1974 - 2003	0.37	0.45
1929 - 1958	0.63	0.47	1952 - 1981	0.59	0.46	1975 - 2004	0.37	0.44
1930 - 1959	0.63	0.47	1953 - 1982	0.57	0.46	1976 - 2005	0.39	0.44
1931 - 1960	0.64	0.47	1954 - 1983	0.56	0.46	1977 - 2006	0.39	0.45
1932 - 1961	0.63	0.46	1955 - 1984	0.55	0.47	1978 - 2007	0.39	0.44
						1979 - 2008	0.36	0.44

See figure 3 for a graphic view of the results in table 3. Starting from the 1945-1976 average there is a gradual decline in the adjustment of the station to the pines, that is in the suitability index of *Pinus sylvestris* for this formation, while the index for the beeches tends to remain stable or decline slightly.



**Figure 3: Comparative evolution of suitability indices of *Pinus sylvestris* (Psy) and *Fagus sylvatica* (Fsy)**

## Discussion

From the results it would appear that the apparent stability between the two target species began to break down commencing with the 1951-1980 period, the pine gradually losing ability to compete with the beech in terms of phytoclimatic suitability.

This scenario of decline is chiefly due to the fact that the pine's adjustment to the station changed more than the beech's. The results indicate that whereas *Fagus sylvatica* presents relatively stable suitability indices and hence also ability to compete throughout the period considered, the index for *Pinus sylvestris* is in constant decline roughly commencing with the 1951-1980 mobile average. From that point on this difference in the behaviour of the two species produces a breakdown of the competitive balance in the forest formation, which is actually inverted starting with the 1970-1999 average, since when the beeches have presented greater suitability than the pines.



This development is quite consistent with the phytoclimatic temperament of the two species. The needle-leaf strategies characteristic of *Pinus sylvestris* are the outcome of adaptation to severe winter cold, long periods of certain frost and short periods of plant activity (WALTER, 1977), all of which deteriorated in the period considered for the pines, depleting its ability to compete with the beeches, which have adjusted more successfully.

This paper opens up new methodological horizons for the study of climate change effects on the composition and adaptation of forest ecosystems to that change. Such a study needs to be accompanied by improvements in techniques for generating future climatic scenarios so that this methodology can be used to make medium- and long-term estimations.

With this methodology it will be possible to interpret estimations of future changes in temperature and precipitation more efficiently and translate them into plant language, in the form of quantifications of the hosting capacities of environment and the competitive relationships between the principal species in the formation. All this will make it possible to perfect the mechanisms used to make assessments and take preventive and adaptative decisions in future scenarios of phytoclimatic uncertainty and thus achieve progress in some of the priority lines of research in this field (GRACIA *et al.*, 2005).

However, there are some important issues affecting the interpretation of the results and future forecasts. One of these is the difference in the abilities of pines and beeches to adapt to the new climatic conditions and the possibility of a change in their competitive behaviour. Some authors (WOODWARD, 1990; THOMAS *et al.*, 2001) have asserted that the study of that ability to adapt and its influence on patterns of competition and tolerance will be an essential line of research for the future.

In addition to these limitations we should cite the reservations expressed by PEARSON & DAWSON (2003) regarding the construction of base ambits of existence in studies of this kind since all the possible situations for each species are not taken into account when constructing factorial spaces, particularly in such spoiled forest environments as are found in the Mediterranean basin.

Phytoclimatic shifts may create new environments comprised of factorial combinations of conditions that did not previously occur and this problem is potentially common in projections of species distribution models (WILLIAMS *et al.*, 2007). Forecasting future distributions or suitabilities of species from current species-climate relationships is problematic because the observed distribution of a species alone provides no information about how the species might respond under novel environments (FITZPATRICK and HARGROVE, 2009).

Finally, we would stress the importance of further elaborating this methodology in the future so that the model takes into consideration more tree species that are compatible with the station and thus provides a more comprehensive picture than the one offered in this paper.

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