**Supplementary Material**

**Table S1** Characteristics of the studied sites where tree-ring width chronologies were obtained: coordinates, number of sampled trees and studied cores, diameter at breast height (Dbh), mean tree-ring width (TRW) and standard deviation, and mean sensitivity (MSx, a measure of the relative variability in width between consecutive rings)..

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Site name** | **ID chrono** | **Latitude (N)** | **Longitude (W/E)** | **Altitud****(m a.s.l)** | **No. trees** | **No. cores** | **1st year of record** | **Last year of record** | **Reliable period** | **Dbh (cm)** | **Tree height (m)** | **TRW (mm)** | **Age at 1.3 m (years)** | **MSx** |
| Gerber  | GER | 42° 37' 11.96" N | 0° 58' 47.97" | 2268 | 41 | 79 | 1270 | 2010 | 1423-2010 | 53.5 ± 14.6 | 6.9 ± 1.4 | 0.59 ± 0.26 | 426 ± 147 | 0.12 |
| Amitges  | AMI | 42° 36' 00" N | 0° 58' 48" | 2390 | 25 | 56 | 1592 | 2009 | 1665-2009 | 69.0 ± 26.0 | 9.3 ± 3.8 | 0.83 ± 0.33 | 355 ± 106 | 0.15 |
| Mirador | MIR | 42° 34' 48" N | 0° 58' 48" | 2180 | 33 | 85 | 1390 | 2009 | 1596-2009 | 55.1 ± 25.8 | 7.6 ± 2.3 | 0.59 ± 0.32 | 401 ± 132 | 0.16 |
| Ratera  | RAT | 42º 35' 24'' N | 1º 00' 00'' | 2300 | 10 | 20 | 1699 | 1999 | 1800-1999 | 46.9 ± 20.4 | 9.6 ± 2.3 | 0.88 ± 0.48 | 196 ± 71 | 0.14 |
| Sant Maurici | SMA | 42° 34' 48" N | 0° 58' 48" E | 1933 | 20 | 40 | 1811 | 1996 | 1819-1996 | 38.2 ± 5.7 | 13.7 ± 1.7 | 0.94 ± 0.68 | 204 ± 23 | 0.18 |
| Estany Llong | LLO | 42°34' 00” N | 0°56’ 00” E | 2323 | 7 | 10 | 1644 | 2011 | 1700-2011 | 64.7 ± 21.6 | 7.5 ± 1.1 | 0.91 ± 0.22 | 272 ± 73 | 0.15 |
| Dellui-Corticelles. Boí | COR | 42º 33' 59.22” N | 0º 56' 59.86” E | 2210 | 21 | 42 | 1509 | 1995 | 1560-1995 | 81.2 ± 28.8 | 10.1 ± 3.63 | 0.67 ± 0.32 | 293 ± 96 | 0.19 |
| Monestero | MON | 42° 33' 36" N | 0° 58' 48" E | 2280 | 30 | 76 | 1481 | 2009 | 1691-2009 | 64.4 ± 16.1 | 9.3 ± 2.1 | 0.92 ± 0.50 | 346 ± 110 | 0.12 |
| Tessó de Son | TESS | 42° 34' 48" N | 1° 1' 48" E | 2239 | 10 | 17 | 1537 | 1995 | 1773-1995 | 74.5 ± 18.8 | 9.3 ± 3.8 | 0.88 ± 0.38 | 346 ± 202 | 0.12 |
| Airoto | AIR | 42° 42' 00" N | 1° 1' 48" E | 2300 | 16 | 31 | 1651 | 1996 | 1748-1996 | 58.5 ± 13.5 | 7.4 ± 1.6 | 1.02 ± 0.35 | 288 ± 100 | 0.14 |
| Barranc de Llacs | BAR | 42° 31' 48" N | 0° 55' 12" E | 2250 | 17 | 17 | 1338 | 1997 | 1548-1997 | 71.7 ± 20.0 | 10.5 ± 2.5 | 0.59 ± 0.29 | 616 ± 175 | 0.11 |
| Mata de València | MAT | 42° 37' 48" N | 1° 4' 12" E | 2019 | 10 | 20 | 1678 | 1997 | 1785-1997 | 43.2 ± 3.6 | 9.8 ± 1.8 | 0.92 ± 0.51 | 237 ± 72 | 0.18 |
| Estany Negre | NEG | 42° 33' 00" N | 1° 1' 48" E | 2451 | 46 | 86 | 1393 | 2009 | 1652-2009 | 71.0 ± 26.0 | 6.6 ± 1.9 | 0.74 ± 0.33 | 411 ± 182 | 0.14 |
| Estany de Lladres | LLAD | 42° 33' 00" N | 1° 3' 00" E | 2120 | 36 | 74 | 1390 | 2009 | 1390-2009 | 52.1 ± 9.8 | 8.3 ± 1.6 | 0.80 ± 0.40 | 313 ± 123 | 0.13 |
| Vall de Conangles | CON | 42º 37' 59.36” N | 00º 44' 59.93” E | 2160 | 19 | 32 | 1537 | 1994 | 1590-1994 | 60.9 ± 12.2 | 7.7 ± 3.3 | 0.86 ± 0.44 | 237 ± 83 | 0.19 |
| Vall de Mulleres | MUL | 42° 37' 12" N | 0° 43' 12" E | 1800 | 12 | 23 | 1476 | 1994 | 1816-1994 | 69.0 ± 26.0 | 9.8 ± 1.8 | 0.77 ± 0.37 | 437 ± 184 | 0.14 |
| Portell | POR | 42º 30’ 59.72” N | 0º 45’ 0.14” E | 2199 | 32 | 76 | 1730 | 2006 | 1760-2006 | 32.0 ± 15.2 | 10.2 ± 3.1 | 0.98 ± 0.39 | 176 ± 67 | 0.14 |
| Bielsa (boca sur del túnel) | BIE | 42º 43' 00" N | 00º 11' 45'' E | 1890 | 11 | 21 | 1707 | 1996 | 1785-1996 | 45.6 ± 9.7 | 8.0 ± 3.1 | 0.78 ± 0.29 | 221± 37 | 0.26 |
| Las Cutas | CUT | 42º 37' 05'' | 00º 11' 24'' W | 2080 | 23 | 42 | 1763 | 1998 | 1820-1998 | 40.4 ± 12.6 | 11.0 ± 2.65 | 1.12 ± 0.57 | 123± 28 | 0.17 |

**Table S2** SignificantSpearman correlations calculated between pollen of the Bassa Nera pond and residual tree-ring width chronologies from nearby forests. Only significant correlations (p < 0.05) are shown.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Gerber** | **Amitges** | **Portell** | **Barranc dels Llacs** | **Vall de Mulleres** | **Lladres** | **Airoto** | **Conangles** | **Coticelles**  | **Mirador** | **Monestero** | **Mata de València** | **Negre** | **Ratera** | **Sant Maurici** | **Tessó de Son** | **Bielsa** | **Cutas** | **Llong** |
| Montane ratio | 0.526 | 0.561 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Abies* |  |  |  |  |  |  |  |  |  |  |  | 0.088 |  |  |  |  |  |  |  |
| *Alnus* | 0.383 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Artemisia* |  |  |  |  |  |  |  |  | -0.482 |  |  |  |  |  |  |  |  |  |  |
| Asteraceae fenest. |  |  |  |  | 0.486 | 0.478 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Asteraceae non fenest |  |  |  |  |  |  |  |  |  |  |  |  |  | -0.928 |  |  |  |  |  |
| Chenopodicaceae/ Amarantaceae |  |  |  |  |  |  |  |  |  |  | 0.474 |  |  |  |  |  |  |  |  |
| *Corylus* | 0.376 |  |  |  |  |  |  |  |  | 0.472 |  |  |  |  |  |  |  |  |  |
| Ericaceae |  |  |  |  |  | -0.574 |  | -0.542 |  |  |  | -0.288 |  |  |  |  |  |  |  |
| Evergreen *Quercus* |  |  | 0.654 | 0.438 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.622 |
| *Fagus* | 0.393 |  |  |  |  |  |  | 0.587 |  | 0.443 |  |  |  |  | -0.886 |  |  |  |  |
| *Fraxinus* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | -0.550 |  |  |  |
| *Galium* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | -0.740 |  |  |
| *Helianthemum* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | -0.895 |  |
| *Juglans* |  |  |  |  |  |  | -0.620 |  |  |  |  |  |  |  |  |  |  |  |  |
| *Olea* |  |  |  |  |  |  |  | -0.492 |  |  |  |  |  |  |  |  |  |  |  |
| *Parnassia* |  |  |  |  | -0.478 |  |  |  |  |  |  | -0.478 |  |  |  |  |  |  |  |
| *Plantago* |  |  |  | -0.403 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | -0.604 |
| *Potentilla* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | -0.645 |  |  |
| *Rumex* |  |  |  |  |  |  |  | 0.584 |  |  |  |  |  |  |  |  |  |  |  |
| *Sanguisorba* | -0.466 |  | -0.620 |  |  |  |  |  |  | -0.436 | -0.696 |  |  |  |  |  |  |  | -0.602 |
| *Secale* | 0.498 |  |  |  |  |  |  |  | -0.407 |  |  |  |  |  |  |  |  |  |  |
| *Tilia* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | -0.497 |  |  |  |
| *Urtica* |  |  |  |  |  |  | -0.577 |  |  |  |  |  | -0.477 |  |  |  |  |  |  |

**Table** **S3.** Spearman rank correlation values (rho) calculated between the montane pollen ratio, different pollen taxa and residual tree-ring width chronologies from forests located near the Bassa Nera pond site. The distance to the pollen site (Bassa Nera pond) and the elevation are indicated for each forest where tree-ring width chronologies were developed (first and second rows, respectively).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Gerber** (5.04 km)(2268 m) | **Amitges** (6.42 km)(2390 m) | **Mirador** (7.83 km)(2180 m) | **Ratera** (7.95 km)(2170 m) | **Sant Maurici** (7.95 km)(1933 m) |
|  | rho | *p* | rho | *p* | rho | *p* | rho | *p* | rho | *p* |
| Montane ratio | 0.526 | 0.002 | 0.561 | 0.032 |  |  |  |  |  |  |
| *Alnus* | 0.383 | 0.034 |  |  |   |   |   |   |   |   |
| Asteraceae non fenestrate |    |   |  |  |   |   | -0.928 | 0.008 |   |   |
| *Corylus* | 0.376 | 0.037 |  |  | 0.472 | 0.023 |   |   |   |   |
| *Fagus* | 0.393 | 0.028 |  |  | 0.443 | 0.034 |   |   | -0.886 | 0.033 |
| *Sanguisorba* | -0.466 | 0.008 |  |  | -0.436 | 0.038 |   |   |   |   |
| *Secale* | 0.498 | 0.004 |  |  |  |   |   |   |   |   |

**Table S4.** Pearson correlations calculated between the montane pollen ratio of Bassa Nera pond (BSN) and residual tree-ring width chronologies. Asterisks indicate correlations values with p < 0.05. Bielsa and Las Cutas forests are far locations added as a control for the mountain-subalpine ratio response. Correlations significant at the 0.05 level are indicated with asterisks.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Forest site** | **Distance to BSN pond (km)** | **Altitude** (m a.s.l) | **Aspect** | **Pearson correlation** | **No. samples used to calibrate pollen and tree-ring width data** | **Period** |
| ***r*** | ***p-value*** |
| Gerber | 5.04 | 2268 | W | 0.459\* | 0.009 | 31 | 1286-1968 |
| Amitges | 6.42 | 2390 | S-E | 0.627\* | 0.012 | 15 | 1624-1968 |
| Mirador | 7.83 | 2180 | SE | 0.360 | 0.091 | 23 | 1417-1968 |
| Ratera | 7.95 | 2170 | N | 0.136 | 0.796 | 6 | 1825-1968 |
| Sant Maurici  | 7.95 | 1933 | S-SE | -0.472 | 0.344 | 6 | 1825-1968 |
| Llong | 8.2 | 2323 | W-NW | -0.078 | 0.791 | 14 | 1658-1968 |
| Corticelles  | 8.61 | 2269 | W-NW | -0.073 | 0.727 | 25 | 1378-1968 |
| Monestero  | 9.76 | 2280  | SE | 0.134 | 0.584 | 19 | 1493-1968 |
| Tessó de Son  | 10.83 | 2239 | N-NE | 0.117 | 0.654 | 17 | 1556-1968 |
| Airoto | 11.03 | 2300 | W | 0.440 | 0.131 | 13 | 1679-1968 |
| Barranc dels Llacs | 11.72 | 2250 | N-NW | 0.188 | 0.345 | 27 | 1349-1968 |
| Mata de València  | 11.73 | 2019 | N-NW | -0.098 | 0.566 | 13 | 1679-1968 |
| Negre | 13.04 | 2451 | SE | 0.217 | 0.319 | 23 | 1417-1968 |
| Lladres | 14.19 | 2120 | NW | 0.122 | 0.578 | 23 | 1417-1968 |
| Conangles  | 14.27 | 2106 | S-SW | 0.051 | 0.838 | 18 | 1528-1968 |
| Vall de Mulleres | 16.83 | 1800 | N-NE | -0.098 | 0.687 | 19 | 1493-1968 |
| Portell | 19.56 | 2199 | W | 0.271 | 0.369 | 13 | 1679-1968 |
| Bielsa | 60.47 | 1890 | E | -0.259 | 0.440 | 11 | 1727-1968 |
| Las Cutas  | 91.74 | 2080 | S-SW | 0.086 | 0.824 | 9 | 1769-1968 |

**Figure S1**. Annual mean temperature and total precipitation covering the period 1901-2010. Monthly CRU mean temperature and the total precipitation were rescaled using local data from the Estany de Sant Maurici local weather station.

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