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Genetic variability of a scattered temperate forest tree: Sorbus torminalis L. (Crantz)

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Abstract – Genetic variation has been assessed in 73 (mostly French) populations of the wild service tree (*Sorbus torminalis*) using 15 isozymes loci. In spite of a relatively high coefficient of genetic differentiation among populations ($F_{ST} = 15\%$), only a weak geographical structure was detected. This may be explained by the small size and young age of the populations due to the importance of founder effects, combined with the high levels of seed flow among populations. These features are typical of species characterised by metapopulation dynamics.

genetic diversity / differentiation / metapopulation / Rosaceae / spatial structure

Résumé – Variabilité génétique d'une espèce forestière disséminée : *Sorbus torminalis* L. (Crantz). De nombreuses études se sont intéressées à la diversité génétique des plantes rares, menacées de disparition, ou à celles largement répandues qui présentent un grand intérêt économique. Par contre, le cas des espèces ayant une aire de répartition importante mais présentant des densités faibles reste peu abordé, en particulier chez les arbres forestiers. Dans les forêts tempérées, les arbres forestiers disséminés occupent une place secondaire. L'alisier torminal (*Sorbus torminalis*) est une espèce fruitière disséminée au comportement post-pionnier nomade. Ses graines sont dispersées par les oiseaux. 67 populations françaises et 6 populations d'Europe centrale ont été étudiées à l'aide des isozymes. Une forte différentiation entre populations a été trouvée ($F_{ST} = 15$ %), combinée à une faible structuration géographique. Ceci peut s'expliquer par les effets de fondation importants liés au comportement écologique de l'espèce, et aux flux de graines entre populations éloignées, liés à la dissémination par des oiseaux. Le modèle en métapopulation, avec des populations subissant des phénomènes de colonisation et d'extinction, mais restant interconnectées par des flux de gènes, semble particulièrement bien s'appliquer à cette espèce. Au vu de ces résultats, une gestion permettant l'implantation de l'alisier dans de nouveaux sites pouvant recevoir des flux de gènes des populations préexistantes doit être encouragée.

Rosaceae / diversité génétique / métapopulation / differentiation / structure spatiale

1. INTRODUCTION

Since the development of isozyme markers, thousands of population genetic studies of wild plants, including a large proportion dealing with forest trees, have been carried out either in temperate or in tropical regions. These studies have pointed out the importance of the size of the geographic range of the species for predicting levels and organisation of genetic diversity: in general, species with widespread distributions maintain higher levels of genetic diversity at allozyme loci than species with narrow or endemic distribution [10,

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11, 32]. Similarly, allozyme surveys have shown that geographically restricted species that are locally abundant contain fewer polymorphic loci and a lower mean number of alleles per locus than widespread congeneric species [14, 15]. The importance of the size of the population has also been investigated for a more limited number of plant species. These studies have shown that common species with large population sizes are more variable than rare species [37]. However, little is known about trees with widespread distribution but having low population densities, i.e. between 0.1 and 30 adults by hectare. This lack of knowledge is due first to the low economic impact of these species compared to social forest trees such as Quercus spp. or Picea abies in Europe and second to the difficulty to inventory them. Yet the scattered trees contribute to increase the biodiversity of the forest, by their presence but also because many animal species rely on them.

Nevertheless, some results concerning genetic diversity of disseminated trees based on enzymes have started to appear recently both in temperate countries [22, 30, 33, 40] as well as in tropical ones [4, 15, 37]. These species generally show lower genetic diversity than widespread species. But comparisons with more abundant species are difficult, because sampling of scattered species often involves few populations with limited sample sizes per population. Here, we present the results of an investigation of the genetic variability of a scattered tree species, the wild service tree, Sorbus torminalis (L.) Crantz, based on an intensive sampling of populations in France. This member of the Rosaceae family is one of the most economically important wild fruit trees in Europe. It is a scattered species (0.1 to 30 adults per hectare) which never occurs in pure populations. It grows on all types of soils. It is a post-pioneer tree that colonises disturbed areas and forest edges. Although the trees are generally overgrown by more competitive species such as Quercus or Fagus [5], individual trees can be very valuable when they benefit from good soil and light conditions. Sorbus torminalis is a diploid species (2n = 34) according to Liljefors [20]. This species is insect pollinated and the seeds are dispersed by birds. A recent study on Sorbus commixta in Japan [45] reports that extraction of seeds from the pulp is necessary for their germination. Sorbus torminalis is also able to propagate asexually through the production of suckers. The natural distribution of Sorbus torminalis is rather large, from the north of Magrehb to the south of Sweden and from the east of Great Britain to the north of Iran. It grows mostly in lowlands. In France, the most important populations of Sorbus torminalis are located in the south-west and in the north-east of the country. Hybridisation with other Sorbus species, especially with *Sorbus aria*, another diploid species, is considered to be frequent in Europe [9].

2. MATERIALS AND METHODS

2.1. Materials

Sixty seven indigenous populations of Sorbus torminalis were sampled in France (figure 1). The collection also included six populations originating from other countries in Europe: Slovakia (3 populations), Slovenia, Bulgaria, and Switzerland (one population each) (table I). A population sample consists of dormant buds from at least 11 mature trees or young stems separated from each other by at least 50 m (to avoid sampling the same clone) on an area of 20 to 50 ha. In such conditions the sampling of individuals may or not be exhaustive, depending on the local density. To allow comparisons among regions, French populations were grouped according to their geographical proximity. Several geographical clustering of populations were tested. The results of gene diversity and differentiation were very similar. The final choice (eight groups) resulted from a compromise between homogeneous number of populations per group and geographical proximity (figure 1).



Fig.1. Geographical distribution of populations of *Sorbus torminalis*. Populations were clustered in 8 groups according to their geographical proximity. Symbols for the groups are group 1 \blacksquare , group 2 \bigtriangledown , group 3 \bullet , group 4 \diamond , group 5 \star , group 6 \bigcirc , group 7 \blacktriangle , group 8 \thickapprox .

Table I. Geographic origin, and genetic diversity estimates and inbreeding coefficient (based on 15 allozyme loci) for 73 populations of *Sorbus torminalis*. $N_{\rm a}$, number of alleles per locus; $H_{\rm o}$, observed heterozygosity; $H_{\rm e}$, expected heterozygosity; $F_{\rm IS}$, heterozygote deficit.

Assence 06*45E 48*07N 8 21 1.600 0.16 0.151 0.232 Auhay 00*28E 46*07N 4 19 1733 0.105 0.175 0.023 Avants Monts 02*1E 43*26N 5 12 1.333 0.105 0.175 0.257 Boir ogue 07*13F 48*24N 3 18 1.667 0.130 0.175 0.253 Bouclogne 00*25F 47*48N 7 20 1.800 0.126 0.135 0.067 Bracome 00*20'W 46*30'N 4 20 1.600 0.149 0.169 0.173 0.33 Darges Indication 01*22'F 49*01'N 8 14 1.733 0.137 0.120 0.000 0.100 0.160 0.000 0.100 0.118 Byrans wir Doub 05*37'S'S'S'S'S'S'S'S'S'S'S'S'S'S'S'S'S'S'S	Populations	Longitude	Lattitude	Groups	Sample size	N _a	$H_{\rm o}$	H _e	$F_{\rm IS}$
Aulnay 00°28'E 46°00'N 4 19 1.733 0.175 0.179 0.028 Belléme 00°31'E 48°24'N 3 11 1.533 0.100 0.080 -0.250 Bercé 00°31'E 48°24'N 3 18 1.667 0.130 0.175 0.237 Bois rogue 00°13'W 46°59'N 4 20 1.600 0.149 0.166 0.135 0.0173 0.333 Bourdogne 00°25'E 47°48'N 6 18 1.600 0.149 0.166 0.118 Braconne 00°20'W 46°30'N 4 20 1.533 0.135 0.153 0.118 Bracone 06°25'E 43°38'N 6 20 1.533 0.135 0.153 0.118 Charve Chave 03°32'E 46°01'N 8 14 1.733 0.137 0.230 0.421 Charve Chave 00°37'W 46°35'N 4 20 1.733 0.137 0.	Assenoncourt	06°45'E	48°47'N	8	21	1.600	0.116	0.151	0.232
Avants Monts 02°41E 43°26'N 5 12 1.333 0.100 0.080 -0.250 Belléne 00°31E 48°24'N 3 11 1.533 0.145 0.164 0.116 Bourd gue 00°13'W 46°39'N 4 20 1.600 0.105 0.173 0.233 Bourd gue 00°23'E 47°48'N 7 20 1.800 0.116 0.133 0.007 Braconne 00°20'W 46°30'N 4 20 1.600 0.149 0.160 0.135 0.067 Capiters 06°25'E 43°38'N 6 20 1.533 0.135 0.133 0.130 0.120 -0.067 Charices 04°37'E 46°0N 7 19 1.667 0.16 0.150 0.202 0.0119 Charices 04°37E 46°33'N 4 20 1.733 0.137 0.186 0.202 0.041 Charices 04°37E 46°33'N 4 20 </td <td>Aulnay</td> <td>00°28'E</td> <td>46°00'N</td> <td>4</td> <td>19</td> <td>1.733</td> <td>0.175</td> <td>0.179</td> <td>0.022</td>	Aulnay	00°28'E	46°00'N	4	19	1.733	0.175	0.179	0.022
Belléme 00°31E 48°24N 3 11 1.533 0.145 0.164 0.1175 0.257 Bois rogue 00°13'W 46°59N 4 20 1.600 0.103 0.175 0.237 Bourdogne 00°25E 47°48N 7 20 1.800 0.157 0.197 0.203 Bourdogne 00°25E 47°05N 8 19 1.533 0.128 0.120 -0.067 Camjuers 06°25E 43°38N 6 20 1.533 0.135 0.153 0.118 Charve Chave 03°22E 46°00N 7 19 1.667 0.116 0.150 0.227 Charve Chave 03°22E 46°00N 7 19 1.667 0.116 0.150 0.227 Charices 04°57E 49°1N 4 20 1.733 0.137 0.200 0.312 Charices 00°217W 46°35N 4 20 1.633 0.146 0.262 0.313	Avants Monts	02°41'E	43°26'N	5	12	1.333	0.100	0.080	-0.250
Bercé 05°02E 45°08N 3 18 1.667 0.130 0.175 0.037 Bourlogne 00°25E 47°48N 7 20 1.600 0.105 0.173 0.393 Bourlogne 00°25E 47°48N 7 20 1.800 0.157 0.173 0.203 Bracome 00°20W 46°30N 4 20 1.600 0.149 0.160 0.113 0.135 0.057 Canjuers 06°25E 43°38N 6 20 1.533 0.128 0.120 -0.007 Charices 04°37E 46°01N 7 19 1.667 0.116 0.150 0.020 0.070 Charices 04°37E 46°33N 4 20 1.733 0.137 0.186 0.202 0.312 Chizé 00°17W 46°33N 4 20 1.630 0.143 0.152 0.639 Chizé 00°17W 46°33N 2 1.667 0.143 0.146 </td <td>Bellême</td> <td>00°31'E</td> <td>48°24'N</td> <td>3</td> <td>11</td> <td>1.533</td> <td>0.145</td> <td>0.164</td> <td>0.116</td>	Bellême	00°31'E	48°24'N	3	11	1.533	0.145	0.164	0.116
Boix rogue 00°137W 46°59'N 4 20 1.600 0.105 0.173 0.203 Bourdogne 00°25'E 47'48'N 7 20 1.800 0.157 0.197 0.203 Braconne 00°20'W 46°30'N 4 20 1.600 0.149 0.169 0.118 Byans sur le Doubs 05°49'E 47'05'N 8 19 1.533 0.132 0.128 0.120 -0.067 Canjuers 06°25'E 49'01'N 1 20 1.800 0.116 0.150 0.227 Charrie 06°25'E 49'01'N 1 20 1.800 0.116 0.150 0.227 Charrie 04°57'E 49'01'N 8 14 1.733 0.137 0.186 0.200 0.070 Charve Chave 04°57'E 49'01'N 8 14 1.733 0.137 0.186 0.263 Chizé 00°17'W 46°35'N 4 20 1.733 0.137 0.186 0.263 Chizé 00°17'W 46°35'N 4 20 1.733 0.137 0.186 0.263 Chizé 00°17'W 46°35'N 4 20 1.733 0.137 0.230 0.404 Chocurs Bommiers 02'00'E 46°51'N 2 211 1.600 0.143 0.452 0.059 Chizé 00°12'E 45'32'N 4 20 1.600 0.113 0.146 0.226 Charve Cocidentales 04'47'E 49'18'N 1 20 1.600 0.113 0.146 0.226 Charve No 20'02'E 45'32'N 4 20 1.600 0.113 0.146 0.226 Charve 01'21'W 47'53'N 3 20 1.667 0.143 0.152 0.059 Chizé 00'12'E 45'32'N 4 20 1.600 0.113 0.146 0.226 Charve 01'23'E 48'46'N 2 20 1.667 0.123 0.161 0.113 Croix aux bois 04'47'E 49'18'N 1 20 1.533 0.107 0.127 0.157 Crugny 0.3'44'E 49'18'N 1 20 1.533 0.142 0.160 0.113 Croix aux bois 04'47'E 49'18'N 1 20 1.667 0.123 0.161 0.174 Groigens 02'43'E 48'50'N 2 26 1.660 0.120 0.164 0.268 Fontainebleau 02'37'E 48'55'N 2 18 1.447 0.095 0.093 -0.022 Garva 01'23'E 48'24'N 6 19 1.600 0.126 0.122 -0.033 Gardiale' 00'20'E 46'59'N 4 21 1.600 0.169 0.0126 0.122 -0.033 Gardiale' 00'20'E 44'2'1'N 3 20 1.667 0.144 0.170 0.153 Gardiale' 00'20'E 44'2'1'N 3 20 1.667 0.144 0.170 0.153 Gardiale' 01'50'W 47'3'1'N 3 20 1.667 0.143 0.168 0.048 Gurs 00'4'8'W 43'5'5'N 5 15 1.667 0.144 0.170 0.153 Gursen 01'4'4'E 44'0'2'N 5 15 1.667 0.144 0.170 0.153 Gursen 01'4'4'E 44'0'2'N 5 15 1.667 0.144 0.170 0.422 -0.038 Gursen 00'4'8'W 43'5'5'N 5 15 1.667 0.144 0.156 0.077 Guerse 01'4'4'W 45'2'N 3 20 1.667 0.133 0.168 0.208 Gursen 00'4'8'W 43'5'5'N 5 15 1.667 0.144 0.156 0.077 Gursen 00'0'W 45'1'N 4 12 0.1600 0.137 0.132 0.166 0.0137 Gursen 00'0'W 45'1'N 45 12 1.667 0.153 0.173 0.104 Huer froudent 00'0'2'E 47'5'5'N 8 12 1	Bercé	05°02'E	45°08'N	3	18	1.667	0.130	0.175	0.257
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Bourg St Andéol 04"34"E 44"25"N 6 18 1.600 0.126 0.135 0.067 Braconne 00"20"W 46"30"N 4 20 1.600 0.126 0.128 0.120 -0.067 Canjuers 06"25E 47"38"N 6 20 1.533 0.135 0.153 0.170 Charve Chave 03"22"E 46"00"N 7 19 1.667 0.116 0.150 0.227 Charve Chave 03"22"E 46"00"N 7 19 1.667 0.116 0.150 0.227 Charve Chave 03"22"E 46"35"N 4 20 1.733 0.137 0.186 0.260 Charve Chave 03"22"E 46"35"N 4 20 1.733 0.137 0.186 0.260 Charve Chave 03"20"E 46"35"N 4 20 1.733 0.137 0.230 0.404 Chours Bommiers 02"00"E 46"35"N 4 20 1.600 0.143 0.152 0.059 Chizé 00"17"W 46"03"N 4 20 1.600 0.143 0.152 0.059 Chizé 00"17"W 46"37N 4 20 1.600 0.143 0.152 0.059 Chizé 00"17"W 46"31"N 4 20 1.533 0.142 0.160 0.113 Croix aux bois 04"47"E 49"18"N 1 20 1.533 0.142 0.160 0.113 Croix aux bois 04"47"E 49"16"N 1 19 1.467 0.123 0.146 0.226 Chizé 01"2"E 45"32"N 4 20 1.667 0.143 0.146 0.226 Chizé 02"17"E 43"02"N 5 23 1.733 0.142 0.160 0.113 Croix aux bois 04"47"E 49"16"N 1 19 1.467 0.123 0.147 0.163 Dreux 01"23"E 48"46"N 2 20 1.667 0.133 0.161 0.174 Ferrières 02"48"E 48"50"N 2 26 1.660 0.120 0.164 0.268 Sontanant 02"08"E 49"49"N 1 22 1.667 0.133 0.161 0.174 Ferrières 02"48"E 48"50"N 2 16 1.600 0.120 0.164 0.268 Gardiole 05"4"E 49"49"N 1 22 1.667 0.157 0.152 -0.122 Gardiole 05"4"E 49"49"N 3 20 1.667 0.155 0.181 0.144 Grand Vallon 06"04"E 44"1"N 6 13 1.460 0.015 0.181 0.144 Grand Vallon 06"04"E 44"1"N 6 13 1.460 0.0155 0.181 0.144 Harth 0.0723"E 47"46"N 8 20 1.600 0.126 0.152 -0.113 Grésigne 01"44"E 44"02"N 5 15 1.667 0.197 0.168 0.048 Gouffern 01"60"W 47"31"N 3 20 1.667 0.157 0.168 0.048 Gouffern 01"60"W 47"31"N 3 20 1.667 0.157 0.168 0.048 Gouffern 01"4W 47"52"N 3 20 1.733 0.147 0.142 -0.035 Harth 00"3"E 47"44"N 4 20 1.733 0.147 0.142 -0.035 Harth 00"3"E 47"44"N 4 20 1.600 0.103 0.144 0.228 Harth 00"3"E 47"44"N 4 20 1.600 0.104 0.144 0.170 Harcin 01"4"E 47"20"N 5 15 1.660 0.131 0.168 0.208 Harth 00"3"E 46"3"N 4 21 1.600 0.104 0.144 0.224 Harth 00"3"E 46"3"N 4 21 1.600 0.104 0.144 0.234 Harth 00"3"E 46"3"N 4 21 1.667 0.153 0.168 0.203 Kareje de Chalais 00"0"E 44"2"N	Bourdogne	00°25'E	47°48'N	7	20	1.800	0.157	0.197	0.203
$\begin{array}{rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr$	Bourg St Andéol	04°34'E	44°25'N	6	18	1.600	0.126	0.135	0.067
Byans ur le Doubs 06°49E 47°05N 8 19 1.533 0.128 0.120 -0.067 Canjuers 06°25E 43°38N 6 20 1.533 0.135 0.153 0.116 0.100 Charve Chave 03°22E 46°00N 7 19 1.667 0.116 0.150 0.217 Charve Chave 03°22E 46°30N 4 20 1.733 0.137 0.186 0.203 0.404 Chizé 00°17W 46°33N 4 20 1.733 0.137 0.186 0.262 0.312 Chouanière 01°21W 47°53N 3 20 1.667 0.143 0.152 0.050 Craix 00°02E 45°32N 4 20 1.533 0.147 0.163 0.146 0.226 Craix ax bois 04°47E 49°16N 1 19 1.467 0.123 0.147 0.163 Grainale 02°37E 48°25N 2 1.667 0.13	Braconne	00°20'W	46°30'N	4	20	1.600	0.149	0.169	0.118
$\begin{array}{c} Canjuers & 06^{\circ}25^{\circ}E & 43^{\circ}38^{\circ}N & 6 & 20 & 1.533 & 0.135 & 0.153 & 0.118 \\ Chantilly & 02^{\circ}29^{\circ}E & 49^{\circ}10^{\circ}N & 1 & 20 & 1.800 & 0.186 & 0.200 & 0.070 \\ Charve Chave & 03^{\circ}22^{\circ}E & 49^{\circ}10^{\circ}N & 8 & 14 & 1.733 & 0.177 & 0.201 & 0.119 \\ Chillou & 00^{\circ}39^{\circ}E & 49^{\circ}01^{\circ}N & 8 & 14 & 1.733 & 0.137 & 0.186 & 0.260 \\ Choilou & 00^{\circ}39^{\circ}E & 49^{\circ}01^{\circ}N & 4 & 20 & 1.733 & 0.137 & 0.186 & 0.260 \\ Chocurs Bommiers & 02^{\circ}00^{\circ}E & 46^{\circ}35^{\circ}N & 4 & 20 & 1.733 & 0.137 & 0.186 & 0.260 \\ Chocurs Bommiers & 01^{\circ}21^{\circ}W & 47^{\circ}53^{\circ}N & 3 & 20 & 1.667 & 0.143 & 0.152 & 0.059 \\ Claix & 00^{\circ}02^{\circ}E & 43^{\circ}02^{\circ}N & 5 & 23 & 1.733 & 0.142 & 0.160 & 0.113 \\ Croix aux bois & 04^{\circ}47^{\circ}E & 43^{\circ}02^{\circ}N & 5 & 23 & 1.733 & 0.142 & 0.160 & 0.113 \\ Croix aux bois & 04^{\circ}47^{\circ}E & 49^{\circ}16^{\circ}N & 1 & 20 & 1.533 & 0.107 & 0.127 & 0.157 \\ Crugny & 03^{\circ}44^{\circ}E & 49^{\circ}16^{\circ}N & 1 & 20 & 1.667 & 0.123 & 0.147 & 0.163 \\ Dreux & 01^{\circ}23^{\circ}E & 48^{\circ}25^{\circ}N & 2 & 26 & 1.660 & 0.120 & 0.164 & 0.268 \\ Fontainebleau & 02^{\circ}37^{\circ}E & 48^{\circ}25^{\circ}N & 2 & 26 & 1.660 & 0.120 & 0.164 & 0.268 \\ Gatinalib^{\circ} & 03^{\circ}44^{\circ}E & 49^{\circ}49^{\circ}N & 1 & 22 & 1.667 & 0.144 & 0.170 & 0.153 \\ Gatinalib^{\circ} & 03^{\circ}44^{\circ}E & 43^{\circ}34^{\circ}N & 6 & 19 & 1.600 & 0.166 & 0.126 & -0.012 \\ Goiverne & 01^{\circ}50^{\circ}W & 47^{\circ}31^{\circ}N & 3 & 20 & 1.667 & 0.157 & 0.165 & 0.048 \\ Gouffern & 00^{\circ}01^{\circ}W & 47^{\circ}31^{\circ}N & 3 & 20 & 1.667 & 0.157 & 0.165 & 0.048 \\ Guarderhe & 01^{\circ}50^{\circ}W & 47^{\circ}31^{\circ}N & 3 & 20 & 1.667 & 0.157 & 0.165 & 0.048 \\ Guarden & 00^{\circ}04^{\circ}E & 47^{\circ}25^{\circ}N & 8 & 12 & 1.533 & 0.142 & 0.100 & 0.175 \\ Gaivene & 01^{\circ}50^{\circ}W & 47^{\circ}31^{\circ}N & 3 & 20 & 1.667 & 0.157 & 0.165 & 0.048 \\ Guarden & 01^{\circ}64^{\circ}E & 47^{\circ}46^{\circ}N & 8 & 20 & 1.800 & 0.234 & 0.223 & -0.049 \\ Harh & 07^{\circ}23^{\circ}E & 47^{\circ}57N & 8 & 12 & 1.600 & 0.162 & 0.012 \\ Harh & 07^{\circ}23^{\circ}E & 47^{\circ}57N & 8 & 12 & 1.600 & 0.132 & 0.144 & 0.256 \\ Harh & 01^{\circ}52^{\circ}E & 47^{\circ}56N & 5 & 12 & 1.600 & 0.133 & 0.144 & 0.256 \\ Harh & 01^{\circ}52^{$	Byans sur le Doubs	05°49'E	47°05'N	8	19	1.533	0.128	0.120	-0.067
$\begin{array}{c} \mbox{Chantilly} & 02"29E & 49"10N & 1 & 20 & 1.800 & 0.186 & 0.200 & 0.070 \\ Charve Ch$	Canjuers	06°25'E	43°38'N	6	20	1.533	0.135	0.153	0.118
$\begin{array}{c} \mbox{Charve Chave } 03^{+}22E & 46^{\circ}00N & 7 & 19 & 1.667 & 0.116 & 0.150 & 0.227 \\ \mbox{Charlices } 04^{+}57E & 49^{\circ}01N & 8 & 14 & 1.733 & 0.177 & 0.201 & 0.119 \\ \mbox{Chillou } 00^{\circ}39FE & 46^{\circ}35N & 4 & 20 & 1.733 & 0.137 & 0.186 & 0.263 \\ \mbox{Chocurs Bommiers } 02^{\circ}00E & 46^{\circ}51N & 2 & 21 & 1.600 & 0.139 & 0.202 & 0.312 \\ \mbox{Chocurs Bommiers } 01^{\circ}21W & 47^{\circ}53N & 3 & 20 & 1.667 & 0.143 & 0.152 & 0.059 \\ \mbox{Chocurs Bommiers } 01^{\circ}21W & 47^{\circ}53N & 3 & 20 & 1.667 & 0.143 & 0.152 & 0.059 \\ \mbox{Croix aux bois } 00^{\circ}02E & 45^{\circ}32N & 4 & 20 & 1.533 & 0.142 & 0.166 & 0.113 \\ \mbox{Croix aux bois } 02^{\circ}17E & 43^{\circ}02N & 5 & 23 & 1.733 & 0.142 & 0.160 & 0.113 \\ \mbox{Croix aux bois } 01^{\circ}23FE & 48^{\circ}6N & 2 & 20 & 1.667 & 0.133 & 0.161 & 0.174 \\ \mbox{Croix aux bois } 01^{\circ}23FE & 48^{\circ}5N & 2 & 26 & 1.600 & 0.120 & 0.164 & 0.268 \\ \mbox{Ferrières } 02^{\circ}43E & 48^{\circ}5N & 2 & 26 & 1.600 & 0.120 & 0.164 & 0.268 \\ \mbox{Forsimant } 02^{\circ}37E & 48^{\circ}25N & 4 & 21 & 1.667 & 0.144 & 0.170 & 0.153 \\ \mbox{Gatinalize } 00^{\circ}20E & 46^{\circ}59N & 4 & 21 & 1.600 & 0.169 & 0.152 & -0.012 \\ \mbox{Gatinalize } 01^{\circ}20W & 47^{\circ}31N & 3 & 20 & 1.667 & 0.157 & 0.165 & 0.048 \\ \mbox{Garder } 01^{\circ}50W & 47^{\circ}31N & 3 & 20 & 1.600 & 0.155 & 0.181 & 0.144 \\ \mbox{Grand Vallon } 06^{\circ}04E & 44^{\circ}1N & 6 & 13 & 1.467 & 0.082 & 0.119 & 0.311 \\ \mbox{Grise } 01^{\circ}44E & 44^{\circ}02N & 5 & 15 & 1.600 & 0.132 & 0.166 & 0.708 \\ \mbox{Gurse } 01^{\circ}44E & 44^{\circ}02N & 5 & 15 & 1.600 & 0.132 & 0.168 & 0.208 \\ \mbox{Gurse } 00^{\circ}04W & 43^{\circ}15N & 5 & 15 & 1.600 & 0.132 & 0.168 & 0.208 \\ \mbox{Gurse } 00^{\circ}04W & 43^{\circ}15N & 5 & 15 & 1.600 & 0.132 & 0.168 & 0.208 \\ \mbox{Gurse } 00^{\circ}04W & 43^{\circ}15N & 5 & 15 & 1.600 & 0.132 & 0.168 & 0.208 \\ \mbox{Gurse } 00^{\circ}04W & 43^{\circ}15N & 5 & 15 & 1.600 & 0.132 & 0.168 & 0.208 \\ \mbox{Gurse } 00^{\circ}04W & 43^{\circ}15N & 5 & 12 & 1.600 & 0.162 & 0.103 & 0.144 & 0.268 \\ \mbox{Gurse } 00^{\circ}04W & 43^{\circ}15N & 5 & 15 & 1.600 & 0.162 & 0.104 & 0.025 \\ \mbox{Gurse } 00^{\circ}04W & 4$	Chantilly	02°29'E	49°10'N	1	20	1.800	0.186	0.200	0.070
$\begin{array}{llllllllllllllllllllllllllllllllllll$	Charve Chave	03°22'E	46°00'N	7	19	1.667	0.116	0.150	0.227
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Chatrices	04°57'E	49°01'N	8	14	1.733	0.177	0.201	0.119
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Chillou	00°39'E	46°35'N	4	20	1.733	0.137	0.186	0.263
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Chizé	00°17'W	46°03'N	4	20	1.733	0.137	0.230	0.404
$\begin{array}{ccccc} Chouanière & 01^\circ 21^\circ W & 47^\circ 53^\circ N & 3 & 20 & 1.667 & 0.143 & 0.152 & 0.059 \\ Claix & 00^\circ 02^\circ E & 45^\circ 32^\circ N & 4 & 20 & 1.600 & 0.113 & 0.146 & 0.226 \\ Corbieres Occidentales & 02^\circ 17^\circ E & 43^\circ 02^\circ N & 5 & 23 & 1.733 & 0.142 & 0.160 & 0.113 \\ Croix aux bois & 04^\circ 47^\circ E & 49^\circ 18^\circ N & 1 & 20 & 1.533 & 0.107 & 0.127 & 0.157 \\ Crugny & 03^\circ 44^\circ E & 49^\circ 16^\circ N & 1 & 19 & 1.467 & 0.123 & 0.147 & 0.163 \\ Dreux & 01^\circ 23^\circ E & 48^\circ 50^\circ N & 2 & 26 & 1.600 & 0.120 & 0.164 & 0.268 \\ Fontainebleau & 02^\circ 37^\circ E & 48^\circ 25^\circ N & 2 & 26 & 1.600 & 0.120 & 0.164 & 0.268 \\ Gatianlière & 02^\circ 34^\circ E & 49^\circ 49^\circ N & 1 & 22 & 1.667 & 0.144 & 0.170 & 0.153 \\ Gardiole & 05^\circ 41^\circ E & 43^\circ 34^\circ N & 6 & 19 & 1.600 & 0.126 & 0.122 & -0.033 \\ Gatianlière & 00^\circ 20^\circ E & 46^\circ 59^\circ N & 4 & 21 & 1.600 & 0.169 & 0.152 & -0.112 \\ Gàvre & 01^\circ 50^\circ W & 47^\circ 31^\circ N & 3 & 20 & 1.667 & 0.157 & 0.165 & 0.048 \\ Gouffern & 00^\circ 01^\circ W & 48^\circ 49^\circ N & 3 & 20 & 1.800 & 0.155 & 0.181 & 0.144 \\ Grand Vallon & 06^\circ 04^\circ E & 44^\circ 11^\circ N & 6 & 13 & 1.467 & 0.082 & 0.119 & 0.311 \\ Gésigne & 01^\circ 44^\circ E & 44^\circ 11^\circ N & 5 & 15 & 1.600 & 0.132 & 0.160 & 0.175 \\ Guerche & 01^\circ 14^\circ W & 47^\circ 52^\circ N & 3 & 20 & 1.733 & 0.147 & 0.142 & -0.035 \\ Harb & 07^\circ 23^\circ E & 47^\circ 46^\circ N & 8 & 20 & 1.800 & 0.234 & 0.223 & -0.049 \\ Hez Froidemont & 02^\circ 16^\circ E & 49^\circ 24^\circ N & 5 & 12 & 1.667 & 0.129 & 0.143 & 0.098 \\ Harb & 07^\circ 23^\circ E & 47^\circ 35^\circ N & 8 & 12 & 1.533 & 0.147 & 0.142 & -0.035 \\ Hospice de Chalais & 00^\circ 04^\circ W & 45^\circ 14^\circ N & 8 & 22 & 1.667 & 0.144 & 0.188 & 0.208 \\ Infré & 01^\circ 28^\circ W & 48^\circ 13^\circ N & 3 & 20 & 1.667 & 0.133 & 0.144 & 0.285 \\ Malmifait & 01^\circ 56^\circ E & 49^\circ 35^\circ N & 1 & 20 & 1.600 & 0.144 & 0.185 & 0.077 \\ Mareuil & 00^\circ 31^\circ E & 46^\circ 37^\circ N & 8 & 12 & 1.667 & 0.144 & 0.188 & 0.209 \\ Ic Plan & 01^\circ 05^\circ E & 46^\circ 37^\circ N & 4 & 22 & 1.667 & 0.144 & 0.142 & -0.085 \\ Pleumartin & 00^\circ 52^\circ E & 46^\circ 37^\circ N & 4 & 22 & 1.667 & 0.144 & 0.197 & 0.269 \\ Nareuil & 00^\circ 91^\circ E & 46^\circ 37^\circ N & 4 & 22 & 1.667 & 0.144 & 0.197 & 0.269 \\ $	Choeurs Bommiers	02°00'E	46°51'N	2	21	1.600	0.139	0.202	0.312
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Chouanière	01°21'W	47°53'N	3	20	1.667	0.143	0.152	0.059
$\begin{array}{c} Corbières Occidentales \\ Corbières Occidentales \\ O2°17E 43°02N 5 23 1.733 0.142 0.160 0.113 \\ Croix aux bois \\ O4'47E 49°18N 1 20 1.533 0.107 0.127 0.157 \\ Crugny 03°44F 49°16N 1 19 1.467 0.123 0.147 0.163 \\ Dreux 01°23E 48°46N 2 20 1.667 0.133 0.161 0.174 \\ Ferrières 02°43TE 48°50N 2 26 1.600 0.120 0.164 0.268 \\ Fontainebleau 02°37E 48°25N 2 18 1.447 0.095 0.093 -0.022 \\ Fossemanant 02°08E 49°49N 1 22 1.667 0.144 0.170 0.153 \\ Gardiole 05°41E 43°34N 6 19 1.600 0.169 0.152 -0.013 \\ Gardiole 05°41E 43°34N 6 19 1.600 0.169 0.152 -0.013 \\ Gardialère 00°20E 46°59N 4 21 1.600 0.169 0.152 -0.012 \\ Gåvre 01°50W 47°31N 3 20 1.667 0.157 0.165 0.048 \\ Gouffern 00°01W 48°49N 3 20 1.800 0.155 0.181 0.144 \\ Grand Vallon 06°04E 44°11N 6 13 1.467 0.082 0.119 0.311 \\ Grésigne 01°44E 44°02N 5 15 1.600 0.132 0.160 0.175 \\ Guerche 01°14W 47°52N 3 20 1.733 0.133 0.168 0.208 \\ Gurs 00°48W 43°15N 5 15 1.667 0.129 0.143 0.098 \\ Harth 07°23E 47°46N 8 20 1.800 0.234 0.223 -0.049 \\ Hez Froidemont 02°16E 49°24N 1 20 1.733 0.133 0.168 0.208 \\ Gurs 00°44E 44°14N 4 20 1.667 0.129 0.143 0.098 \\ Harth 07°23E 47°46N 8 12 1.533 0.162 0.144 0.012 \\ Hospice de Chalais 00°04W 45°4N 4 20 1.600 0.137 0.132 -0.038 \\ Hurecourt 06°02E 47°55N 8 12 1.533 0.162 0.164 0.012 \\ Le Plan 01°56E 49°38N 5 12 1.600 0.0137 0.132 -0.038 \\ Hurecourt 06°02E 47°25N 8 12 1.533 0.162 0.164 0.012 \\ Le Plan 01°05E 43°08N 5 12 1.600 0.0137 0.132 -0.038 \\ Hurecourt 06°02E 47°25N 8 12 1.533 0.162 0.164 0.012 \\ Le Plan 01°057E 43°08N 5 12 1.600 0.0137 0.132 -0.038 \\ Hurecourt 06°02E 47°25N 8 12 1.533 0.162 0.164 0.012 \\ Le Plan 01°057E 43°08N 5 12 1.600 0.137 0.132 -0.038 \\ Hardh 01°25E 49°35N 1 20 1.667 0.103 0.144 0.285 \\ Malmifait 01°56E 49°35N 1 20 1.667 0.103 0.144 0.285 \\ Malmifait 01°56E 49°35N 1 20 1.667 0.103 0.144 0.285 \\ Malmifait 01°56E 49°35N 1 20 1.667 0.103 0.144 0.285 \\ Malmifait 01°56E 49°35N 1 20 1.667 0.154 0.164 -0.018 \\ Mareuil 00°31E 46°34N 4 17 1.733 0.160 0.122 0.166 0.077 \\ Mareuil 00°32E 46°49N 4 19 1.667 0.221 0.186 -0.188 \\ Mancles t Anour $	Claix	00°02'E	45°32'N	4	20	1.600	0.113	0.146	0.226
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Corbières Occidentales	02°17'E	43°02'N	5	23	1 733	0.142	0.160	0.113
Crugny $03^{\circ}44^{\circ}E$ $49^{\circ}16^{\circ}N$ 119 1.467 0.123 0.147 0.163 Dreux $01^{\circ}23^{\circ}E$ $48^{\circ}26^{\circ}N$ 220 1.667 0.133 0.161 0.174 Ferrières $02^{\circ}37^{\circ}E$ $48^{\circ}25^{\circ}N$ 218 1.447 0.095 0.093 -0.022 Fontainebleau $02^{\circ}37^{\circ}E$ $48^{\circ}25^{\circ}N$ 218 1.447 0.095 0.093 -0.022 Fossemanant $02^{\circ}08^{\circ}E$ $49^{\circ}49^{\circ}N$ 122 1.667 0.144 0.170 0.153 Gariole $05^{\circ}41^{\circ}E$ $43^{\circ}34^{\circ}N$ 619 1.600 0.166 0.152 -0.112 Gavre $01^{\circ}50^{\circ}W$ $47^{\circ}31^{\circ}N$ 320 1.667 0.157 0.165 0.048 Gouffern $00^{\circ}01^{\circ}W$ $48^{\circ}49^{\circ}N$ 320 1.667 0.152 0.113 0.168 0.208 Guerche $01^{\circ}14^{\circ}W$ $47^{\circ}52^{\circ}N$ 320 1.667 0.122 0.033 0.168 0.208 Guers $00^{\circ}04^{\circ}W$ $43^{\circ}15^{\circ}N$ 515 1.667 0.122 0.143 0.098 Harth $07^{\circ}23^{\circ}E$ $47^{\circ}6^{\circ}N$ 820 1.733 0.137 0.142 -0.038 Horeourt $06^{\circ}02^{\circ}E$ $47^{\circ}26^{\circ}N$ 812 1.667 0.144 0.142 -0.038 Ibe s/le Doubs $06^{\circ}34^{\circ}E$ $47^{\circ}26^{\circ}N$ 812	Croix aux bois	04°47'E	49°18'N	1	20	1.533	0.107	0.127	0.157
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Crugny	03°44'E	49°16'N	1	19	1.467	0.123	0.147	0.163
Ferrières $02^{+}32^{+}$ $48^{+}50N$ 2 26^{-} 1.600 0.120 0.164 0.268 Fontainebleau $02^{+}37^{-}$ $48^{+}25^{+}N$ 2 18 1.447 0.095 0.093 -0.022 Fossemanant $02^{+}08^{+}$ $48^{+}25^{+}N$ 2 1.667 0.144 0.170 0.153 Gardiole $05^{+}41^{+}E$ $43^{+}34^{+}N$ 6 19 1.600 0.126 0.122 -0.033 Gatinalière $00^{+}20^{+}E$ $46^{+}59^{+}N$ 4 21 1.667 0.157 0.165 0.048 Gouffern $00^{+}01^{+}W$ $47^{+}31^{+}N$ 3 20 1.800 0.155 0.181 0.144 Grand Vallon $06^{+}04^{+}E$ $44^{+}01^{+}N$ 6 13 1.467 0.082 0.119 0.311 Grard Vallon $06^{+}04^{+}E$ $44^{+}02^{+}N$ 5 15 1.600 0.132 0.160 0.175 Guerche $01^{+}14^{+}W$ $47^{+}52^{+}N$ 3 20 1.733 0.133 0.168 0.208 Gurs $00^{+}48^{+}W$ $43^{+}15^{+}N$ 5 15 1.667 0.129 0.143 0.098 Harth $07^{-}23^{+}E$ $47^{+}6^{+}N$ 8 20 1.800 0.324 0.223 -0.034 Harth $07^{+}275^{+}N$ 8 12 1.533 0.162 0.164 0.122 Hospice de Chalais $00^{+}04^{+}H^{+}N$ 4 20 1.667 0.1	Dreux	01°23'E	48°46'N	2	20	1 667	0.133	0.161	0 174
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Ferrières	02°43'E	48°50'N	2	26	1.600	0.120	0.164	0.268
Normatic $0^{\circ}0^{\circ}8^{\circ}E$ $49^{\circ}49^{\circ}N$ 1221.6670.1440.1700.152Gardiole $05^{\circ}41^{\circ}E$ $43^{\circ}34^{\circ}N$ 6191.6000.1260.122-0.033Gatinalière $00^{\circ}20^{\circ}E$ $46^{\circ}59^{\circ}N$ 4211.6000.1690.152-0.112Gàvre $01^{\circ}50^{\circ}W$ $47^{\circ}31^{\circ}N$ 3201.6670.1570.1650.048Gouffern $00^{\circ}01^{\circ}W$ $48^{\circ}49^{\circ}N$ 3201.8000.1550.1810.144Grand Vallon $06^{\circ}04^{\circ}E$ $44^{\circ}11^{\circ}N$ 6131.4670.0820.1190.311Grésigne $01^{\circ}44^{\circ}E$ $44^{\circ}02^{\circ}N$ 5151.66070.1290.1430.098Gurs $00^{\circ}48^{\circ}W$ $43^{\circ}15^{\circ}N$ 5151.6670.1290.1430.098Harth $07^{\circ}23^{\circ}E$ $47^{\circ}46^{\circ}N$ 8201.8000.2340.223-0.049Hez Froidemont $02^{\circ}16^{\circ}E$ $49^{\circ}24^{\circ}N$ 4201.6600.1370.132-0.038Hurecourt $06^{\circ}02^{\circ}E$ $47^{\circ}25^{\circ}N$ 8121.5330.1620.1640.012Is le lo Dubs $06^{\circ}34^{\circ}E$ $47^{\circ}26^{\circ}N$ 8121.6670.1440.1880.250Le Plan $01^{\circ}05^{\circ}E$ $49^{\circ}35^{\circ}N$ 1201.6670.1440.1860.293Liffré $01^{\circ}25^{\circ}E$ $49^{\circ}35^{$	Fontainebleau	02°37'E	48°25'N	2	18	1 447	0.095	0.093	-0.022
Absolution0.2 002 H21002 H2	Fossemanant	02°08'E	49°49'N	1	22	1.667	0 144	0.170	0.153
Gatinalière00°20E46°59N4211.6000.1620.1120.112Gávre01°50W47°31N3201.6670.1570.1650.048Gouffern00°01W48°49N3201.8000.1550.1810.144Grand Vallon06°04E44°11N6131.4670.0820.1190.311Grésigne01°44E44°02N5151.6000.1320.1600.175Guerche01°14W47°52N3201.7330.1330.1680.208Gurs00°48W43°15N5151.6670.1290.1430.098Harth07°23'E47°46N8201.8000.3340.223-0.049Hez Froidemont02°16'E49°24'N1201.7330.1470.142-0.035Hospice de Chalais00°04'W45°14'N4201.6000.1370.132-0.038Horecourt06°34'E47°26'N8181.6670.1410.1880.250Le Plan01°05'E43°08'N5121.6000.1060.1500.293Liffré01°28'W48°13'N3201.6670.1230.1660.212Mareuil00°31'E46°34'N4171.7330.1700.1910.110Mas d'agenais00°09'E44°24'N5221.5330.1230.1560.212Mo	Gardiole	05°41'E	43°34'N	6	19	1.600	0.126	0.170	_0.033
Gâvre $0^{10}50W$ $47^{\circ}31N$ 3 20 1.667 0.157 0.165 0.144 Gouffern $00^{\circ}01W$ $48^{\circ}49N$ 3 20 1.800 0.155 0.181 0.144 Grand Vallon $06^{\circ}04'E$ $44^{\circ}11'N$ 6 13 1.467 0.082 0.119 0.311 Grésigne $01^{\circ}44'E$ $44^{\circ}02N$ 5 15 1.667 0.132 0.160 0.175 Guerche $01^{\circ}14'W$ $47^{\circ}52'N$ 3 20 1.733 0.133 0.168 0.208 Gurs $00^{\circ}48'W$ $43^{\circ}15'N$ 5 15 1.667 0.129 0.143 0.098 Harth $07^{\circ}23'E$ $47^{\circ}45'N$ 8 20 1.800 0.234 0.223 -0.049 Hez Froidemont $02^{\circ}16'E$ $49^{\circ}24'N$ 1 20 1.600 0.137 0.132 -0.038 Horecourt $06^{\circ}02'E$ $47^{\circ}55'N$ 8 12 1.533 0.162 0.164 0.012 Isle s/E Doubs $06^{\circ}34'E$ $47^{\circ}25'N$ 8 12 1.667 0.141 0.188 0.250 Le Plan $01^{\circ}05'E$ $43^{\circ}08'N$ 5 12 1.600 0.164 0.156 0.273 Liffré $01^{\circ}28'W$ $48^{\circ}13'N$ 3 20 1.667 0.144 0.186 0.243 Malmifait $01^{\circ}05'E$ $49^{\circ}35'N$ 1 20 1.600 0.144 0.156 0.77 <	Gatinalière	00°20'E	46°59'N	4	21	1.600	0.169	0.152	-0.112
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Gâvre	01°50'W	40°31'N	3	20	1.667	0.157	0.152	0.048
Gornell06 01 H40 91 N5201.0000.1150.1100.144Grand Vallon06 01 H44 91 IN6131.4670.0820.1190.311Grésigne01 94 H47 92 N3201.7330.1330.1680.208Gurs00 94 W43 91 S/N5151.6670.1290.1430.098Harth07 23 E47 946 N8201.8000.2340.223-0.049Hez Froidemont02 °16 E49 °24 'N1201.7330.1470.142-0.035Hospice de Chalais00 °04 W45 °14 'N4201.6000.1370.132-0.038Hurecourt06 °02 E47 °25 'N8121.5330.1620.1640.012Isle s/le Doubs06 °34 E47 °25 'N8181.6670.1410.1880.250Le Plan01 °05 E43 °08 'N5121.6000.1060.1500.293Liffré01 °28 W48 °13 'N3201.6670.1030.1440.285Malmifait01 °56 E49 °37 N4171.7330.1700.1910.110Mareuil00 °31 'E46 °34 'N4171.7330.1230.1660.212Mareuil00 °31 'E46 °34 'N4171.7330.1700.1910.110Mareuil00 °31 'E46 °34 'N4171.7330	Gouffern	00°01'W	48°49'N	3	20	1.8007	0.155	0.181	0.040
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Grand Vallon	06°04'E	44°11'N	6	13	1.000	0.082	0.119	0.311
Oresign01 4+1247 621N3101.0000.1120.1000.112Guerche01°14'W47°52'N3201.7330.1130.1680.208Gurs00°48'W43°15'N5151.6670.1290.1430.098Harth07°23'E47°46'N8201.7330.1470.142-0.049Hez Froidemont02°16'E49°24'N1201.7330.1470.142-0.038Hospice de Chalais00°04'W45°14'N4201.6000.1370.132-0.038Hurecourt06°02'E47°55'N8121.5330.1620.1640.012Isle s/le Doubs06°34'E47°26'N8181.6670.1410.1880.250Le Plan01°05'E43°08'N5121.6000.1060.1500.293Liffré01°28'W48°13'N3201.6670.1030.1440.285Malmifait01°56'E49°35'N1201.6000.1440.1560.077Marcuil00°31'E46°34'N4171.7330.1700.1910.110Mas d'agenais00°09'E44°24'N5221.5330.1230.1560.212Mouliére00°32'E46°49'N4191.6670.1240.1820.184Mouliére00°52'E47°56'N2211.5330.0830.1850.551 </td <td>Grásigna</td> <td>01°44'E</td> <td>44°02'N</td> <td>5</td> <td>15</td> <td>1.407</td> <td>0.132</td> <td>0.119</td> <td>0.175</td>	Grásigna	01°44'E	44°02'N	5	15	1.407	0.132	0.119	0.175
Gurs $00^{\circ}48^{\circ}W$ $43^{\circ}15^{\circ}N$ 5 15 1.667 0.123 0.163 0.104 0.012 Ise s/le Doubs $06^{\circ}34^{\circ}4^{\circ}4^{\circ}726'N$ 818 1.667 0.103 0.144 0.012 0.160 0.106 0.150 0.293 Liffré $01^{\circ}05'E$ $43^{\circ}08'N$ 512 1.600 0.106 0.150 0.293 Liffré $01^{\circ}05'E$ $49^{\circ}35'N$ 120 1.660 0.144 0.156 0.077 Mareuil $00^{\circ}31'E$ $46^{\circ}34'N$ 417 1.733 0.170 0.191 0.110 Mas d'agenais $00^{\circ}09'E$ $44^{\circ}24'N$ 522 1.533 0.123 0.156 0.212 Montceau $04^{\circ}21'E$ $47^{\circ}29'N$ 213 1.600 0.122 <td< td=""><td>Guerche</td><td>$01^{\circ}14'W$</td><td>44 02 N 47°52'N</td><td>3</td><td>20</td><td>1 733</td><td>0.132</td><td>0.160</td><td>0.175</td></td<>	Guerche	$01^{\circ}14'W$	44 02 N 47°52'N	3	20	1 733	0.132	0.160	0.175
Gais 60.48 W 43.13 N 3 10 1.607 0.123 0.143 0.143 0.043 Harth $07^2 23'E$ $47^2 46'N$ 8 20 1.800 0.234 0.223 -0.049 Hez Froidemont $02^\circ 16'E$ $49^\circ 24'N$ 1 20 1.733 0.147 0.142 -0.035 Hospice de Chalais $00^\circ 04'W$ $45^\circ 14'N$ 4 20 1.600 0.137 0.132 -0.038 Hurecourt $06^\circ 02'E$ $47^\circ 55'N$ 8 12 1.533 0.162 0.164 0.012 Isle s/le Doubs $06^\circ 34'E$ $47^\circ 26'N$ 8 18 1.667 0.141 0.188 0.250 Liffré $01^\circ 05'E$ $43^\circ 08'N$ 5 12 1.600 0.166 0.150 0.293 Liffré $01^\circ 28'W$ $48^\circ 13'N$ 3 20 1.667 0.103 0.144 0.285 Malmifait $01^\circ 56'E$ $49^\circ 35'N$ 1 20 1.600 0.144 0.156 0.077 Mareuil $00^\circ 31'E$ $46^\circ 34'N$ 4 17 1.733 0.170 0.191 0.110 Mas d'agenais $00^\circ 09'E$ $44^\circ 24'N$ 5 22 1.533 0.122 0.161 0.242 Montceau $04^\circ 21'E$ $47^\circ 25'N$ 7 13 1.600 0.122 0.161 0.242 Nanc les St Amour $05^\circ 17'E$ $46^\circ 25'N$ 7 13 1.467 0.154 0.142 <	Gurs	00°48'W	47 52 N	5	15	1.755	0.129	0.108	0.208
Hardin $0723E$ $4740N$ 8 20 1.500 0.234 0.223 -0.045 Hez Froidemont $02^{\circ}16E$ $49^{\circ}24N$ 1 20 1.733 0.147 0.142 -0.035 Hospice de Chalais $00^{\circ}04W$ $45^{\circ}14N$ 4 20 1.600 0.137 0.132 -0.038 Hurecourt $06^{\circ}02E$ $47^{\circ}55N$ 8 12 1.533 0.162 0.164 0.012 Isle s/le Doubs $06^{\circ}34'E$ $47^{\circ}26'N$ 8 18 1.667 0.141 0.188 0.250 Le Plan $01^{\circ}05'E$ $43^{\circ}08'N$ 5 12 1.600 0.106 0.150 0.293 Liffré $01^{\circ}05'E$ $49^{\circ}35'N$ 1 20 1.667 0.103 0.144 0.285 Malmifait $01^{\circ}5'E$ $49^{\circ}35'N$ 1 20 1.600 0.144 0.156 0.077 Mareuil $00^{\circ}31'E$ $46^{\circ}34'N$ 4 17 1.733 0.170 0.191 0.110 Mas d'agenais $00^{\circ}09'E$ $44^{\circ}24'N$ 5 22 1.533 0.122 0.161 0.242 Montceau $04^{\circ}21'E$ $47^{\circ}29'N$ 2 13 1.600 0.122 0.161 0.242 Mouliére $00^{\circ}32'E$ $46^{\circ}49'N$ 4 19 1.667 0.154 0.142 -0.085 Nanc les St Amour $05^{\circ}17'E$ $46^{\circ}25'N$ 7 13 1.467 0.154 0.142 -0	Harth	07°23'E	45 15 N 47°46'N	8	20	1.007	0.12)	0.145	0.078
Hez Holdenford02 10 E49 24 N1201.7530.1470.142-0.035Hospice de Chalais00°04'W45°14'N4201.6000.1370.132-0.035Hurecourt06°02'E47°55'N8121.5330.1620.1640.012Isle s/le Doubs06°34'E47°26'N8181.6670.1410.1880.250Le Plan01°05'E43°08'N5121.6000.1060.1500.293Liffré01°28'W48°13'N3201.6670.1030.1440.285Malmifait01°56'E49°35'N1201.6000.1440.1560.077Mareuil00°31'E46°34'N4171.7330.1700.1910.110Mas d'agenais00°09'E44°24'N5221.5330.1230.1560.212Montceau04°21'E47°29'N2131.6000.1220.1610.242Mouliére00°32'E46°49'N4191.6670.124-0.085Orléans01°52'E47°56'N2211.5330.0830.1850.551Pleumartin00°52'E46°37'N4191.6670.1250.1630.233Ravières04°16'E47°44'N2221.8000.1280.1890.323Roche bran00°28'E46°42'N4201.6670.1530.1730.116 <td>Haz Eroidamont</td> <td>07 25 E</td> <td>47 40 IN 40°24'N</td> <td>0</td> <td>20</td> <td>1.000</td> <td>0.234</td> <td>0.223</td> <td>-0.049</td>	Haz Eroidamont	07 25 E	47 40 IN 40°24'N	0	20	1.000	0.234	0.223	-0.049
Hospite de Charas00 04 w4.5 T4 N4201.6000.1370.132-0.038Hurecourt06°02E47°55'N8121.5330.1620.1640.012Isle s/le Doubs06°34'E47°26'N8181.6670.1410.1880.250Le Plan01°05'E43°08'N5121.6000.1060.1500.293Liffré01°28'W48°13'N3201.6670.1030.1440.285Malmifait01°56'E49°35'N1201.6000.1440.1560.077Mareuil00°31'E46°34'N4171.7330.1700.1910.110Mas d'agenais00°09'E44°24'N5221.5330.1220.1610.242Montceau04°21'E47°29'N2131.6000.1220.1610.242Mouliére00°32'E46°49'N4191.6670.1540.142-0.085Orléans01°52'E47°56'N2211.5330.0830.186-0.188Nanc les St Amour05°17'E46°25'N7131.4670.1540.142-0.085Orléans01°52'E47°56'N2211.5330.0830.1850.551Orléans01°52'E46°37'N4191.6670.1550.1730.104Puygareau00°17'E46°50'N4221.6670.1440.197<	Hospiga da Chalais	02 10 E $00^{\circ}04'W$	49 24 IN 45°14'N	1	20	1.755	0.147	0.142	-0.033
Hulecoult $06\ 02\ E$ $47\ 35\ N$ 8 12 1.535 0.162 0.164 0.012 Isle s/le Doubs $06\ 34\ E$ $47\ ^{\circ}26\ N$ 8 18 1.667 0.141 0.188 0.250 Le Plan $01\ 05\ E$ $43\ ^{\circ}08\ N$ 5 12 1.600 0.106 0.141 0.188 0.293 Liffré $01\ ^{\circ}05\ E$ $49\ ^{\circ}08\ N$ 5 12 1.667 0.103 0.144 0.285 Malmifait $01\ ^{\circ}56\ E$ $49\ ^{\circ}35\ N$ 1 20 1.667 0.103 0.144 0.156 0.077 Mareuil $00\ ^{\circ}31\ E$ $46\ ^{\circ}34\ N$ 4 17 1.733 0.170 0.191 0.110 Mas d'agenais $00\ ^{\circ}09\ E$ $44\ ^{\circ}24\ N$ 5 22 1.533 0.123 0.156 0.212 Montceau $04\ ^{\circ}21\ E$ $47\ ^{\circ}29\ N$ 2 13 1.600 0.122 0.161 0.242 Mouliére $00\ ^{\circ}32\ E$ $46\ ^{\circ}25\ N$ 7 13 1.467 0.154 0.142 -0.085 Nanc les St Amour $05\ ^{\circ}17\ E$ $46\ ^{\circ}25\ N$ 2 21 1.533 0.083 0.185 0.551 Orléans $01\ ^{\circ}52\ E$ $47\ ^{\circ}56\ N$ 2 21 1.533 0.083 0.185 0.551 Pleumartin $00\ ^{\circ}52\ E$ $46\ ^{\circ}37\ N$ 4 19 1.667 0.125 0.163 0.233 Ravières $04\ ^{\circ}16\ E$ <td></td> <td>00 04 W</td> <td>43 14 IN 47055'NI</td> <td>4</td> <td>20</td> <td>1.000</td> <td>0.157</td> <td>0.152</td> <td>-0.038</td>		00 04 W	43 14 IN 47055'NI	4	20	1.000	0.157	0.152	-0.038
Isite Site Doubs $00^{\circ} 34^{\circ} E$ $47^{\circ} 20^{\circ} N$ 8° 18° 1.007° 0.141° 0.188° 0.230° Le Plan $01^{\circ} 05^{\circ} E$ $43^{\circ} 08^{\circ} N$ 5 12 1.600° 0.106° 0.150° 0.293° Liffré $01^{\circ} 28^{\circ} W$ $48^{\circ} 13^{\circ} N$ 3 20° 1.667° 0.103° 0.144° 0.285° Malmifait $01^{\circ} 56^{\circ} E$ $49^{\circ} 35^{\circ} N$ 1 20° 1.600° 0.144° 0.156° 0.077° Mareuil $00^{\circ} 31^{\circ} E$ $46^{\circ} 34^{\circ} N$ 4 17° 1.733° 0.170° 0.191° 0.110° Mas d'agenais $00^{\circ} 09^{\circ} E$ $44^{\circ} 24^{\circ} N$ 5° 22° 1.533° 0.122° 0.161° 0.242° Moutiére $00^{\circ} 32^{\circ} E$ $46^{\circ} 49^{\circ} N$ 4° 19° 1.667° 0.122° 0.161° 0.242° Moutiére $00^{\circ} 32^{\circ} E$ $46^{\circ} 49^{\circ} N$ 4° 19° 1.667° 0.154° 0.142° -0.085° Orléans $01^{\circ} 52^{\circ} E$ $47^{\circ} 56^{\circ} N$ 2° 21° 1.533° 0.083° 0.185° 0.551° Pleumartin $00^{\circ} 52^{\circ} E$ $46^{\circ} 37^{\circ} N$ 4° 19° 1.667° 0.125° 0.163° 0.233° Rambouillet $01^{\circ} 47^{\circ} E$ $48^{\circ} 40^{\circ} N$ 2° 21° 1.667° 0	Isla a/la Dauba	00 02 E	47 JJ N 47026'N	0	12	1.333	0.102	0.104	0.012
Le Frain01 05 E45 08 N3121.0000.1060.1300.295Liffré01°28'W48°13'N3201.6670.1030.1440.285Malmifait01°56'E49°35'N1201.6000.1440.1560.077Mareuil00°31'E46°34'N4171.7330.1700.1910.110Mas d'agenais00°09'E44°24'N5221.5330.1230.1560.212Montceau04°21'E47°29'N2131.6000.1220.1610.242Mouliére00°32'E46°49'N4191.6670.2210.186-0.188Nanc les St Amour05°17'E46°25'N7131.4670.1540.142-0.085Orléans01°52'E47°56'N2211.5330.0830.1850.551Pleumartin00°52'E46°37'N4191.6670.1250.1630.233Ravières04°16'E47°44'N2211.6670.1250.1630.233Roche de bran00°28'E46°42'N4201.6670.1530.1730.116Roche posay00°44'E46°47'N4191.6670.1530.1730.116	Isle s/le Doubs	00 34 E	47 20 IN 42009'N	0	10	1.007	0.141	0.160	0.230
Liffe $01^{\circ}28$ w $48^{\circ}15$ N 5 20 1.667 0.103 0.144 0.285 Malmifait $01^{\circ}56$ E $49^{\circ}35'$ N1 20 1.600 0.144 0.156 0.077 Mareuil $00^{\circ}31'$ E $46^{\circ}34'$ N4 17 1.733 0.170 0.191 0.110 Mas d'agenais $00^{\circ}09'$ E $44^{\circ}24'$ N5 22 1.533 0.123 0.156 0.212 Montceau $04^{\circ}21'$ E $47^{\circ}29'$ N2 13 1.600 0.122 0.161 0.242 Mouliére $00^{\circ}32'$ E $46^{\circ}49'$ N4 19 1.667 0.221 0.186 -0.188 Nanc les St Amour $05^{\circ}17'$ E $46^{\circ}25'$ N7 13 1.467 0.154 0.142 -0.085 Orléans $01^{\circ}52'$ E $47^{\circ}56'$ N2 21 1.533 0.083 0.185 0.551 Pleumartin $00^{\circ}52'$ E $46^{\circ}37'$ N4 19 1.667 0.155 0.173 0.104 Puygareau $00^{\circ}17'$ E $46^{\circ}50'$ N4 22 1.667 0.144 0.197 0.269 Rambouillet $01^{\circ}47'$ E $48^{\circ}40'$ N2 21 1.667 0.128 0.189 0.323 Roche de bran $00^{\circ}28'$ E $46^{\circ}42'$ N4 20 1.667 0.153 0.173 0.116 Roche posay $00^{\circ}44'$ E $46^{\circ}47'$ N4 19 1.667 0.151 0.162 0.0618 <td></td> <td>0103E</td> <td>45 UOIN</td> <td>3</td> <td>12</td> <td>1.000</td> <td>0.100</td> <td>0.130</td> <td>0.295</td>		0103E	45 UOIN	3	12	1.000	0.100	0.130	0.295
Mainfiniti $01^{\circ}30 E$ $49^{\circ}35 N$ 1 20 1.000 0.144 0.156 0.077 Mareuil $00^{\circ}31'E$ $46^{\circ}34'N$ 4 17 1.733 0.170 0.191 0.110 Mas d'agenais $00^{\circ}09'E$ $44^{\circ}24'N$ 5 22 1.533 0.123 0.156 0.212 Montceau $04^{\circ}21'E$ $47^{\circ}29'N$ 2 13 1.600 0.122 0.161 0.242 Mouliére $00^{\circ}32'E$ $46^{\circ}49'N$ 4 19 1.667 0.221 0.186 -0.188 Nanc les St Amour $05^{\circ}17'E$ $46^{\circ}25'N$ 7 13 1.467 0.154 0.142 -0.085 Orléans $01^{\circ}52'E$ $47^{\circ}56'N$ 2 21 1.533 0.083 0.185 0.551 Pleumartin $00^{\circ}52'E$ $46^{\circ}37'N$ 4 19 1.667 0.125 0.173 0.104 Puygareau $00^{\circ}17'E$ $46^{\circ}50'N$ 4 22 1.667 0.144 0.197 0.269 Rambouillet $01^{\circ}47'E$ $48^{\circ}40'N$ 2 21 1.667 0.125 0.163 0.233 Roche de bran $00^{\circ}28'E$ $46^{\circ}42'N$ 4 20 1.667 0.153 0.173 0.116 Roche posay $00^{\circ}44'E$ $46^{\circ}47'N$ 4 19 1.667 0.152 0.162 0.008	Lillre	01°28 W	48°13 N 40°25'N	5	20	1.007	0.105	0.144	0.285
Mareun $00^{\circ}31 \text{ E}$ $40^{\circ}34 \text{ N}$ 4 17 1.735 0.170 0.191 0.110 Mas d'agenais $00^{\circ}09^{\circ}\text{E}$ $44^{\circ}24^{\circ}\text{N}$ 5 22 1.533 0.123 0.156 0.212 Montceau $04^{\circ}21^{\circ}\text{E}$ $47^{\circ}29^{\circ}\text{N}$ 2 13 1.600 0.122 0.161 0.242 Mouliére $00^{\circ}32^{\circ}\text{E}$ $46^{\circ}49^{\circ}\text{N}$ 4 19 1.667 0.221 0.186 -0.188 Mac les St Amour $05^{\circ}17^{\circ}\text{E}$ $46^{\circ}25^{\circ}\text{N}$ 7 13 1.467 0.154 0.142 -0.085 Orléans $01^{\circ}52^{\circ}\text{E}$ $47^{\circ}56^{\circ}\text{N}$ 2 21 1.533 0.083 0.185 0.551 Pleumartin $00^{\circ}52^{\circ}\text{E}$ $46^{\circ}37^{\circ}\text{N}$ 4 19 1.667 0.155 0.173 0.104 Puygareau $00^{\circ}17^{\circ}\text{E}$ $46^{\circ}50^{\circ}\text{N}$ 4 22 1.667 0.144 0.197 0.269 Rambouillet $01^{\circ}47^{\circ}\text{E}$ $48^{\circ}40^{\circ}\text{N}$ 2 21 1.667 0.125 0.163 0.233 Roche de bran $00^{\circ}28^{\circ}\text{E}$ $46^{\circ}42^{\circ}\text{N}$ 4 20 1.667 0.153 0.173 0.116 Roche posay $00^{\circ}44^{\circ}\text{E}$ $46^{\circ}47^{\circ}\text{N}$ 4 19 1.667 0.151 0.162 0.008	Mamilat	01°50 E	49°33 IN	1	20	1.000	0.144	0.150	0.077
Mas d agenais $00^{\circ}0^{\circ}9^{\circ}E$ $44^{\circ}24^{\circ}N$ 5 22 1.53° 0.123° 0.156° 0.212° Montceau $04^{\circ}21^{\circ}E$ $47^{\circ}29^{\circ}N$ 2 13 1.600 0.122° 0.161° 0.242° Mouliére $00^{\circ}32^{\circ}E$ $46^{\circ}49^{\circ}N$ 4 19 1.667° 0.221° 0.186° -0.188° Nanc les St Amour $05^{\circ}17^{\circ}E$ $46^{\circ}25^{\circ}N$ 7 13° 1.467° 0.154° 0.142° -0.085° Orléans $01^{\circ}52^{\circ}E$ $47^{\circ}56^{\circ}N$ 2 21° 1.533° 0.083° 0.185° 0.551° Pleumartin $00^{\circ}52^{\circ}E$ $46^{\circ}37^{\circ}N$ 4 19 1.667° 0.155° 0.173° 0.104° Puygareau $00^{\circ}17^{\circ}E$ $46^{\circ}50^{\circ}N$ 4 22° 1.667° 0.125° 0.163° 0.233° Ravières $04^{\circ}16^{\circ}E$ $47^{\circ}44^{\circ}N$ 2 22° 1.800° 0.128° 0.189° 0.323° Roche de bran $00^{\circ}28^{\circ}E$ $46^{\circ}42^{\circ}N$ 4 20° 1.667° 0.153° 0.173° 0.116° Roche posay $00^{\circ}44^{\circ}E$ $46^{\circ}47^{\circ}N$ 4 19° 1.667° 0.157° 0.162° 0.068°	Mareuil	00°31'E	46°34'N	4	17	1./33	0.170	0.191	0.110
Montceau $04^{\circ}21^{\circ}E$ $47^{\circ}29^{\circ}N$ 2 13 1.600 0.122 0.161 0.242 Mouliére $00^{\circ}32^{\circ}E$ $46^{\circ}49^{\circ}N$ 4 19 1.667 0.221 0.186 -0.188 Nanc les St Amour $05^{\circ}17^{\circ}E$ $46^{\circ}25^{\circ}N$ 7 13 1.467 0.154 0.142 -0.085 Orléans $01^{\circ}52^{\circ}E$ $47^{\circ}56^{\circ}N$ 2 21 1.533 0.083 0.185 0.551 Pleumartin $00^{\circ}52^{\circ}E$ $46^{\circ}37^{\circ}N$ 4 19 1.667 0.155 0.173 0.104 Puygareau $00^{\circ}17^{\circ}E$ $46^{\circ}50^{\circ}N$ 4 22 1.667 0.144 0.197 0.269 Rambouillet $01^{\circ}47^{\circ}E$ $48^{\circ}40^{\circ}N$ 2 21 1.667 0.125 0.163 0.233 Ravières $04^{\circ}16^{\circ}E$ $47^{\circ}44^{\circ}N$ 2 22 1.800 0.128 0.189 0.323 Roche de bran $00^{\circ}28^{\circ}E$ $46^{\circ}42^{\circ}N$ 4 20 1.667 0.153 0.173 0.116 Roche posay $00^{\circ}44^{\circ}E$ $46^{\circ}47^{\circ}N$ 4 19 1.667 0.151 0.162 0.0618	Mas d'agenais	00°09'E	44°24'N	5	22	1.533	0.123	0.156	0.212
Mouliere $00^{\circ}32^{\circ}E$ $46^{\circ}49^{\circ}N$ 4 19 1.667 0.221 0.186 -0.188 Nanc les St Amour $05^{\circ}17^{\prime}E$ $46^{\circ}25^{\prime}N$ 7 13 1.467 0.154 0.142 -0.085 Orléans $01^{\circ}52^{\prime}E$ $47^{\circ}56^{\prime}N$ 2 21 1.533 0.083 0.185 0.551 Pleumartin $00^{\circ}52^{\prime}E$ $46^{\circ}37^{\prime}N$ 4 19 1.667 0.155 0.173 0.104 Puygareau $00^{\circ}17^{\prime}E$ $46^{\circ}50^{\prime}N$ 4 22 1.667 0.144 0.197 0.269 Rambouillet $01^{\circ}47^{\prime}E$ $48^{\circ}40^{\prime}N$ 2 21 1.667 0.125 0.163 0.233 Ravières $04^{\circ}16^{\prime}E$ $47^{\circ}44^{\prime}N$ 2 22 1.800 0.128 0.189 0.323 Roche de bran $00^{\circ}28^{\prime}E$ $46^{\circ}42^{\prime}N$ 4 20 1.667 0.153 0.173 0.116 Roche posay $00^{\circ}44^{\prime}E$ $46^{\circ}47^{\prime}N$ 4 19 1.667 0.151 0.162 0.0618	Montceau	04°21'E	47°29'N	2	13	1.600	0.122	0.161	0.242
Nanc les St Amour $05^{\circ}17'E$ $46^{\circ}25'N$ 713 1.467 0.154 0.142 -0.085 Orléans $01^{\circ}52'E$ $47^{\circ}56'N$ 221 1.533 0.083 0.185 0.551 Pleumartin $00^{\circ}52'E$ $46^{\circ}37'N$ 419 1.667 0.155 0.173 0.104 Puygareau $00^{\circ}17'E$ $46^{\circ}50'N$ 422 1.667 0.144 0.197 0.269 Rambouillet $01^{\circ}47'E$ $48^{\circ}40'N$ 221 1.667 0.125 0.163 0.233 Ravières $04^{\circ}16'E$ $47^{\circ}44'N$ 222 1.800 0.128 0.189 0.323 Roche de bran $00^{\circ}28'E$ $46^{\circ}42'N$ 420 1.667 0.153 0.173 0.116 Roche posay $00^{\circ}44'E$ $46^{\circ}47'N$ 419 1.667 0.151 0.162 0.068	Mouliere	00°32'E	46°49'N	4	19	1.667	0.221	0.186	-0.188
Orléans $01^{\circ}52'E$ $47^{\circ}56'N$ 2 21 1.533 0.083 0.185 0.551 Pleumartin $00^{\circ}52'E$ $46^{\circ}37'N$ 4 19 1.667 0.155 0.173 0.104 Puygareau $00^{\circ}17'E$ $46^{\circ}50'N$ 4 22 1.667 0.144 0.197 0.269 Rambouillet $01^{\circ}47'E$ $48^{\circ}40'N$ 2 21 1.667 0.125 0.163 0.233 Ravières $04^{\circ}16'E$ $47^{\circ}44'N$ 2 22 1.800 0.128 0.189 0.323 Roche de bran $00^{\circ}28'E$ $46^{\circ}42'N$ 4 20 1.667 0.153 0.173 0.116 Roche posay $00^{\circ}44'E$ $46^{\circ}47'N$ 4 19 1.667 0.151 0.162 0.068	Nanc les St Amour	05°17'E	46°25'N	7	13	1.467	0.154	0.142	-0.085
Pleumartin $00^{\circ}52'E$ $46^{\circ}37'N$ 419 1.667 0.155 0.173 0.104 Puygareau $00^{\circ}17'E$ $46^{\circ}50'N$ 422 1.667 0.144 0.197 0.269 Rambouillet $01^{\circ}47'E$ $48^{\circ}40'N$ 221 1.667 0.125 0.163 0.233 Ravières $04^{\circ}16'E$ $47^{\circ}44'N$ 222 1.800 0.128 0.189 0.323 Roche de bran $00^{\circ}28'E$ $46^{\circ}42'N$ 420 1.667 0.153 0.173 0.116 Roche posay $00^{\circ}44'E$ $46^{\circ}47'N$ 419 1.667 0.151 0.162 0.068	Orléans	01°52'E	47°56'N	2	21	1.533	0.083	0.185	0.551
Puygareau $00^{\circ}1'/E$ $46^{\circ}50'N$ 422 1.667 0.144 0.197 0.269 Rambouillet $01^{\circ}47'E$ $48^{\circ}40'N$ 221 1.667 0.125 0.163 0.233 Ravières $04^{\circ}16'E$ $47^{\circ}44'N$ 222 1.800 0.128 0.189 0.323 Roche de bran $00^{\circ}28'E$ $46^{\circ}42'N$ 420 1.667 0.153 0.173 0.116 Roche posay $00^{\circ}44'E$ $46^{\circ}47'N$ 419 1.667 0.151 0.162 0.068	Pleumartin	00°52'E	46°37'N	4	19	1.667	0.155	0.173	0.104
Rambouillet $01^{\circ}4'/E$ $48^{\circ}40'N$ 221 1.667 0.125 0.163 0.233 Ravières $04^{\circ}16E$ $47^{\circ}44'N$ 222 1.800 0.128 0.189 0.323 Roche de bran $00^{\circ}28'E$ $46^{\circ}42'N$ 420 1.667 0.153 0.173 0.116 Roche posay $00^{\circ}44'E$ $46^{\circ}47'N$ 419 1.667 0.151 0.162 0.068	Puygareau	00°17'E	46°50'N	4	22	1.667	0.144	0.197	0.269
Ravières $04^{\circ}16'E$ $47^{\circ}44'N$ 2221.8000.1280.1890.323Roche de bran $00^{\circ}28'E$ $46^{\circ}42'N$ 4201.6670.1530.1730.116Roche posay $00^{\circ}44'E$ $46^{\circ}47'N$ 4191.6670.1510.1620.068Roche posay $00^{\circ}24'E$ $46^{\circ}47'N$ 4191.6670.1510.1620.068	Rambouillet	01°47'E	48°40'N	2	21	1.667	0.125	0.163	0.233
Roche de bran $00^{\circ}28'E$ $46^{\circ}42'N$ 4201.6670.1530.1730.116Roche posay $00^{\circ}44'E$ $46^{\circ}47'N$ 4191.6670.1510.1620.068Roche posay $00^{\circ}24'E$ $46^{\circ}47'N$ 4191.6670.1510.1620.068	Ravières	04°16'E	47°44'N	2	22	1.800	0.128	0.189	0.323
Roche posay $00^{\circ}44^{\circ}E$ $46^{\circ}47^{\circ}N$ 4 19 1.667 0.151 0.162 0.068	Roche de bran	00°28'E	46°42'N	4	20	1.667	0.153	0.173	0.116
	Roche posay	00°44'E	46°47'N	4	19	1.667	0.151	0.162	0.068
Rouvroy sur Marne $05^{\circ}29$ E $48^{\circ}23$ N 8 20 1.600 $0.1/3$ $0.1/0$ -0.018	Rouvroy sur Marne	05°29'E	48°23'N	8	20	1.600	0.173	0.170	-0.018
St André 00°13'W 48°52'N 3 20 1.533 0.097 0.131 0.260	St André	00°13'W	48°52'N	3	20	1.533	0.097	0.131	0.260

Table	I.	Continued.
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Populations	Longitude	Lattitude	Groups	Sample size	$N_{\rm a}$	$H_{\rm o}$	$H_{\rm e}$	$F_{\rm IS}$
St Babel	03°16'E	45°34'N	7	14	1.533	0.167	0.150	-0.113
St Gobain	03°50'E	49°35'N	1	11	1.467	0.061	0.134	0.545
St Vallier	06°08'E	48°10'N	8	24	1.667	0.127	0.175	0.274
Ternay	00°21'W	47°08'N	4	20	1.533	0.114	0.140	0.186
Trois Fontaines	04°55'E	48°46'N	8	14	1.600	0.178	0.192	0.073
Valay	05°38'E	47°20'N	8	30	1.533	0.151	0.151	0.000
Valbonne	04°34'E	44°16'N	6	19	1.467	0.086	0.120	0.283
Vendresse	04°46'E	49°37'N	1	16	1.733	0.154	0.166	0.072
Vierzon	02°27'E	47°10'N	2	21	1.467	0.095	0.118	0.195
Villasavary	01°59'E	43°13'N	5	15	1.533	0.102	0.090	-0.133
Wasselone	07°25'E	48°36'N	8	11	1.467	0.108	0.113	0.044
Central Europe								
Bulgarie	27°05'E	43°18'N	EC	20	1.733	0.105	0.117	0.103
Slovaquie 1	21°36'E	49°07'N	EC	42	1.667	0.070	0.100	0.300
Slovaquie 2	19°18'E	48°30'N	EC	34	1.800	0.152	0.139	-0.094
Slovaquie 3	21°03'E	48°48N	EC	65	1.800	0.127	0.143	0.112
Slovénie	13°26'E	45°16'N	EC	29	1.600	0.123	0.122	-0.008
Suisse	09°04'E	45°30'N	EC	86	1.800	0.152	0.179	0.151

2.2. Electrophoresis

The buds sampled (3 to 5 per tree) were ground in a cooled mortar containing the protein extraction buffer (360 μ L for 200 mg of plant material), which was a Tris-HCl buffer (0.02 M, pH = 7.6) supplemented with 1.0% bovine serum albumin, 2% polyethyleneglycol 8000, 1% dithiothreitol, 14 μ M β -mercaptoethanol. The homogenates were centrifuged at 15 000 g for 20 min at 4 °C. The extracts were stored at -80 °C until analysis. The electrophoretic migration took place at 4 °C in horizontal starch gels under an electric field of 80 mV cm⁻¹ for one night.

Of the 18 enzyme systems tested (some were tested with various substrates and staining procedures) the following 11 were finally retained because of the reproducible patterns and of the straightforward genetic interpretations: AAP, E.C. 3.4.11.1 (alanine aminopeptidase, one locus: AAP-1), ACP, E.C. 3.1.3.2 (acid phospatase, one locus: ACP-1), ADH, E.C. 1.1.1.1 (alcohol dehydrogenase, one locus: ADH-1), GOT, E.C. 2.6.1.1 (glutamate oxaloacetate transaminase, one locus: GOT-2), IDH, E.C. 1.1.1.42 (isocitrate dehydrogenase, two loci: IDH-1, IDH-2), PRX, E.C. 1.11.1.7 (peroxidase, two loci: PRX-1, PRX-2), ME E.C. 1.1.1.40 (malic enzyme, one locus: ME-1), MR E.C. 1.6.99.2 (menadione reductase, two loci: MR-1, MR-2), PGM, E.C. 5.4.2.2 (phosphoglucomutase, two loci: PGM-1, PGM-2), 6PGD E.C. 1.1.1.44 (6-phosphogluconate dehydrogenase, one locus: 6PGD-1) SKDH, E.C. 1.1.1.25 (shikimate dehydrogenase, one locus: SKDH-1). Standard staining procedures [2, 28, 39, 42] were adapted with some minor modifications. Segregation analysis of polymorphic systems (Demesure and Le Guerroué, unpublished data) showed that these enzymes were encoded by 15 loci. The alleles were numbered from the fastest to the slowest.

2.3. Data analysis

Geographical variation of gene diversity and allele frequencies were tested in different ways. Several genetic diversity parameters were calculated, for all French populations, but also for each regional group. In addition, a comparison between the French populations and the Central European ones was carried out. Allele frequencies were calculated for each population and gene diversity parameters estimated on a within population basis. The number of alleles per locus (N_a) was calculated over all the loci, as well as Nei's genetic diversity indices [26, 27]. Population differentiation can be summarised by F-statistics (F_{IS} , F_{ST}) as defined by Wright [44], for groups of populations [13]. The similarity between pairs of populations was measured by Nei's unbiased genetic distances corrected for small sample sizes [27]. Dendrograms were produced based on this distance using the UPGMA method [13]. All estimators of the parameters of interest (allele frequencies, genetic diversity and differentiation) were computed using POP-GENE 1.2 [46]. Another useful parameter to evaluate differences in levels of diversity H across populations is the coefficient of variation of H (standard deviation of H

divided by the mean). One-way analysis of variance was used to investigate the difference between groups of populations, based on the parameters estimated in each individual population. For each parameter (N_a , H_o , H_e and $F_{\rm IS}$) considered, we therefore tested whether significant (P < 0.05) differences occurred among groups. For the comparison between France and Central Europe, standard errors of diversity parameters were based on the sampling of loci.

Multivariate analyses (factorial analysis) based on the presence or absence of each detected allele at each locus were also performed. For each allele in each individual, the data was coded as 2, 1 or 0 when the allele was observed in the homozygous condition, in the heterozygous condition or not observed, respectively. In order to assess the effect of geographical distances between populations on their genetic distances, multilocus genetic distances were computed between all pairs of populations, following Degen and Scholz [3]. All pairs of populations were then classified in ten geographic distance classes from 0 to 1000 km, and the relationship between genetic and geographical distances was tested against the hypothesis of random spatial genetic structure by permutation analysis [3].

3. RESULTS

3.1. Overall genetic variability of *Sorbus torminalis* in France

Nine of the 15 loci were polymorphic in France (*table II*), with a range of 5 to 9 polymorphic loci in each population. The number of alleles per polymorphic locus ranged from 2 to 5 with a mean of 2.0. In France, the average of observed and expected heterozygosities were respectively 0.137 and 0.190 (*table II*). The F_{IS} values were positive at six loci and negative at three other ones (*ADH*, 6-*PDH*, *IDH*-1): the combined value over all loci was 0.15. The coefficient of differentiation among populations, F_{ST} , ranged from 0.10 to 0.32 across loci, with an overall value of 0.15 (*table II*). The coefficient of variation of *H* across all 73 populations was 0.20.

Most alleles were found throughout France. However, allele *e* of *PGM*-2 was only observed in the Pyrénées (group 5) and allele *d* of *ADH* was restricted to north of France (group 1). In addition, allele *b* of *AAP* was absent in group 5 and allele *b* of *SKDH* was absent from group 1. The mean number of alleles per group (*table III*) varied very little: from 1.53 (group 6) to 1.60 (group 2), and no significant group effect was detected by the analysis of variance. Observed and expected heterozygosities ranged from 0.111 (group 6) to 0.154 (group 8), and from 0.130 (group 6) to 0.172 (group 4)

Table II. Genetic diversity estimates per locus among the French populations and the Central European ones. $N_{\rm a}$, number of alleles per locus; $H_{\rm o}$, observed heterozygosity; $H_{\rm g}$, expected heterozygosity; $F_{\rm IS}$, heterozygote deficit; $F_{\rm ST}$ differentiation coeficient; SD, standard deviation.

France	Locus	N _a	$H_{\rm o}$	H _e	$F_{\rm IS}$	$F_{\rm ST}$
	ADH	4	0.421	0.473	-0.00	0.11
	ACP	1	_	_	_	_
	6-PDH	2	0.361	0.393	-0.03	0.12
	PRX-1	2	0.102	0.296	0.56	0.24
	PRX-2	2	0.094	0.131	0.22	0.10
	ME	3	0.488	0.647	0.15	0.11
	SKDH	2	0.031	0.130	0.62	0.32
	AAP	2	0.082	0.155	0.25	0.27
	IDH-1	2	0.099	0.106	-0.04	0.11
	IDH-2	1	_	_	_	_
	PGM-1	1	_	_	_	_
	PGM-2	5	0.382	0.521	0.13	0.16
	MR-1	1	_	_	_	_
	MR-2	1	_	_	_	_
	GOT-2	1	_	_	_	_
	Mean	2.0	0.137	0.190	0.15	0.15
	SD	1.2	0.178	0.221		
Central Europe						
	ADH	3	0.319	0.317	-0.01	0.04
	ACP	1	_	_	_	_
	6-PDH	2	0.291	0.288	-0.15	0.07
	PRX-1	2	0.048	0.207	0.77	0.14
	PRX-2	2	0.022	0.029	0.41	0.02
	ME	4	0.565	0.629	0.03	0.12
	SKDH	2	0.026	0.047	0.40	0.05
	AAP	2	0.008	0.030	0.60	0.03
	IDH-1	2	0.118	0.117	-0.04	0.03
	IDH-2	1	_	_	_	_
	PGM-1	1	_	_	_	_
	PGM-2	5	0.428	0.529	0.13	0.06
	MR-1	1	_	_	_	_
	MR-2	1	_	_	_	_
	GOT-2	3	0.125	0.131	-0.07	0.10
	Mean	2.1	0.130	0.155	0.09	0.08
	SD	1.2	0.411	0.203		

respectively. Here, the analysis of variance revealed significant differences among groups (P = 0.02 for H_o and P = 0.01 for H_e). The mean within-population heterozygote deficit ($F_{\rm IS}$) ranged from 0.07 (group 7) to 0.28 (group 2), with no significant differences among groups. The coefficient of genetic differentiation ($F_{\rm ST}$) was computed in each of the eight groups. It ranged from 0.08 in Brittany (group 3) to 0.15 in the southwest of France (group 4).

B. Demesure et al.

68

Region	N_{a}	$H_{ m o}$	H_{e}	F _{IS}	$F_{\rm ST}$
Group 1 (SD)	1.62 (0.13)	0.133 (0.037)	0.155 (0.023)	0.14 (0.17)	0.10
Group 2 (SD)	1.60 (0.11)	0.115 (0.020)	0.160 (0.034)	0.28 (0.15)	0.12
Group 3 (SD)	1.66 (0.09)	0.133 (0.022)	0.160 (0.017)	0.17 (0.09)	0.08
Group 4 (SD)	1.65 (0.07)	0.147 (0.029)	0.172 (0.024)	0.14 (0.16)	0.15
Group 5 (SD)	1.58 (0.14)	0.119 (0.018)	0.131 (0.036)	0.09 (0.20)	0.11
Group 6 (SD)	1.53 (0.07)	0.111 (0.025)	0.130 (0.014)	0.14 (0.15)	0.11
Group 7 (SD)	1.62 (0.15)	0.149 (0.022)	0.160 (0.025)	0.07 (0.18)	0.10
Group 8 (SD)	1.61 (0.10)	0.154 (0.036)	0.168 (0.033)	0.08(0.12)	0.11
Central Europe (SD)	1.73 (0.08)	0.122 (0.031)	0.133 (0.027)	0.09 (0.13)	0.08
Overall mean (SD)	1.63 (0.10)	0.134 (0.031)	0.156 (0.030)	0.13 (0.15)	0.15

Table III. Genetic diversity measures within the 8 French groups and the central European group.

 $N_{\rm a}$, number of alleles per locus; $H_{\rm o}$, observed heterozygosity; $H_{\rm e}$, expected heterozygosity; $F_{\rm IS}$, heterozygote deficit; $F_{\rm ST}$ differentiation coefficient; SD, standard deviation.

3.2. Comparison of French populations with central European populations

Ten of the 15 loci were polymorphic in Europe (*table II*). The locus *GOT*-2 was polymorphic only in 3 populations (two in Slovakia and one in Bulgaria). One rare allele appears in the eastern European populations at the locus *ME*. There were no consistent differences between the French and the Central European populations groups (*table III*). It can be noticed that the number of alleles is slightly higher (2.1) and the value of the $F_{\rm ST}$ (0.08) lower for the eastern European populations than for the French populations (*table III*). However, the analysis of variance based on the differences between the French populations and Central European ones.

3.3. Geographic structuring of the diversity in France

The UPGMA dendrogram using Nei's unbiased distance (*figure 2*) did not reveal any clustering of geographically close populations. A multivariate analysis indicates the same lack of geographic structure (data not shown). However, the analysis of the correlation between Nei's genetic distances and geographic distances revealed a slight but significant positive relationship at distances up to 120 km (*figure 3*).

4. DISCUSSION

Our results for the wild service tree are consistent with those obtained for allozyme markers in most forest trees studied to date: little differentiation among popula-

tions and a comparatively high level of genetic diversity. The estimates of genetic variation at the species level that we obtained in S. torminalis (P = 66%, A = 2.20, $H_{e} = 0.185$) were very close to those obtained by Hamrick et al. [11] in long-lived woody perennials $(P = 65\%, A = 2.22, H_e = 0.177)$. Similarly, at the within population level, results for *S. torminalis* (P = 57%, $A = 1.62, H_{e} = 0.156$) are very close to those of the other trees $(P = 49\%, A = 1.76, H_e = 0.148)$. The diversity values for S. torminalis are however lower than those obtained by Raspé et al. for Sorbus aucuparia in Europe [33] within population (P = 63%, A = 2.25, $H_e = 0.212$) and within species (P = 90%, A = 3.70, $H_e = 0.229$). The difference observed between the two species may be explained by ecological differences and postglacial history. Indeed Sorbus aucuparia grows in relatively wet and cool climate, consequently it is confined to mountain areas in the southernmost part of its range, and it can be found at high latitudes. On the other hand, Sorbus tormi*nalis* is found in drier habitats, in the plains at lower latitudes, and is absent at high altitudes. Hence, it is likely that during the last ice-age the climate was more adapted to Sorbus aucuparia which could persist in numerous small populations in glacial refugia, and maintain higher levels of diversity. Our results for S. torminalis indicate that the genetic diversity is equally distributed in France. No strong differences can be noted for the mean number of alleles per population. The coefficient of variation of H(0.20) is only slightly larger than that observed in a compilation of 62 outcrossing tree species (0.17) (R.J. Petit, in prep.), indicating that levels of diversity are not especially heterogeneous. Although still small compared to herbaceous species, the observed F_{ST} value (0.15) is however higher than that reported in other forest tree species (e.g., $F_{ST} = 0.06$ for S. aucuparia, [33];



Fig. 2. UPGMA clustering of 67 populations of *Sorbus torminalis* based on Nei's genetic distance.

 $F_{\rm ST} = 0.03$ for *Quercus petraea*, [47]; $F_{\rm ST} = 0.05$ for *Prunus avium*, [6]). It is also of comparable magnitude to the estimate obtained Prat & Daniel in a previous more limited study of the species ($F_{\rm ST} = 0.10$) [29]. According to Hamrick et al. [11], the mean $F_{\rm ST}$ for trees with animal-dispersed seeds (0.05) is much lower than



Fig 3. Genetic distogram (genetic distances *versus* geographic distances) for 9 distance classes (0–900 km), and 95% confidence intervals of the genetic distance, computed by means of 1000 permutations.

the value observed in Sorbus torminalis. Interestingly, other authors have also reported relatively high $F_{\rm ST}$ values for scattered species having small populations: 0.33 for Ulmus laevis [23], 0.18 for Ulmus minor [21], 0.13 for Acer platanoides [34], 0.13 for Ocotea tenera [7], 0.20 for Alnus glutinosa [30]. Allozyme studies show clearly that population subdivision promotes differentiation: values of F_{ST} are higher in subdivided than in continuous habitats [1, 31]. Most disseminated tree species are not randomly mating, due to their scattered distribution and pollination by vectors which fly over short distances only [19]. Therefore genetic drift can have a great importance in their evolution. Although Sorbus torminalis seems to be mainly outcrossing, as suggested by the small heterozygote deficit in the populations, a rapid divergence between populations can appear. The high $F_{\rm ST}$ value can also be explained by founder effects. Indeed, S. torminalis is a nomad species and its populations have a rapid turnover. Theoretical studies have shown that founding events may increase differences between young populations, depending notably on the number of individuals involved in the founding events and the number of source populations from wich they are drawn [41].

Hence, the major result of this study is the combination of the relatively high $F_{\rm ST}$ and the weak geographic structure. The distogram indicates that populations separated by less than 150 km are more related than those further apart, but the other analyses have failed to detect any geographic structure at the monolocus level. Paradoxically, some comparable studies in forest trees have found low $F_{\rm ST}$ values combined with a strong geographic structure at the multilocus level [16] or even at the monolocus level [17]. Studies of the genetic consequences of population dynamics within a forest but also over a larger scale, will be necessary to clarify this finding in order to examine how populations are interconnected by gene flow. Sorbus torminalis is distributed all over France except in the mountains and it is possible that this species functions in metapopulations. Indeed, as a nomad species, S. torminalis populations can be defined as a set of subpopulations in which the individual demes are subject to frequent local extinction, but may be replaced through colonisation [12, 18]. This definition could apply well to the dynamics of the wild service tree. Recently there has been a considerable interest in the genetic properties of metapopulations, particularly on the influence of the frequent extinction and colonisation events on the maintenance of genetic variation and on the partitioning of this variation within and among local populations [8, 25, 36]. Extinction and recolonisation may produce a certain amount of genetic differentiation through founder effects, if the groups that found the new populations are sufficiently small and homogeneous [37, 41, 43]. McCauley et al. [24] have shown that a set of recently founded populations of Silene alba displays considerable genetic differentiation and this structure can be ascribed to a mode of colonisation in which there is only limited mixing of individuals from different sources.

Although further investigations will be necessary to understand in more details the population genetics of Sorbus torminalis, the results of our investigation can already contribute to a more rationale management of the genetic resources of this scattered and valuable tree species. Indeed, if the species does function as a metapopulation, local extinction and colonisation are expected in the forest. So the manager must take care to leave free areas in the forest that can be colonised by new populations of wild service tree. This implies for example local absence of social tree species and a special care during the seedling development. Because gene flow is naturally important, as evidenced from the weakness of geographic structure at the studied scale, maintenance of conditions favouring high gene flow are essential; in particular, animal dispersers (insects and birds) should be preserved. The birds and especially the thrushes (Turdus sp.) seem to play an important role in the homogenisation of the genetic structure over large distances. Indeed the fruits of wild service tree are mature during the migration of the birds, in autumn. The development of maternally inherited cytoplasmic markers in Sorbus torminalis will also give more information on the number and origin of founder trees, when new populations become established.

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