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FROM RURALITY TO FERALITY: A CASE STUDY FROM THE UPPER MOSELLE VALLEY, FRANCE

Annik SCHNITZLER¹, Damien AUMAÎTRE² & Christophe SCHNITZLER³

RÉSUMÉ. — *Du « rural » au « féral », une étude de cas en haute vallée de la Moselle, France.* — Quelques résultats sur la dynamique de succession dans la vallée de la Moselle en amont de Nancy sont présentés dans cet article. Le régime naturel de la rivière a été relativement bien préservé en dépit de prélèvements conséquents de sédiments dans la rivière dans un passé récent, et des gravières toujours en activité sur les bords externes de la vallée alluviale. La vallée a également bénéficié de pratiques agricoles extensives jusqu'en 1950 mais les forêts avaient presque totalement disparu au 19^{ème} siècle. Deux périodes d'abandon partiel de ces activités ont permis une progression de la forêt depuis la fin du 19^{ème} siècle. 2377 ha sont maintenant dans le réseau Natura 2000. Dans cette zone, la dynamique de recolonisation forestière a été quantifiée sur la base de photographies aériennes à l'échelle du cinquante millième, datant de 1950 et 2003. 136 relevés ont été effectués selon la méthode classique de phytosociologie. La visualisation des impacts forestiers (coupes, plantations, vergers) a été évaluée par les observations de terrain. Les forêts ont été séparées en deux catégories de type de conservation : bon état (caractère naturel de l'architecture forestière) et état moyen (avec impacts anthropiques visibles). À partir de ces données, les surfaces de chaque communauté forestière définie par la phytosociologie, ainsi que l'état de conservation ont été quantifiés. Deux espèces exotiques très abondantes (*Fallopia x bohemica* Chrtek & Khrtkova et *Impatiens glandulifera* Royle) ont été testées au regard des facteurs suivants : association forestière, périmètre, surface, âge. Les données ont été analysées par le test non paramétrique de Kruskal-Wallis. La surface totale des forêts est de 545,5 ha, répartie en 397 boisements, de surfaces variant de 0,1 à 16,6 ha. 11,1 % des surfaces forestières sont âgées de moins de 50 ans. Quatre types forestiers ont été identifiés : saulaie buissonnante, saulaies souvent mêlées de frêne, aulnaie à frêne en situation plus protégée des inondations, et aulnaie marécageuse à hautes herbes dans les chenaux en voie de comblement. La richesse totale est de 126 espèces. Les frênaies-aulnaies sont les plus riches en espèces, les plus complexes en architecture quand elles ne sont pas influencées par les activités humaines. Les boisements bien préservés se situent dans tous les types forestiers, mais sont moindres en surface que ceux à état de conservation inférieur (28,4 % contre 71,6 %). Comparés à d'autres forêts d'écologie similaire de la plaine du Rhin, les boisements de la Moselle sont plus fragmentés, mais plus naturels car issus d'un développement spontané. Leur relative jeunesse explique qu'il manque certaines espèces des stades de succession matures parmi les arbres et les géophytes. Les saulaies sont les plus riches en espèces exotiques, et les forêts jeunes sont plus envahies que les forêts âgées par les deux espèces envahissantes (Renouée du Japon, Impatiens de l'Himalaya). La recolonisation forestière qui a pu se produire grâce à la déprise agricole peut être considérée comme un modeste succès pour la biodiversité de la vallée, soumise depuis des siècles à des usages anthropiques qui ont détruit les milieux originels. Certes, cette nouvelle nature n'est pas celle des milieux originels. Elle pourrait plutôt être considérée comme une nature de type « féral », issue d'une « dédomestication » d'espaces cultivés laissés en déshérence sur le long terme. Afin de rétablir les liens entre habitats terrestres et aquatiques, même différents de la nature originelle, il faudrait donc laisser le plus d'espace possible en évolution libre.

SUMMARY. — In this paper we present the woodland dynamics of the Moselle valley, upstream from Nancy in north-eastern France. The Moselle flow regime has been partly preserved, although the valley underwent extensive land-uses in the past, with two periods of abandonment of agriculture practices since

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the 1870s. In the 2377 hectares of the Natura 2000 zone, the surface areas of all woodland patches of more than 0.1 ha were quantified by GIS (Arcview 3.3R), on the scale of 1:50.000 from aerial photographs from 1950 and 2003. One hundred and thirty-six phytosociological surveys were performed on vascular plants, and abundance – dominance was estimated by eye using the phytosociological scale. Human impact (cuttings, plantations, presence of ancient orchards) was evaluated by field trip. Woodlands were separated into two categories of conservation: high (i.e. natural character of forest architecture) and low (with human impacts). From these data, we quantified the surface areas of each forest community defined by phytosociology, as well as their conservation value. *Fallopia x bohemica* Chrtek & Chrtkova and *Impatiens glandulifera* Royle were tested with regard to the following factors: forest type, shape (perimeter), size (surface area), and age (more or less than 50 years old), and the frequency of flooding. Data were analysed using the Kruskal-Wallis test. The total forest surface was 546.6 ha, split into 397 patches of various areas (ranging from 0.1 to 16.6 ha). On the current wooded forest surface, 11.1% was less than 50 years old. Four forest types were identified: willow bush (*Salicetum triandrae*) and willow tree (*Salicetum albae*) forest communities, both on river banks close to the river; ash-alder (*Pruno-Fraxinetum*) on more elevated sites; and marsh alder (*Alnetum glutinosae*) in old channels. The total species richness was 126. Ash-alder patches were the richest in species, and the most complex in architecture when not influenced by human activities. Communities of high conservation value were found in all forest types but in lower proportion than those of lower conservation value (28.4 versus 71.6%, respectively). Compared with other floodplain forests of similar ecology in the Rhine plain, the woodlands of the upper Moselle valley were more fragmented, but more natural because of the lack of recent silvicultural activities. Their relative youth explains why they lack native species of trees and some geophytes that are typical of mid- or late successional stages. Willow forests showed greater invasion by exotic species, and younger forests were invaded to a greater extent than forests over 50 years old by *Fallopia x bohemica* Chrtek & Chrtkova and *Impatiens glandulifera* Royle. The increase of woodlands in willow stands can be considered as a sign of modestly successful recovery from long-term deforestation. Of course, these fallows will never return to pristine old-growth forests. They could be defined as “feral” or “dedomesticated” landscapes because succession processes will take different courses and different lengths of time compared with natural processes. Such “dedomesticated” landscapes would however provide interesting evolutionary perspectives for the long term and suggest the interest of research in the context of changing uses. Forests should be therefore allowed to continue their expansion so that the entire range of natural habitats, as well as novel habitats, are re-created and full functional links can be established between terrestrial and aquatic communities.

The floodplain forests of most European river plains result from a combination of physical and temporal gradients associated with flood regime and nutrient fluxes (among many: Ruffinoni *et al.*, 2003), and human activities. Human pressures on floodplain forests have been high for many centuries, causing fragmentation of forests and river channels (Flobar2 project 2003). These activities increased during the second half of the 20th century, resulting in extensive damming, sediment extraction, regulation, river diversion (Dynesius & Nilsson, 1994; Tockner & Stanford, 2002), and silvicultural practices for remnant woodlands (Carbiener, 1990). Natural old forests thus became very sparse, limited to a few woodlands in Eastern Europe.

Fortunately, the collapse of the agro-sylvo-pastoral system led to local abandonment of lands, which underwent renewed colonization by riparian forests. Nevertheless, debate continues over the effect of spontaneous forest succession on biodiversity. Scientists (among many: Ellenberg, 1988; Young *et al.*, 2005) argue that the abandonment of traditional management leads to a decrease in species richness by changing habitats associated with the agro-sylvo-pastoral landscapes. Spontaneous wild landscapes due to lack of local policy are also seen as a danger for those landscapes on the World Heritage List for their high biological and aesthetic value (Luginbühl, 1999). A third argument against spontaneous forest reconquest is that these new ecosystems will never recover the value of primeval habitats, after centuries of intensive clearing and resource exploitation. Noteworthy is the increasing number of exotics (plants, animals, bacteria, fungi) that often integrate natural systems, modifying the species assemblages (Schnitzler *et al.*, 2007).

In this study, we investigated the vegetation dynamics provoked by the land-use changes in the upper Moselle valley, on a linear landscape of 30 km directly upstream from Nancy (north-eastern France). The ecological values of this valley, (i.e. the free coursing river and associated biodiversity) has been recognized at the national level, and an environmentally sensitive area of 2377 ha was included in the Natura 2000 network in 1999. One hundred and twenty-two hectares of spontaneous forest growth caused by the abandonment of land uses in

the 20th century have also benefited from strict protection within the framework of a regional nature reserve, created in 2006 and managed by the “Conservatoire des Sites Lorrains”.

Nevertheless, the processes of succession that have taken place remain strongly dependent on the prior land use, which may have affected the rhythms of colonization and species assemblage. We set out to answer the following question: What types of plant communities have colonized the floodplain after centuries of deforestation and development of rurality, and what are their species assemblages? Our findings allow us to discuss the concept of naturalness in conservation, in the sense of Schnitzler *et al.* (2008), Höchtl *et al.* (2005), similar to the concept of “ferality” developed by Marris (2009) i.e., the values of “wilderness” in a context of man-influenced system, however significantly free from direct human intervention.

MATERIAL AND METHODS

STUDY SITE

The Moselle River is a second-order tributary of the Rhine River that originates in the Vosges Mountains of France and flows across the Lorraine plateau before joining the Rhine in Coblenz (Germany).

The study site (latitude 48°53'N; longitude 6°39'E) covers a 25 km-long area (2.377 ha) between Tonnoy and Châtel-sur-Moselle, upstream from Nancy (Fig. 1). The elevation is about 250 m above sea level. The average annual precipitation is approximately 750 mm, with a mean annual temperature of about 9°C. The underlying gravel bed varies in depth from 10 to 200 cm and is covered by stratified acidic sand deposits (Maire & Corbonnois, 2000).

The fluvial dynamics are determined by an abundant and contrasted water regime. The river has a mean annual discharge of 49.7 m³.s⁻¹. The high flows peak in the late winter and most floods occur between October and March. The limits of maximal flooding and the mapping of decennial and centennial floods are available in the “Atlas des zones inondables de la Moselle” (2004). During exceptional floods (1983, 1990, 2003), a peak of 789 m³.s⁻¹ was attained in the upper reaches of the plain. During these events, dead wood from adjacent natural woodlands was washed away and accumulated along convex parts of meanders or within the river bed, increasing the mass of woody debris along the river continuum.

Historical studies suggest that, like most floodplains in Europe, the valley was totally deforested for meadows and cultures until the end of the 19th century. The lack of woodlands within the valley and on adjacent hills brought large amounts of sediments into the river. Coupled with the great floods during the entire Little Ice Age (1400-1850), these accumulations of sediments had a strong influence on the channel pattern, favouring a system of braids and islands. A

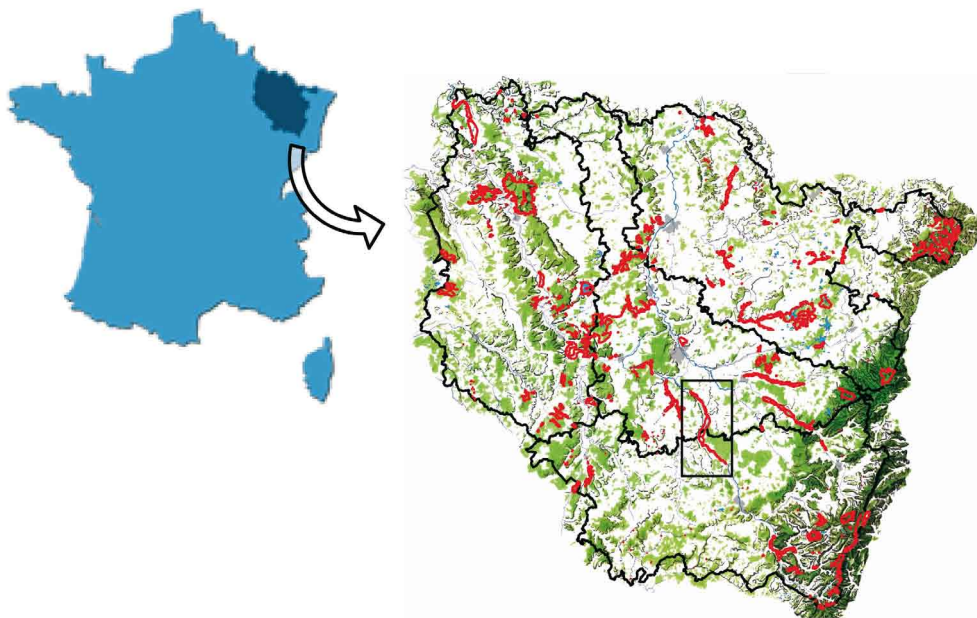


Figure 1. — Location of the upper Moselle valley in France, overlapping the Departements of Meurthe-et-Moselle and Vosges. In red, rivers in Natura 2000.

meander system developed at the end of the 19th century with the end of the Little Ice Age (1850). The increasingly alteration in the flow regime, which is due to various water uses and sediment extraction, has lowered the mean water-table by about 70 cm in a few decades, except in the 2000-to-2200 m-wide area between Charmes and Bayon, where sediments accumulate, increasing the channel sinuosity and the transversal migration of meanders over 2000 to 2200 m (Hydratec, 1999; Maire & Corbonnois, 2000; Beck & Corbonnois, 2003; Sinbio, 2010). Forests continue to grow in this new hydrological context.

Spontaneous successions began after the 1870 Franco-Prussian war and continued after the Second World War (Edelblutte, 1997).

METHODS

The surface areas of all woodland patches in the 2377 ha of the Natura 2000 zone were digitalized and georeferenced by GIS (Arcview 3.3R), using aerial photographs from the year 2003 established on the scale of 1:50,000. From these first results we were able to select woodlands of at least 0.1 ha (considered as a minimum for creating a forest “interior” and limiting edge effects) for an *in situ* survey. We also quantified the surfaces of fallows.

Changes in forest cover between 1950 and 2004 and estimation of woodland age

Changes in forest cover were evaluated by comparing aerial photographs from the years 1950 and 2003 (Figs 2 & 3). The age of woodlands was evaluated by determining whether they were present in 1950 and 2004. Forests visualized in 1950 were estimated to be at least 50 years old, dating back to the first wave of colonization. Forests that covered new areas after this date were assumed to be 20-50 years old.

Vegetation survey

Phytosociological surveys (n=136) were conducted in 2007 and 2008. Each one covered an area of approximately 400 m². The Braun-Blanquet abundance-dominance scale with six coefficients from + to 5 was used (Guinochet, 1973). Results were compared with those from studies in adjacent floodplains with similar hydro-edaphical conditions but larger areas (hundred of hectares) in the Rhine valley (Schnitzler, 1988, 1995a; Schnitzler & Muller, 1998). These latter are also ancient (at least 200 years according to the Cassini map) and intensively managed.

In the Moselle valley, the number of patches per forest community or per mosaic of two forest communities as well as their respective surface areas and perimeters, were quantified using the aerial photographs from 2004.



Figure 2. — Landscape along the active channels of the upper Moselle valley (near Bainville-aux-miroirs) in 1949 (IGN 1949). In red, limits of Natura 2000 area.



Figure 3. — The landscape along the active channels of the upper Moselle valley (near Bainville-aux-miroirs) in 2004. (IGN 2004). In red, limits of Natura 2000 area.

Quantification of human impacts

Nearly all the woodlands are currently left to free development but past land uses may have strongly affected successional pathways. From the aerial photographs and the field trip we could easily make a distinction between forests issuing from a spontaneous recolonization from bare substrates of the Moselle and woodlands issuing from ancient pastures, which were characterized by small areas of meadows integrated within patches and the persistence of a few cultivated trees. We also separated woodlands presenting local cuttings and/or plantations (*Robinia pseudoacacia* L., *Quercus robur* L. or cultivated poplars) from woodlands presenting a natural architecture (complex multilayer architecture with big trees, both alive and dead, Oldeman, 1990; Peterken, 1996).

Patches presenting natural architectures were classified as woodlands of high conservation value. In contrast, patches issued from ancient pastures, affected by recent cuttings or issued from plantations were considered as woodlands of lower conservation value. The surface areas concerned by this classification were calculated.

Impact of two exotics on forest succession

A focus was therefore placed on exotic plants in the study area. In particular, we tried to assess the impact of two invasive species, *Fallopia x bohemica* Chrték & Chrtkova and *Impatiens glandulifera* Royle on succession with regard to the following factors: forest type, shape (perimeter), size (surface area), and age (less or more than 50 years old). Statistics were processed with Minitab 15.1 software (Minitab Inc). Distribution normality (Ryan Joiner test) and variance homogeneity (Bartlett and Levene test) were verified. As the distribution was not normal, data were analysed using the non-parametric Kruskal-Wallis test. For significant factors, a post-hoc test (Mann-Whitney) was applied to determine which category diverged from the others. For all data, results were considered as statistically significant for $p < 0.05$.

RESULTS

CHANGES IN FOREST COVER BETWEEN 1950 AND 2003 AND ESTIMATION OF WOODLAND AGE

The number of woodland patches (397) totalled 546.6 ha in 2003. This value corresponds to 23% of the total surface of the Natura 2000 zone. Sixty-one hectares (11.1%) of this current wooded forest surface were less than 50 years old, indicating forest expansion since 1950. To this forest expansion we can add the expansion of fallows whose surface areas increased by 145 ha, *i.e.* 6.1% of the surface of the Natura 2000 zone. As these fallows are composed of a mixture of herbaceous/woody plants, they were not included in the study.

DEFINITION AND DISTRIBUTION OF FOREST COMMUNITIES

The phytosociological study revealed 126 species, all of which belonged to one of the four alliances present at the site: *Salicion*, *Alno-Ulmion*, *Alnion* and *Carpinion* (Oberdorfer, 1990).

Four associations were recorded along the gradients of flooding disturbance and the moisture gradient, as shown in Tables I & II. These forest communities have been described by other authors for many alluvial plains of Western Europe (Ellenberg, 1988; Oberdorfer, 1990) and in adjacent floodplains (Schnitzler, 1988, 1995a; Schnitzler & Muller, 1998). A fifth community was too reduced in surface and thus influenced by edge effects to be correctly interpreted.

TABLE I

Species richness of the four main phytosociological forest associations in the upper Moselle valley

	Willow bush	Willow tree	Ash-alder	Alder
Number of plots	13	36	60	27
Total number of species	49	83	98	82
Total number of woody species	12	29	41	27
Mean species richness	13.6 ± 2.8	16.1 ± 3.8	18 ± 4.1	16.5 ± 4.4
TREE SPECIES				
<i>Salicion albae</i>				
<i>Salix alba</i> L.	IV 1	IV 2	I +	I 1
<i>Salix fragilis</i> L. and hybrids	IV 1	IV 2	I +	III 1
<i>Populus nigra</i> L.		I 1	I +	
<i>Alno-Ulmion/Carpinion</i>				
<i>Acer campestre</i> L.			I +	
<i>Acer platanoides</i> L.	I 1	I 2	II 1	I +
<i>Acer pseudoplatanus</i> L.		I +	I +	I 1
<i>Alnus glutinosa</i> L.		II 1	II 1	V 3
<i>Betula pendula</i> L.			I +	I +
<i>Carpinus betulus</i> L.		I +	I +	
<i>Fraxinus excelsior</i> L.	I 1	III 1	V 3	V 3
<i>Populus alba</i> L.			I +	
<i>Prunus avium</i> L.			I +	I +
<i>Prunus padus</i> L.		I 2	III 2	III 3
<i>Quercus robur</i> L.			III 1	II 1
<i>Tilia cordata</i> Mill.			I +	
<i>Ulmus laevis</i> Pall.		I +	I +	I 1
<i>Ulmus minor</i> Mill.			I +	
Exotics and cultivated species				
<i>Robinia pseudoacacia</i> L.		I 1	II 2	I +
<i>Acer negundo</i> L.		I +	I +	
<i>Juglans regia</i> L.		I +	I +	
<i>Pyrus communis</i> L.		I +	I +	
<i>Malus domestica</i> L.		I +		
PARASITE SPECIES				
<i>Viscum album</i> L.	I 1	I +	I +	
VINE SPECIES				
Phanerophytes				
<i>Salicion/Alno-Ulmion/Carpinion</i>				
<i>Hedera helix</i> L. (high strata)		I 1	III 1	I +

	Willow bush	Willow tree	Ash-alder	Alder
<i>Hedera helix</i> L. (ground)		II	II +	II 1
<i>Rosa canina</i> L.		I +	I +	
<i>Rubus fruticosus</i> L.	I 1	I 1	III 2	III 1
Carpinion				
<i>Lonicera periclymenum</i> L.			I +	
Exotics				
<i>Parthenocissus quinquefolia</i> (L.) Planchon		I 1	I +	I 1
Hemicryptophytes				
Salicion				
<i>Calystegia sepium</i> (L.) R. Br.	IV 1	III 1		
<i>Humulus lupulus</i> L.	III 1	IV 1	II 1	III 1
Salicion/Alnion				
<i>Solanum dulcamara</i> L.		I +		I 1
Alno-Ulmion				
<i>Vicia cracca</i> L.			I +	
<i>Vicia sepium</i> L.			I +	
Therophytes				
<i>Galium aparine</i> L.	IV 1	IV 2	III 2	I 1
BUSH SPECIES				
Salicion				
<i>Salix caprea</i> L.		I +		
<i>Salix purpurea</i> L.	IV 2	III 2	I 1	I +
<i>Salix triandra</i> L.	II 1	I 1	I 1	
<i>Salix viminalis</i> L.	V 3	I +		
Salicion/Alno-Ulmion				
<i>Cornus sanguinea</i> L.	I 1	I +	I +	I 2
<i>Crataegus oxyacantha</i> L.	I 1	I +	III 1	III 1
<i>Evonymus europeus</i> L.	I 1	II +	IV 1	III 1
<i>Rubus caesius</i> L.	V 2	IV 2	IV 1	IV 2
Alno-Ulmion/Carpinion				
<i>Corylus avellana</i> L.			II +	II 1
<i>Crataegus monogyna</i> Jacq.			II 1	I +
<i>Ligustrum vulgare</i> L.			I +	
<i>Lonicera xylosteum</i> L.			I +	
<i>Prunus spinosa</i> L.		I +	II +	I 1
<i>Rhambus frangula</i> L.			I +	
<i>Ribes rubrum</i> L.		I 1	I 1	I 1
<i>Sambucus nigra</i> L.		I +	I +	I 1
<i>Viburnum lantana</i> L.			I +	
<i>Viburnum opulus</i> L.			I +	II +
HERBACEOUS SPECIES				
Geophytes				
Salicion/Alno-Ulmion/Alnion				
<i>Cardamine pratensis</i> L.	I 1	I 1	I 2	I 2

	Willow bush	Willow tree	Ash-alder	Alder
<i>Ficaria verna</i> Huds.	II 2	II 2	I 2	
<i>Iris pseudacorus</i> L.		I +	I 1	
Alno-Ulmion				
<i>Arum maculatum</i> L.			I +	I +
<i>Corydalis solida</i> (L.) Clairv		I 1	I 1	I +
<i>Paris quadrifolia</i> L.			I +	
<i>Polygonatum multiflorum</i> (L.) All.			I +	I 1
<i>Primula elatior</i> (L.) Hill			I 1	I +
<i>Anemone ranunculoides</i> L.			III	
Hemicryptophytes				
Salicion				
<i>Brassica olearacea</i> L.	I +	I +		
<i>Carex acutiformis</i> Ehrh.	I +	I +		I 1
<i>Eupatorium cannabinum</i> L.		I +		
<i>Artemisia vulgaris</i> L.	I +	I +		
<i>Carex riparia</i> Curtis Huds.	I +			
<i>Lamium album</i> L.		I +	I +	
<i>Lycopus europaeus</i> L.	I +			
<i>Equisetum palustre</i> L.	II 1	I +		I 1
<i>Lysimachia vulgaris</i> L.	I 1	I 1		
<i>Lysimachia nummularia</i> L.	I 2	I 1	I +	
Alno-Ulmion/Salicion/Alnion				
<i>Aegopodium podagraria</i> L.	II 1	II 1	I +	I 3
<i>Angelica sylvestris</i> L.	I +	I 1	I 1	I +
<i>Anthriscus sylvestris</i> (L.) Hoffm.	I 1	I +	I 1	I +
<i>Heracleum spondylium</i> L.		I +	I +	
<i>Alliaria officinalis</i> Andrz.	II 1	I +	III 1	II 1
<i>Melandryum dioicum</i> (L.) Coss. & Germ.		II 1	III 1	II +
<i>Stellaria holostea</i> L.		I +	II 1	I +
<i>Stellaria nemorum</i> L.	I 1	I +	I +	I 1
<i>Geranium robertianum</i> L.		I 1	II 1	II 1
<i>Dipsacus pilosus</i> L.	I +	I 1	I +	I 1
<i>Brachypodium sylvaticum</i> (Huds.) P.Beauv.		II 2	IV 2	II 2
<i>Carex remota</i> L.		I +	I +	I +
<i>Glechoma hederacea</i> L.	III 2	IV 2	IV 2	V 3
<i>Lamium maculatum</i> L.	II 1	III 1	III 2	IV 1
<i>Stachys sylvatica</i> L.	II 1	I 1	III 1	II 1
<i>Festuca gigantea</i> (L.) Vill.	I 1	I +	I 1	I 1
<i>Milium effusum</i> L.	I +	I 1	I 1	I +
<i>Phalaris arundinacea</i> L.	III 1	IV 1	I 1	I 1
<i>Poa trivialis</i> L.	IV 2	IV 2	II 2	IV 1
<i>Rumex sanguineus</i> L.	II 1	I 1	I 1	I +
<i>Urtica dioica</i> L.	V 4	V 4	IV 2	III 1
<i>Geum urbanum</i> L.	I 1	III 1	IV 2	IV 2

	Willow bush	Willow tree	Ash-alder	Alder
<i>Filipendula ulmaria</i> (L.) Maxim.	II 1	I 1	I 1	III +
Alno-Ulmion/Alnion				
<i>Carex sylvatica</i> L.			I +	I 1
<i>Juncus bulbosus</i> L.		I +		I +
<i>Dryopteris filix mas</i> L.			I +	I +
<i>Dryopteris carthusiana</i> (Vilars) Fuchs			I +	I +
<i>Circaea lutetiana</i> L.			I 1	I +
<i>Arrhenatherum elatius</i> P. Beauv. ex J. Presl & C. Presl		I 1	I 1	
<i>Dactylis glomerata</i> L.		I +	I 1	
<i>Athyrium filix femina</i> (L.) Roth			I +	I 1
<i>Ranunculus repens</i> L.		I 1	I +	
<i>Galium mollugo</i> L.		I 1		I +
<i>Scrofularia nodosa</i> L.			I +	
<i>Veronica montana</i> L.		I 1	I 1	I +
<i>Valeriana dioica</i> L.		I +	I +	I +
Exotics				
<i>Vinca minor</i> L.			I 1	
<i>Fallopia x bohemica</i> Chrtek & Chrtkova	III 2	IV 2	I 1	II 1
<i>Heracleum mantegazzianum</i> Sommer & Levier	I +			
<i>Solidago gigantea</i> Aiton		I 2		
Therophytes				
Salicion				
<i>Bidens tripartita</i> L.		I +		I +
<i>Impatiens noli tangere</i> L.			I +	I +
<i>Chenopodium album</i> L.	I +	I +		
<i>Polygonum aviculare</i> L.	I 1	I 1		I +
Alno-Ulmion/Salicion/Alnion				
<i>Galeopsis tetrahit</i> Cranz.	I +	I 1	II 1	II +
Exotics				
<i>Impatiens glandulifera</i> Royle	V 3	IV 2	I 1	II 1

(1) and (2) Softwood forest communities (Salicion alliance).

The softwoods included two associations: a willow tree community (*Salicetum albae* Issler 1926) and (2) a willow bush community (*Salicetum triandrae* Tuxen 1931). Softwoods (willow-dominated forests, i.e. willow tree or willow bush forests, mosaics of willow/willow bush, willow/ash forest) were growing within the active zone near the Moselle at two topographical levels (terraces and channels). The willow tree forests and willow bush forests formed distinct patches as well as mosaics. The willow/ash forests were situated in zones where the river had been stabilized by incision.

The total number of 215 patches included mosaics and mixed willow/ash communities and covered 300.2 ha (the mean range of surface areas: 0.1 to 13 ha). Willow tree communities were the most widespread forests of the area with a total surface of 152 ha. The perimeters of willow bush were relatively high because they followed the meandering of the channels.

The location of the softwoods along active channels explained the relatively simple architecture of all the softwood communities (i.e. two main strata composed of the canopy and high grasses with scattered bushes), the luxuriance of the ground layer (grasses, herbaceous vines),

TABLE II
Characteristics of forest patches (surface, distribution, phytosociological type) in the upper Moselle valley

Phytosociology	Distribution	N patches	Total area (ha)	Range of patch size (ha)	Mean perimeter (m)	Conservation status high	Conservation status low
<i>Salicetum triandrae</i>	Terraces within the active zone of the Moselle	46	34.7	0.6 - 4	4446 ± 40	13.5	21.2
<i>Salicetum albae</i>	Old channels within the active zone of the Moselle	99	152.6	0.1 - 13	695 ± 52	53.5	99.1
<i>Salicetum albae/Salicetum triandrae</i>	Terraces with old channels within the active zone of the Moselle	19	23.6	0.3 - 3.2	9072 ± 0.2	4.6	19
<i>Salicetum albae/Pruno-Fraxinetum</i>	Stabilized zones (terraces) within the active zone of the Moselle	51	89.3	0.1 - 6.1	8729 ± 0.4	13.1	76.2
<i>Pruno-Fraxinetum</i>	Terraces on the edges of the plain	123	175.5	0.2 - 16.6	731 ± 36.7	36.7	138.8
<i>Alnetum glutinosae</i>	Isolated old channels on the edges of the plain	53	65.3	0.1 - 4.3	12 245 ± 36	30.5	34.8
<i>Pruno-Fraxinetum/Alnetum glutinosae</i>	Terraces with old channels on the edges of the plain	6	5.6	0.8 - 3.3	6141 ± 3.5	3.4	2.2
	Total	397	546.6			155.3	391.3

and the low number of woody species particularly in willow bush (only 12). Many exotics were found in the softwoods, in particular *Fallopia x bohemica* Chrtek & Chrtkova and *Impatiens glandulifera* Royle which grow in large dense stands and can reach up to 2 m high.

Compared with the willow communities of adjacent plains (the Fecht, Giessen, Andlau Rivers), the softwood forests of the upper Moselle valley lacked poplars (*Populus nigra*, *P. x canescens*; *P. tremula*; *P. alba*), but were richer in *Salix*. Saplings of poplars were however observed within fallows.

(3) *Ash-alder forest association* (Pruno-Fraxinetum Oberdorfer 1993, Alno-Ulmion alliance).

The ash-alder forest community grows preferentially on moist terraces on the edges of the plain where flooding is less erosive. This forest community was the most prevalent with 123 patches and a total surface of 175.5 ha. This community also had the largest patches (up to 16 ha). It was characterized by a relatively complex architecture (at least four layers) and higher species richness (98). *Fraxinus excelsior* L. occupied the canopy with *Quercus robur* L. and *Acer platanoides* L, while *Prunus padus* L. dominated in underlayers. Hemicryptophytes greatly dominated over geophytes and therophytes (78.8 versus 12.1 and 1.7%, respectively). Among the herbaceous species, geophytes were rather scarce in the spring, except for *Ficaria verna* Huds. In contrast, the number of exotics was relatively low compared with softwoods. No exotics were able to reach the coverages of the willow forests.

Compared with the ash-alder forest communities described in the Rhine plain, the Moselle forests lacked species like *Malus sylvestris* (L.) Mill. (totally absent), *Carpinus betulus* L., *Ulmus minor* Mill., *U. laevis* Pall., *Prunus avium* L., *Tilia cordata* Mill. (very rare). Poplars (*Populus nigra* L., *P. alba* L.) were also very rare. The ash-alder forest communities in the Rhine were also richer in geophytes in the spring and the geophytes covered greater areas (up to 80% for *Allium ursinum* along the Fecht and the Andlau).

(4) *Alder forest community* (Alnetum glutinosae, Alnion alliance).

Alder forests develop in hydromorphic conditions (high groundwater levels even in summer) and far from the river. This forest community was present in 53 patches and covered a total of 65.3 ha. The patches were rather small but higher perimeters were found here (a mean of 12.245 m), because they followed the meanders of old channels far from the river. Alder trees are able to withstand long periods of water stress mainly due to groundwater rising. These forests are only flooded by great floods. The canopy of this alder forest community was not totally closed because of the permanence of open water surfaces rich in *Carex* species or other hygrophilic grasses.

Water stress explained the dominance of alder over willow and the rather low number of woody species (27). The characteristics of the ground layer were similar to those of ash-alder (dominance of hemicryptophytes, rarity of exotics) but geophytes were rare because of hydro-morphy. These characteristics are similar to those from the Rhine valley.

(5) *Probably the Oak-elm-ash association* (Stellario-Carpinetum Oberdorfer 1993; Carpinion alliance).

This fifth forest community was so scarce and so small that it was not possible to make a phytosociological diagnosis. But comparison with other adjacent plains suggests that this hardwood forest, which occupies the higher terraces on the edges of floodplains now devoted to agriculture, must have been present in the remote past.

CONSERVATION STATUS

Only 28.4% of the woodlands presented a high degree of conservation, i.e. natural architecture. These woodlands were willow woodlands of different ages, alder communities and ash-alder communities, most more than 50 years old. These were considered as the most interesting and beautiful forest patches of the plain. The other 71.6% of woodlands, which may have been issued from ancient pastures or presented local extensive managements or plantations, showed a relatively lower degree of conservation. But all were now left to free development, which gives hope for a favourable evolution in the future.

EXOTIC SPECIES

Species richness in the Moselle plain

Ten neophytes (introduced in the 18th and the 19th centuries) and two archaeophytes (*Juglans regia* L. and *Vinca minor* L.) were found in the floodplain of the Upper Moselle, but these have not all integrated the forests. Four were trees (*Juglans regia*, *Acer negundo* L., *Robinia pseudoacacia* L., *Ailanthus altissima* (Mill.) Swingle) and two were woody climbers (*Parthenocissus quinquefolia* (L.) Planch; *Fallopia baldschuanica* (Regel)). Among the herbaceous plants, one was annual (*Impatiens glandulifera* Royle), and the others were perennial (*Heracleum mantegazzianum* (Somm.) Lev, a monocarpic plant; *Fallopia x bohemica* Chrték & Chrtkova, *Helianthus tuberosus* L., *Solidago gigantea* Ait., *Vinca minor* L.). Except for *Vinca minor*, all the herbaceous plants were tall (2 to 3 m) and all are able to form exclusive stands. *Parthenocissus quinquefolia* and *Solidago gigantea* can reach the heart of the willow forests, but were here limited to gaps and forest edges. *Helianthus tuberosus* was abundant in the open, but could become established in bush willow on islands or river banks. *Parthenocissus quinquefolia* also displayed a strong capacity for colonizing abandoned meadows and pastures, creeping on the soil or crawling on bushes or stands of other exotics. Stands of exotics growing in the open area were often directly connected with stands growing in adjacent forests. *Fallopia x bohemica* and *Impatiens glandulifera* were the most frequent exotic plants of the area, in particular along the main channel of the Moselle where they formed dense, exclusive stands several metres long. They had developed clonal, intolerant stands within willow and willow-ash woodlands.

Factors promoting invasion

Only the two most abundant plants (*Fallopia x bohemica* Chrték & Chrtkova and *Impatiens glandulifera* Royle) were included in this analysis. The main effect on *Impatiens glandulifera* and *Fallopia Japonica* are presented in Tables III & IV, respectively: Kruskal Wallis test revealed that Habitat was the only significant effect ($p < 0.05$). Mann Whitney pairwise test revealed that habitats 1 and 2 differed significantly from habitat 3 (average rank: habitat 1: 58.8; habitat 2: 49.3; habitat 3: 83.4; $p < 0.05$). The test revealed also a significant difference for both age and habitat effect for *Fallopia japonica* only.

TABLE III

Abundance of Impatiens glandulifera (n = 132) as a function of habitat, age, floodability and area covered

Main effects	H	DF (degree of freedom)	P (probability)
Habitat	31.17	2	0.001
Age effect	0.03	1	0.86 NS
Floodability	0.34	1	0.45 NS
Area	2.63	2	0.30 NS

TABLE IV

Abundance of Fallopia japonica (n = 133) as a function of habitat, age, floodability and area covered

Main effects	H	DF (degree of freedom)	P (probability)
Habitat	20.63	2	0.001
Age effect	11.36	1	0.001
Floodability	0.27	1	0.60 NS
Area	98.85	2	0.24 NS

On habitat effect, Mann-Whitney pairwise comparison showed that Alder and Ash-alder did not differ significantly, but both differed from Willow (Average rank: Alder: 61.1; Ash-alder: 53.9; Willow: 81.5; $p < 0.05$).

On age effect, Mann-Whitney procedure showed that young forest exhibited significantly more *Fallopia* abundance as compared with old ones (average rank: 86.6 vs 62.5; $p < 0.05$).

DISCUSSION

RELATIONSHIPS BETWEEN THE FOREST COMMUNITIES, THE HYDROLOGICAL REGIME AND HUMAN PRESSURE

The pattern of softwoods and hardwoods depended globally on two factors: the hydrological regime and human pressure. Flood frequency and intensity determine the gradients of moisture and topography, which then selected the forest communities and determined the successional processes. Indeed, softwoods and hardwoods are interpreted as different steps in the same succession, making it clear that *Salix* and *Populus* are the first tree genera to invade river banks. After a few decades within dynamic flooding events, these species show declines in growth and lack of reproduction whereas *Fraxinus*, *Quercus* and *Acer* begin to establish themselves (Ellenberg, 1988; Schnitzler, 1995b). In the upper Moselle valley, hardwood species have begun to invade willow communities in sectors where the river bed has incised and the river dynamics have partially stabilized.

Human pressure also determines land-use legacies (which influence the course of successions, Prevosto *et al.*, in press), as well as the surface areas of the patches: forest expansion was more limited along the river edges where cultures and pastures were widespread, than within the active river channels. These two factors explain why after several decades of free development, the surfaces of forests and fallows were so modest. Noteworthy was the lack of expansion of the oak-elm-ash forests which indicate better plain zones for agriculture.

WHY DO THE MOSELLE FORESTS DIFFER FROM THE FORESTS OF THE UPPER RHINE VALLEY?

The forests of the Moselle are small, highly fragmented and young, in contrast with the Rhine plain forests, which are much older (at least 200 years according to the Cassini map) and wider (hundred of hectares). Moreover, the Moselle valley was nearly totally deforested, which eliminated many sources of propagules. In this case, recolonization rates for species of low dispersal capacity like zoochorous species or geophytes are recognized as very slow, particularly if the soils were fertilized over many years of agricultural practices (Hermy & Stieperaere, 1981; Hermy *et al.*, 1999; Verheyen & Hermy, 2004). In particular, phosphorus from agricultural use prevents mycorrhization (Boerner *et al.*, 1996).

The exotics present in the Moselle valley are also found in the Rhine plain and in most floodplain forests of Western and Central Europe. Their impacts on successions are very high (Planty-Tabacchi *et al.*, 1995; Schnitzler *et al.*, 2007), particularly in willow communities. These communities are known to be more vulnerable to plant colonization, both native and exotic, in close relation to flood events which regularly create bare substrates, facilitate the spread of seeds and propagules (Tabacchi *et al.*, 1998; Gurnell, 1999), and present high fluctuations in resources (Davis *et al.*, 2000).

In the Moselle valley, however, these processes may be enhanced by the high fragmentation of the woodlands which increases edge effects (Honnay *et al.*, 2002). *Fallopia x bohemica* and *Impatiens glandulifera*, the most common exotic plants in the study area and the most widespread in alluvial plains (Beerling, 1993; Beerling & Perrins, 1993; Bailey, 2005; Bailey & Wisskirchen, 2006), integrated the willow successions after 1950 and their role in fallows has increased steadily, sometimes preventing tree establishment. The size and shape of willow patches were not found to play a significant role in their expansion. Similar results were found in the mesic forests of Indiana where forests have been highly fragmented by agriculture (Brothers & Spengarn, 1992). One possible explanation proposed by these authors is that small

forests produce a higher protective response by developing a dense wall of vegetation that may shield the wood against invasion through reduced interior light levels.

Exotics were scarcer in the ash-alder and marsh alder stands whatever their age. The biotic resistance was based on a multistorey architecture which decreases light availability and makes resource levels less accessible. In ash-alder, however, some exotics (*Robinia pseudoacacia*, *Parthenocissus quinquefolia*, *Fallopia baldschuanica*, *Fallopia x bohemica* or *Impatiens glandulifera*) were able to establish in gaps, gap edges or above the canopy (for lianas).

Virginia creeper (*Parthenocissus quinquefolia*), a woody climber from the Vitaceae family, is rarely recorded as invasive in the literature, but its expansion along roads, railways, large rivers and fallows is a reality in Europe. This liana has expanded vigorously in the Moselle floodplain, probably from nearby gardens. Its faculties for invasion may come from its advantages over native European climbers, e.g. a higher net photosynthesis value ($28 \text{ } \mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$ in full light, Teramura *et al.*, 1991). Other exotics like *Heracleum mantegazzianum* Sommier & Levier, *Ailanthus altissima* (Mill.) Swingle, or *Polygonum polystachyum* C.F.W.Meissn, are still at modest densities along pathways of the upper Moselle valley, but they are recognized as highly invasive in Europe, and may become invasive in the region in the near future.

ARCHITECTURE AND DEAD WOOD

In contrast to the managed forests of the Rhine valley, the woodlands of the Moselle are rich in dead wood. The best preserved of the oldest patches displayed significant amounts of dead wood. The causes of tree mortality are many in the Moselle plain: i) fungal diseases like the alder disease (caused by the *Phytophthora alni* fungus) and Dutch elm disease (caused by *Ophiostoma ulmi* and *O. novoulmi*); ii) stress due to abnormal variations in water conditions following gravel-pit digging; iii) bank erosion for forests growing within the active channels; iv) flooding, which decreases soil cohesion by the action of the water flow pattern and the rising of ground waters; v) beaver activity; and vi) the competition inherent to natural forest dynamics (succession, maturation of older stands).

Dead wood recruitment increases the qualitative value of biodiversity by offering niches for the majority of threatened European species (Bobic *et al.*, 2005; Paillet *et al.*, 2009). But large woody debris is also an important component of river systems, contributing to geomorphic processes (bank stabilization, sediment retention, water flow processes, Gregory & Davis, 1992; Piegay *et al.*, 2003; Gautier *et al.*, 2000), and habitat diversity, and providing food resource and shelter for benthic macrofauna, fish and specialist mammals like beaver (Johnston & Naiman, 1987; Tabacchi *et al.*, 2000). The amounts of coarse woody debris were, however, still modest compared with ancient forests (Harmon *et al.*, 1986; Thévenet *et al.*, 1998; Vandekerkove *et al.*, 2009) and probably the Ain valley (Piegay & Gurnell, 1997; Lassetre *et al.*, 2007), although a quantification of the woody debris along and within the river is lacking in the upper Moselle valley.

THE CONCEPT OF FERALITY

The increase of woodlands in the Moselle valley, in association with spontaneous forest dynamics can be considered as a sign of modestly successful recovery of natural and autonomous ecosystems after centuries of deforestation. It is therefore important that these forests continue their free expansion and sylvigenetic maturation over the long term, in order to allow connections between patches, to re-create the whole range of natural habitats and species. This would ensure as well full functional links between terrestrial and aquatic communities.

In order to achieve this goal, the Conservatoire des Sites Lorrains has focused on minimizing or stopping all intervention in forest expansion and forest dynamics in the sectors where it is the owner or lodger (i.e. 380 ha), by progressively eliminating pasture with the agreement of local farmers. An upland forested surface (2 ha) on a hill adjacent to the river, was also bought by the Conservatoire in order to continue to furnish dead wood to the river. The large-scale re-wilding of the Natura 2000 zone nevertheless remains difficult because of the persistence of various land-uses (local use of hydroelectricity, pastures or cultures, gravel-pits) and the presence of roads and isolated houses.

The upper Moselle valley could become a reference area, free from silvicultural and agricultural use wherever possible, for other floodplains of Europe. By so doing, nature conservationists and decision makers would encourage respect for spontaneous successions in floodplains and change the perception of a decline in land use as a failure of human society. But we should not forget that the recovery of the native biotic organization of processes is particularly long for some species (Paillet *et al.*, 2009; Vandekerhoven *et al.*, 2009) and sometimes requires large connected areas (Oldeman, 1990). Indeed, the re-creation of old-growth floodplain forests will take centuries. Moreover, as a result of persistent, past human uses, spontaneous successions may develop differently than they would have if never influenced by human land use. Similar conclusions were drawn about successions issued from formerly cultivated lands in other alluvial plains (Dufour, 2005) as well in upland sites (Prevosto *et al.*, in press).

The return of cultivated lands to the wild state can be likened to the notion of ferality used by zoologists. A feral animal is one that has “left domestication and is able to reproduce outside of domestication”, which describes what occurs at the landscape level. Feral landscapes were once cultivated and were then left to spontaneous development, with processes deriving fully or in part from prior land uses. In other words, feral landscapes are issued from a process of “dedomestication”. Of course, feral nature types will never return to pristine ecosystems because succession processes will depend on these prior land uses. They will take different courses and different lengths of time, depending on environmental factors, novel species assemblages, and the specific links between them (Marris, 2009).

But in reality, we have no other choice to recover floodplain forests in the anthropo-dominated world, and we must accept that organisms cannot respond to pre-conceived models of how communities should be when the context has changed profoundly. Such landscapes provide also interesting evolutionary perspectives in the long term, and more research on spontaneous forest succession in the context of changing uses is called for.

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