Global Ecology and Biogeography Letters (1997) 6, 397–406

RESEARCH LETTER

Contemporary floodplain forest evolution along the middle Ubaye River, Southern Alps, France

HERVÉ PIÉGAY and PIERRE-GIL SALVADOR *CNRS-UMR 5600 'Environnement-Ville-Société', 18 rue Chevreul, 69362, Lyon, France and U.F.R. de Geographie, Universite des sciences et techniques de Lille, Villeneuve d'Ascq, 59655 cedex, France*

Abstract. Contemporary evolution of forest margins was studied on the middle section of the Ubaye, a gravel bed river of the Southern Alps. A recolonization of the valley flat by *Pinus sylvestris* which began around 1920–1925 is described. This forest expansion was accompanied by a reduction of active channel area and by local changes in geomorphological pattern, shifting from braided to meandering. This biometamorphosis, explained by the decrease of coarse bedload and peak flows, was primarily related to human activities—watershed reforesting and torrent control, abandonment of agro-pastoral activities—perhaps naturally reinforced by the end of the Little Ice Age climatic degradation. Moreover, spatial variations of forest-channel contact are also shown on the scale of a few decades, for the period of 1945–1990. These variations were also apparently controlled by hydrology and bedload. Management of these floodplains, characterized by complex, dynamic and fragile ecosystems, is discussed.

Key words. Riparian forest, history, watershed land use, landscape evolution, Ubaye river, French Alps.

INTRODUCTION

The geographical distribution and the physiognomic characteristics of vegetation units bordering braiding or free-meandering rivers change with time (Pautou & Décamps, 1985; Malanson, 1993). The internal structure and spatial extension of these units are affected by factors such as human activities, maximum discharge, and bedload supply. Each of these may change over a few decades or even several centuries (Schumm, 1977; Bravard *et al.*, 1986). The geographical dynamics of the riparian forests and more specifically their progression in channels are thus controlled by Holocene climatic variations (Nanson, Barbetti & Taylor, 1995). On a shorter time scale, discharge alteration caused by dams or irrigation can also explain forest expansion in active channels (Johnson *et al.*, 1995 ; Miller *et al.*, 1995).

Most of the European riparian forests are relatively young (Piégay, 1995). Many authors have stressed the absence of forests in the floodplains of the rivers of southeastern France in the late 18th and 19th centuries (Bravard, 1986; Peiry, 1988). Except for riparian forests located on old international boundaries, like the Rhine or the Danube (Yon & Tendron, 1981), the pristine corridors were cut down during the Middle Ages. The causes and the chronology of afforestation during the contemporary period should be examined.

This article aims to describe and explain the 19th and 20th century evolution of the riparian vegetation of an alpine river, the Ubaye (Fig. 1).

STUDY AREA

The Ubaye is a 5th order tributary of the middle Durance. It is a steep river (1.3%) whose mean annual discharge is 10.1 $m^3 \cdot s^{-1}$ (Table 1). It is characterized by a transitional snow regime (Pardé, 1925). The maxima of May and June combine with a secondary rainfall maximum in Autumn. The study reach is at a high altitude (900–1200 m), and covers 24 km from Jausiers to Lauzet-Ubaye (Fig. 1). This alluvial corridor, oriented west east, becomes progressively narrower downstream, as the last 6 km before the confluence are in gorges. This steep corridor is controlled by alluvial fans, many of which are no longer active. In open parts of the basin near Barcelonnette,

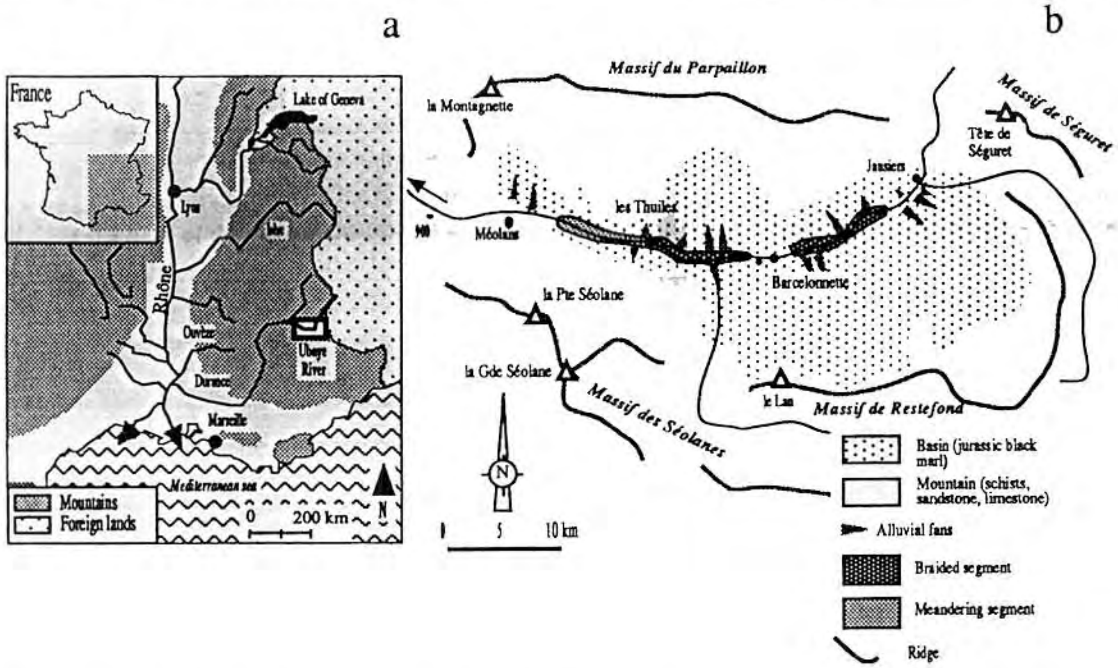

Fig. 1. The Ubaye river in the Southern Alps (a) located in a complex morphostructural environment (b) (after the *Carte géologique de Barcelonnette* 1/50 000°, BRGM, 1972).

Table 1. Geographical characteristics of the Ubaye.

Stream order:	5
Length (km):	82
Watershed area (km^2):	970
Watershed geology:	Flysch and black marls
Mean annual discharge at Barcelonnette ($m^3.s^{-1}$)	10.9
1 in 1.5 year discharge* ($m^3.s^{-1}$)	62 (B.H.)
1 in 10 year discharge ($m^3.s^{-1}$) (B.H.)*	130
Hydrological regime (Pardé, 1925)	Snow regime influenced by Mediterranean climate
Altitudes (m)	900–1210
Slope (m per km)	12.92
Stream power ($W.m^{-2}$)	30–40† à 400–600‡
Sinuosity rate	1.06

* Gumbel adjustment.
† In the braiding segment, ‡ in the downstream gorges.
B.H.: HYDRO data bank/Barcelonnette station (1903–1990).

the river has an active channel of roughly 300–400 m in width. In narrower sectors such as the Thuiles-Méolans segment, the channel meanders. Meander amplitude becomes increasingly constrained by valley narrowness downstream, while the fluvial pattern becomes less sinuous and straight.

The valley bottom is colonized by *Pinus sylvestris*, a typical species of the inner Alps. It generally occupies the entire tree layer, the undergrowth layer being filled by *Buxus sempervirens*, *Amelanchier vulgaris* and *Juniperus sabrina*. This zonal vegetation colonizes gravel bars, succeeding to a pioneer unit typical of very dry environments and dominated by *Hippophaë rhamnoïdes*. *Pinus sylvestris* occupies areas where pioneer and post-pioneer hygrophile species such as *Salix eleagnos*, *Salix triandra*, *Populus nigra*, *Alnus incana*, usually grow. These traditionally riparian species were indeed observed on the Ubaye. However, as they are at the limit of their zonal distribution, they do not constitute the structure of the Ubaye forest corridor.

METHODS

Analysis of historical change in vegetation

Archive documents were the primary source of information. Maps, graphs, and photographs, as well as written reports, are of particular value in studying historical change in vegetation (Hooke & Redmond, 1989 ; Girel, 1994). The photographic archives of the Mountain Terrain Restoration (MTR) agency provided views of the watershed dating as far back as 1860. Several of them show the Ubaye, notably at the confluences with the Riou Bourdoux and the Gimette torrent.

Nineteenth century land use was studied using the Napoleon land register. In the study area, these documents were established between 1810 and 1842. General land register maps (1/10000° or 1/20000°) were used to evaluate the width of the active channel, the area of which was calculated after geographical rectification and scale transformation for maps of each of the riparian communities. As historical riparian land use is not indicated on section maps (1/5000°), but must be looked up in the section register, land use has only been analysed for the Thuiles segment.

For more recent periods, five series of vertical air photographs were used: 1948, 1956, 1973, 1982 and 1990. Their scales vary from 1/37000° to 1/21000°. These series of photographs were used to assess historically and quantitively the area occupied by vegetation units along the study reach. Floodplain cross-sections were systematically positioned every 250 m. For each cross-section representing a 250 m channel course, the widths of landscape units were measured: active channel (gravel bars and wet channels), shrubby units, tree units, prairies and moors, developments (municipal dump sites, water treatment stations, campgrounds, etc.). As explained by Piégay (1995), surface S occupied by each unit type u was estimated as shown below:

$$Su = \sum_{n=1}^{120} 250\, u_i$$

where u_i is the width of a unit type on a cross-section i and 250 m is the constant distance in metres between two cross-sections. This sampling method allows us to estimate vegetation unit type area with an error of <5%.

Dendrochronological analysis was undertaken in the floodplain near the Thuiles and in the braided section upstream from Barcelonnette not only to confirm observations obtained from archive documents, but also to ascertain chronology, as no precise document was available for the period from 1894 to 1948. This study used principles previously developed by Everitt (1968) and Nanson & Beach (1977) who studied recent floodplain history based on the age of pioneer species such as *Populus balsamifera*. *Pinus sylvestris* is a good indicator of the abandonment of gravel bars in the rivers of the southern Alps. As it is both a pioneer species and remains present in mature vegetation units, it enables dating of most of the topographic levels in the valley bottom. Eleven trees, considered to be the biggest, were sampled at 1.3 m above the ground (Fagot *et al.*, 1989) along two floodplain cross-sections.

Causes of historical change in vegetation

The hydrological series and the evolution of watershed land use were successively studied and compared. Historical variability of bedload was not analysed due to a lack of data. However, bedload changes were examined with regards to channel geometry modification, peak flow evolution, and change in forest cover. Annual peak flow evolution during the 20th century was analysed and compared with the recent evolution of riparian vegetation cover. Results were based on the HYDRO data bank of the Ministry of Agriculture which has supplied continuous data series from the Barcelonnette station from 1904 to the present day.

Nineteenth century watershed land use was studied using local municipality land register statistics. The items 'General Section Summary' and 'Recapitulation of Capacity and Taxable Income' provide a summary of the area occupied by each type of culture at the community level. It was thus possible to estimate the forest area of a watershed at the middle of the 19th century.

These sources enabled us to determine the influence of watershed vegetation cover evolution upon changes in peak flow and bedload (Combes, Hurand & Meunier, 1994) which greatly affect riverbed geometry (Schumm, 1977) as well as the riparian vegetation.

RESULTS

A very changed riparian forest extension

Two major changes were observed over the last century: a riparian afforestation in the 1920s and a spatial fluctuation of forest-channel borders after the 1950s. Napoleon land register maps enabled us to determine that around 1830, the Ubaye occupied most of the valley bottom, whereas agricultural land use extended up to the edge of the active channel. The area of active channel decreased from 246–252 ha to 174 ha between the first third of the 19th century and 1948. Correspondingly, valley bottom tree units were absent on the Napoleon land register, but covered 209 ha in 1948. A detailed study of the Thuiles-Rioclar Torrent segment, based on 1/5000 section maps confirmed this situation. The buffer strip observed on the land register, separating the wet channel from private plots, corresponds to the gravelly and non-vegetated part of the active channel. This is confirmed by the fact that parcels of very limited economic value are shown on the map (termed 'vacant' or 'waste land'). Indeed, an 1894 photograph shows a wide bed comprised of non-vegetated gravel bars at the confluence between the Ubaye and the Gimette torrent. On this segment, the active band decreased from 81 ha in the early 19th century to 19 ha in 1948 whereas the riparian forest, non-existent in the early 19th century, covered 54 ha in 1948.

The active channel area was colonized by *Pinus sylvestris*. Dendrochronological analysis in the Thuiles sector indicates forest recolonization of the active channel took place around 1920–1925 based on the age of *Pinus sylvestris*, which is estimated to be 75 years ±7 years. Recolonization was accompanied by fluvial metamorphosis, changing from a braided pattern to a sinuous single-bed pattern, as well as by bed incision. The topographical cross-section of this sector demonstrates that the actual bed is 2 m lower than it was 75 years ago.

Air photographs indicate that the forested area remained stable between 1948 and 1990, as tree units went from 209 ha to 196 ha, i.e. a slight reduction of 6% over a 42-year period. The active channel was also restricted during this period mostly due to human installations developed in the corridor downstream from Barcelonnette. This new factor modified the trend observed since the 1920s where the respective area change of the active channel and of the riparian forest were opposed and correlated. Nonetheless, recent evolution of floodplain vegetation and the active channel can be divided into two sequences (Table 2). The 1948–1973 period, notably between 1948 and 1956, was characterized by the reduction of forest area in favour of the active channel area. These changes, lasting only two decades, were in opposition with the trend observed at the beginning of the century. The 1973–1990 period shows forest progression, and additional restriction of the active channel. However, the forest gained only 9 ha, whereas the active channel lost 40 ha. A great part of the active channel was colonized by pioneer units. These units were observed in the 1982 air photographs (+19 ha between 1982 and 1990). The remainder of the active channel, which disappeared between 1973 and 1990, has been modified by human activities (water treatment stations, camping grounds, public dump sites).

In contrast with the vegetation explosion of the early 20th century, changes were observed in the riparian forest—active channel contacts, over shorter time periods and in smaller areas. These changes appear to be cyclic. A relationship thus exists between the evolution of active channel width measured on 250 m equidistant cross-sections for the periods 1948–1973 (Y) and 1973–1990 (X). This evolution is more typical in the braided reach located upstream from Barcelonnette as shown by the following equations:

Entire reach: $Y = -0.71X - 4.5$ ($r^2 = 0.56$; $P<0.0001$);
Reach upstream from Barcelonnette: $Y = -1.19X - 25.9$ ($r^2 = 0.92$; $P<0.0001$).

In fact, sector analysis from 1948 to 1990 shows a complex geographical evolution (Fig. 2). The 1948–73 vegetative colonization of the active channel primarily affected the segment upstream from Barcelonnette where the forest decreased by 44% (Table 2). Such decreases were also occasionally observed downstream but not in any case throughout the entire period. From 1973 to 1990, the sector located upstream from Barcelonnette showed major continuous vegetation colonization of the active channel whereas downstream,

Table 2. Area change of the active channel and floodplain forest between 1948 and 1990 in hectares.

Date	Active channel area		Floodplain forest area	
	Entire segment	Upstream from Barcelonnette	Entire segment	Upstream from Barcelonnette
1948	183.3	65.7	209.1	34.6
1956	205.8	71.9	189.2	31.5
1971	206.6	84.1	186.9	19.2
1980	178.0	71.2	194.9	26.2
1990	165.5	63.4	195.6	34.0

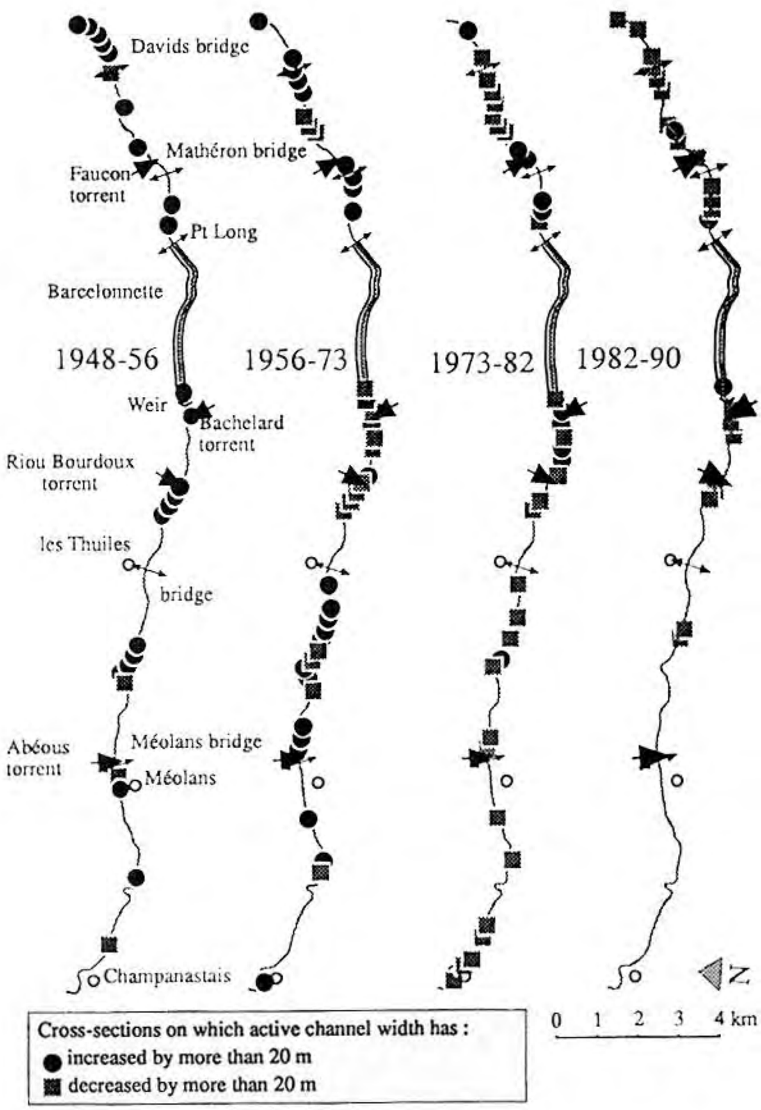

Fig. 2. Active channel area evolution on the middle Ubaye for the periods 1948–1956, 1956–1973, 1973–1982 and 1982–1990 (widths estimated every 250 m cross-section from air photographs).

these changes were discontinuous and were only apparent between 1973 and 1982.

Causes of contemporary fluctuations of the forest margins during the 20th century

New territorial management at the end of the 19th century

Before 1880, the reach located upstream from Barcelonnette was characterized by a dynamic equilibrium corresponding to high peak flow and abundant bedload. This segment is typical of alpine fluvial landscapes which registered major modifications between the late 14th century and the 19th century, evolving towards active braiding. While for many years mountain populations were considered to be responsible for this evolution (Sclafert, 1933), recent views have focused on the influence of the Little Ice Age climatic degradation, affecting slopes whose vegetation cover was altered by overgrazing. This led to an intensification of flooding and to increased bedload supply which, in turn, produced channel aggradation and widening (Bravard, 1989; Salvador, 1991). Thus the Ubaye occupied the entire valley flat when human society exploited slopes to the fullest by combining dominant pastoral activities with subsistence crops.

The riparian forest development in the active channel from 1920 to 1925 was the result of reduced rejuvenation processes like peak flow and bedload supply, mainly due to a slope afforestation policy and torrent correction works undertaken in the late 19th century by the MTR agency (law of 28 July, 1860). The largest restoration perimeter defined in France took place in the Ubaye watershed (Demontzey, 1882). As early as 1892, 3500 ha were reforested with Austrian black pine while 8589 ha had already been reforested in 1905. Comparison of data from the old land register (1813–1842) and the local district inventory (1988) shows that the forest area of the thirteen local districts of the watershed changed from 101 km^2 to 324 km^2. Forest covered only 10.3% of the watershed in the early 19th century, but now occupies 33% of the watershed area. This recolonization has affected all the local districts, as 70% of them have more than doubled in forested area (Fig. 3). Indeed, the proportion of forested land in the watershed is now superior to the national average (25%). The effort to reforest slopes was accompanied by weir constructions on the more dangerous torrents, with the intention of 'extinguishing' them. Dry stone wall weirs were initially built on less dangerous torrents such as the Faucon in 1861, then in 1866, on the Riou Bourdoux, nicknamed 'the monster' (Combes, 1982).

This reforestation policy was probably made easier by rural exodus, which led to reduced demographic and pastoral stresses. This social change also favoured spontaneous forest recolonization on slopes. From 1876 to 1990, the population decreased by 50–60% in the Barcelonnette basin and by more than sixfold in the upper valley. Current population densities do not exceed 30 inhabitants/km^2 in the watershed with only 0.96 inhabitants/km^2 in the St Paul commons. In fact, since 1860, when the population peaked in this region, the population has decreased by 75 to 80%.

The mobility of channel-forest contact

The cyclic evolution of the forest margin-active channel contact during the recent period appears to be controlled by fluctuations in hydrology and bedload. A progressive increase in peak flow between 1941 and 1957 shows close chronological ties with active channel expansion (+12.3% from 1948 to 1956) and a correlated decrease in riparian woodlands (−10.5%). In contrast, the 1970–1990 period is characterized by reduced peak flow and vegetative recolonization (+5%) of the active channel (Fig. 4).

As no air photographs were available from 1956 to 1973, the influence of the 1957 millennial flood could not be precisely determined but the reduction of riparian vegetation was observed before this exceptional event took place, at least during the period 1948–56. Lecarpentier (1963) remarked that the 1957 flood impacts had been largely attenuated below the braided section upstream from Barcelonnette. The exceptional dimensions of the floodplain in this sector greatly contributed to attenuating the flood, favouring bedload deposition. Thus the millennial flood caused comparatively little damage to the riparian vegetation in the study area, excepting the upstream sector which is characterized by specific changes.

Comparative analysis of 1908 and 1991 long profiles shows considerable aggradation of the Ubaye in the reach upstream from Barcelonnette (Fig. 5). Dendrochonological analysis shows that the units colonized over the last 20 years are even higher in altitude than those colonized by *Pinus sylvestris* between 1920 and 1930. This confirms the importance of the 1957 flood in the aggredation of the valley bottom in this sector. Conversely, dikes downstream were destabilised by a 0.5–1 m bed incision.

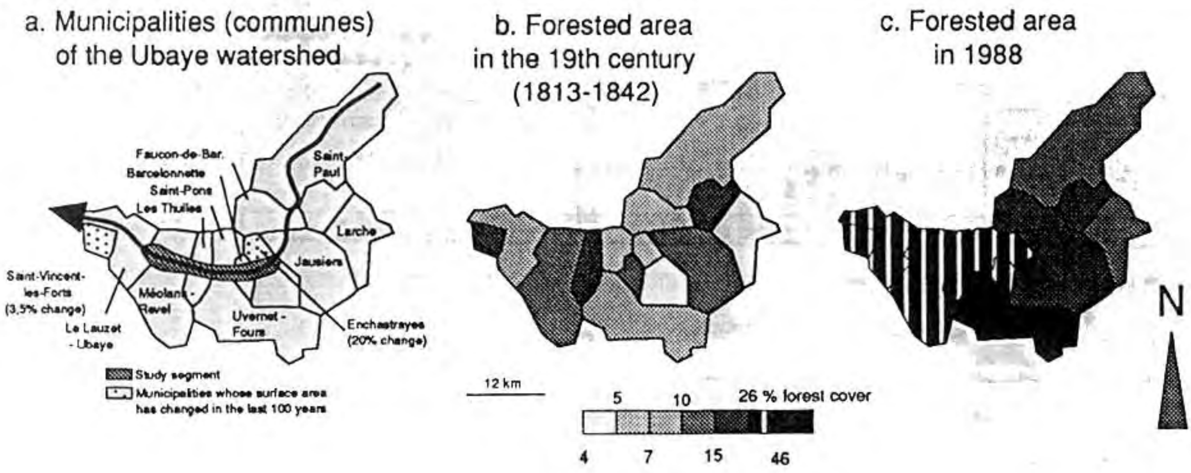

Fig. 3. Evolution of forested lands during the 19th and 20th centuries, municipalities of the Ubaye watershed (*after the Napolean cadaster and the 1988 Communs Inventory*).

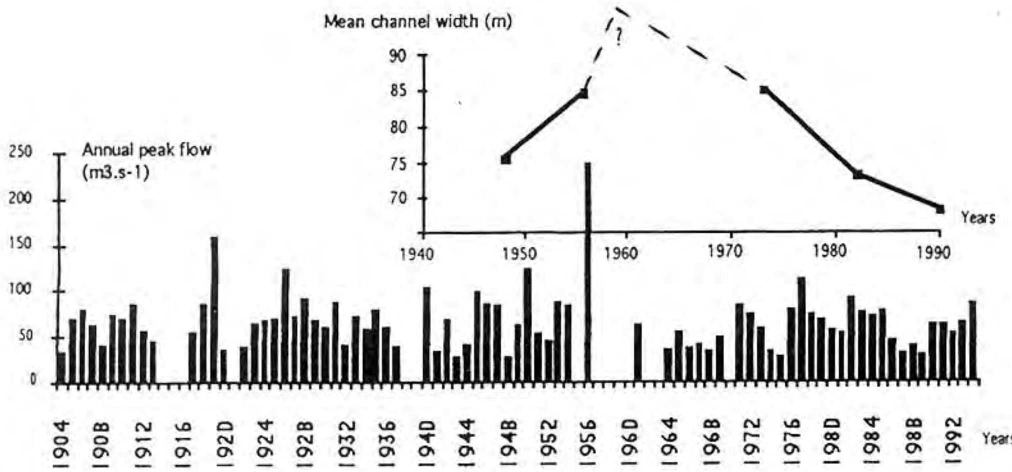

Fig. 4. Evolution of active channel average width and annual peak flow from 1945 to 1990 on the middle Ubaye (*after Hydro bank data and air photographs*).

The 1957 flood also reduced channel slope and hydraulic power upstream from Barcelonnette which explains the adjustment of vegetation and bed geometry over the ensuing decades. These adjustments are ongoing at this site, whereas they have not been observed since 1982 downstream from Barcelonnette.

DISCUSSION AND CONCLUSIONS

Biometamorphosis, an anthropogenic exogenous phenomenon

Given the close chronological relationship existing between watershed afforestation and channel biometamorphosis, it may be said that anthropogenic factors played a major part in initiating active channel restriction at the turn of the century, with an improved climate being a secondary factor. Slopes were stabilized through extensive reforesting, torrent control measures, and progressive abandonment of agro-pastoral activities, thereby reducing peak flow and bedload supply. The flood of 1919, one of the most serious floods of this century, took place a few years before *Pinus sylvestris* expansion and did not modify this trend. We also noted that, except for the 1919 event, most of the floods which took place at the beginning of the century were of lesser intensity than those observed after 1924.

The precise data used to study this site made it

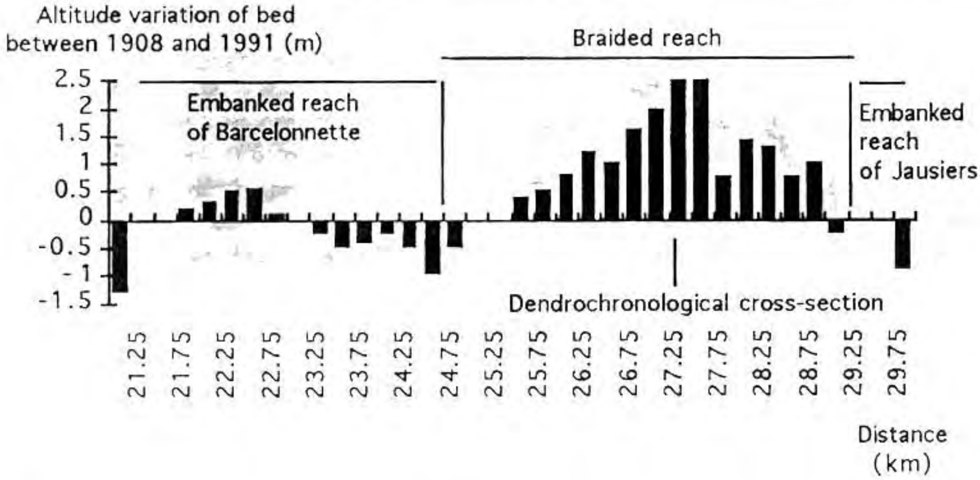

Fig. 5. 1908–1991 altitudinal variation of long profile of the Ubaye upstream from the Bachelard confluence.

possible to ascertain the respective importance of natural and anthropogenic factors that prior studies were unable to dissociate due to a lack of discriminating evidence (Bravard, 1989). However, we cannot say that there is a perfect relationship between this major change in riparian vegetation and anthropogenic actions, as this change took place at the end of the Little Ice Age. Active channel reduction can also be observed in areas where anthropogenic influence is limited (Church, 1983). In a particularly favourable climatic context, anthropogenic reduction of bedload and discharge may well have been naturally accentuated.

The evolution of the Ubaye riverbed at the turn of the 20th century provides an instructive example of short-term watershed influence on a river segment. This biometamorphosis is original in that its causes are external to the reach, being related to fluvial metamorphosis. As shown by Schumm (1977), channel geometry is equally adjusted to external factors and is modified at the same time as riparian vegetation. Channel deepening and narrowing on the major part of the Ubaye course was noted, as well as channel pattern modification. The sector downstream of Les Thuiles, which was braided at the end of the 19th century, is wandering today due to a bedload shortage.

By increasing hydraulic roughness and favouring bar stabilization, forest expansion exerts an internal control on the alluvial mosaic and contributes to a reduction in bed width. The genesis of a floodplain forest is, in fact, accompanied by the development of tree units within the active channel, and therefore rivers draining forest corridors are generally not as wide as those located in prairie sectors (Hey & Thorne, 1986). Internal factors which are biological or physical, are in fact interrelated and adjusted with the external factor changes.

This afforestation is different from situations observed downstream of flood control dams (Gondé, 1981). Its evolution is more progressive and more long-term, as riparian vegetation eventually adjusts to natural hydrological variations. This phenomenon also differs from other cases of piedmont river evolution where vegetation metamorphosis has been found to be due to floodplain abandonment by farmers (Piégay, Bravard & Dupont, 1994a).

Riparian corridor restoration and suggested management strategy

As presented on the Ubaye river, the development of riparian forest contributes to restoring valley landscapes. The mobility of floodplain–channel contacts in space and time is one of the most important characteristics of braiding and meandering piedmont or intramountain rivers (Church, 1992). It leads to forest channel interpenetration which creates the richness of these systems by producing highly complex mosaics (Shankman, 1993). In Great Britain, some authors refer to environmental heritage conservation programs (*'Sites of Special Scientific Interest'*) concerning segments characterized by active lateral erosion (Hooke, 1992). The objective of these programmes is to maintain this diversity. The Ubaye is thus of ecological and national heritage interest due to its recent landscape changes, particularly upstream from Barcelonnette. The riparian forest change is relative to multiple-decade hydrological cycles that determine rejuvenation conditions.

In Europe, managers must be able to cope with highly regulated rivers (Petts, 1987). Their forest corridors are not primitive, and the genesis of these corridors, which control variables in fluvial adjustment, is determined by human actions. Moreover, active channel-forest margin contacts are often mobile due to temporal discontinuity in the bedload transport. Management problems must therefore be approached in a particular dynamic context in which landscape mosaics continue to adjust to anthropogenic impacts. The French 1992 water law advocates sustained integrated river development, considering environmental conservation ·e a prerequisite to user satisfaction (Piégay, Bravard & Dupont, 1994b). The forest corridor is seen as an environment of interest that must be preserved or restored.

This being said, attempts to identify or return to an unknown original state are difficult, so a desired target state should be defined. In the case of the Ubaye, two points merit consideration. First, over the last few decades, with the development of 'green' tourism, human installations have been established closer and closer to the riverbed. This trend is prejudicial to floral and faunal diversity, by sectioning the forest corridor. However, it equally increases risk exposure as shown by growing demands for bank protection. Second, mosaic value is recognized as being linked to preserving high energy rivers that are able to control lateral vegetation progression. These natural margins are thus high risk areas for human installations. Their functional ·racteristics may only be preserved by strictly limiting human use of these areas. Moreover, the stands of Austrian black pine planted in the watershed at the end of the last century have attained maturity and are no longer capable of regenerating themselves (Combes & Bartet, 1982). As the 19th century reforesting policy is not economically feasible today, increased sediment supply to the river, which implies bed aggradation and avulsions, is to be foreseen in medium-term planning.

These two opposing changes should be examined by managers. Two measures should be taken in the near future to conserve this forest margin: local politicians should be involved in limiting human activities in the river margins; and conservation measures should be taken on segments where active channel-forest margin connectivity is high. The latter point is all the more important because the Ubaye has one of the last regenerated floodplain forests of the French Mediterranean mountains.

ACKNOWLEDGMENTS

The authors would like to express their profound gratitude to the Agence de l'Eau Rhône-Méditerranée-Corse which financed their project. They would like to thank State agencies for their help, particularly Mr Goueffon, head of the MTR in Digne, Mr Gibelin at the DDE Hautes-Alpes and Mr Subrenat at the National Forestry Service. They would also like to thank L. Astrade and S. Stroffek for their assistance in the field and C. Etienne for the translation into English.

REFERENCES

Bravard, J.-P. (1986) *Le Rhône, du Léman à Lyon*. 450 pp. La Manufacture, Lyon.

Bravard, J.-P. (1989) La métamorphose des rivières des Alpes françaises à la fin du moyen-âge et à l'époque moderne. *Bull. Soc. Géog. Liège*, **25**, 145–157.

Bravard, J.-P., Amoros, C. & Pautou, G. (1986) Impact of civil engineering works on the successions of communities in a fluvial system. A methodological and predictive approach applied to a section of the Upper Rhone River, France. *Oikos* **47**, 92–111.

Church, M.(1983) Pattern of instability in a wandering gravel bed channel. *Spec. Publ. int. Ass. Sedim.* **6**, 169–180.

Church, M. (1992) Channel morphology and typology. *The rivers handbook. Hydrological and ecological principles* (ed. by P. Calow and G.E. Petts), pp. 126–143. Blackwell Scientific Publications, Oxford.

Combes, F. (1982) Un centenaire: le grand barrage Demontzey. *Revue forest. française*, **5**, 80–86.

Combes, F. & Bartet, J.H., (1982) Plaidoyer pour le pin noir en Haute-Provence. *Revue Forest. française*, **5**, 40–49.

Combes, F., Hurand, A. & Meunier, M. (1994) La forêt de montagne, un remède aux crues. *23èmes Journées de l'Hydraulique: Crues et inondations* (ed. by Société Hydrotechnique de France), pp. 481–486. Nîmes.

Demontzey, P. (1882) *Traité pratique de reboisement et du gazonnement des montagnes*, 528 p. J. Rothschild, Paris.

Everitt, B.M. (1968) The use of cottonwood in the investigation of the recent history of a floodplain. *Am. J. Sci.* **206**, 417–439.

Fagot, P., Gadiolet, P., Magne, M. & Bravard, J.P. (1989) Une étude dendrochronologique dans le lit majeur de l'Ain: la forêt alluviale comme descripteur d'une "métamorphose" fluviale. *Rev. Géogr. Lyon*, **64**, 213–223.

Girel, J. (1994) Old distribution procedure of both water and matter fluxes in floodplains of western Europe: impact on present vegetation. *Environ. Mgmnt*, **18**, 203–221.

Gondé, R. (1981) *Les aménagements du lit de la Durance et l'évolution du milieu naturel*, 65 pp. Report of Ministère de l'Environnement et du Cadre de Vie, Paris.

Hey, R.D. & Thorne, C.R. (1986) Stable channels with mobile gravel-bed rivers. *J. Hydraul. Eng.* **8**, 671–689.

Hooke, J.M. & Redmond, C.E. (1989) Use of Cartographic sources for analysing river channel change with examples from Britain. *Historical change of large alluvial rivers: Western Europe* (ed. by G.E. Petts, H. Möller and A.L. Roux), pp. 79–93. Wiley, Chichester.

Hooke, J.M. (1992) Conservation: the nature and value of active river sites. *Proceedings of the conference conserving our landscape: evolving landforms and ice-age heritage* (ed. by C. Stevens, J.E. Gordon, C.P. Green C.P. & M.G. Macklin), pp. 110–116. Crewe.

Johnson, W.C., Dixon, M.D., Simons, R., Jenson, S. & Larson, K. (1995) Mapping the response of riparian vegetation to possible flow reductions in the snake river, Idaho. *Geomorphology*, **13**, 159–174.

Lecarpentier, C. (1963) *La crue de juin 1957 en Ubaye et ses conséquences morphodynamiques*. Thèse de doctorat de 3° cycle, Faculté de Géographie, Université de Strasbourg.

Malanson, G.P. (1993) *Riparian landscapes*, 296 pp. Cambridge University Press, Cambridge.

Miller, J.R., Schulz, T.T., Hobbs, N.T., Wilson, K.R., Schrupp, D.L. & Baker, W.L. (1995) Changes in the landscape structure of a southeastern Wyoming riparian zone following shifts in stream dynamics. *Biol. Conserv.* **72**, 371–379.

Nanson, G.C. & Beach, H.F. (1977) Forest succession and sedimentation on a meandering-river floodplain, Northeast British Columbia, Canada. *J. Biogeogr.* **4**, 229–251.

Nanson, G.C., Barbetti, M. & Taylor, G. (1995) River stabilisation due to changing climate and vegetation during the late Quaternary in western Tasmania, Australia. *Geomorphology*, **13**, 145–158.

Pardé, M. (1925) *Le régime du Rhône, étude hydrologique*, pp. 883 & 440. Institut des Etudes Rhodaniennes, Lyon.

Pautou, G. & Décamps, H. (1985) Ecological interactions between the alluvial forests and hydrology of the upper Rhône. *Arch. Hydrobiol.* **104**, 13–37.

Peiry, J.L. (1988) *Approche Géographique de la Dynamique spatio-temporelle des Sédiments d'un Cours d'Eau intra-montagnard: l'exemple de la plaine alluviale de l'Arve (Haute-Savoie)*, pp. 378. Thèse de Géographie et Aménagement, Université J. Moulin-Lyon III, Lyon.

Petts, G.E. (1987) Ecological management of regulated rivers; a European perspective. *Regulated Rivers Res. Manag.*, **1**, 363–369.

Piégay, H., Bravard, J.P. & Dupont, P. (1994a) Les ripisylves et les crues dans la France du sud-est: de l'histoire à la gestion contemporaine. *23èmes Journées de l'Hydraulique: Crues et inondations* (ed. by Société Hydrotechnique de France), pp. 277–289. Nîmes, France.

Piégay, H., Bravard, J.P. & Dupont, P. (1994b) The French water law: a new approach for alluvial hydrosystem management. *Annual summer symposium of the American Water Resources Association, effects of human-induced changes on hydrologic systems* (ed. by R.A. Marston and Hasfurther V.R.), pp. 371–383. American Water Resources Association, Jackson Hole, Wyoming.

Piégay, H. (1995) *Dynamiques et gestion de la ripisylve de cinq cours d'eau à charge grossière du bassin du Rhône (l'Ain, l'Ardèche, le Giffre, l'Ouvèze et l'Ubaye), XIXème-XXème Siècles*, 529 pp. Thèse de Géographie et Aménagement, Université Paris IV-Sorbonne, Paris.

Salvador, P.G. (1991) *Le thème de la métamorphose fluviale dans les plaines alluviales du Rhône et de l'Isère (Bassin de Malville et Ombilic de Moirans, Bas-Dauphiné)*, 529 pp. Thèse de géographie, Université Lyon III, Lyon.

Schumm, S.A. (1977) *The fluvial system*, 338 pp. J. Wiley, New York.

Sclafert, T. (1933) A propos du déboisement des Alpes du Sud. *Ann. Géogr.* **42**, 266–277.

Shankman, D. (1993) Channel migration and vegetation patterns in the southeastern coastal plain. *Conserv. Biol.* **7**, 176–183.

Yon, T. & Tendron, G. (1981) *Alluvial forest of Europe*, 76 pp. Council of Europe, National Environmental Service, 22.