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Floodplain sedimentation rates, soil properties and recent flood history in southern Québec

D. Saint-Laurent [a,*], L. Lavoie [b], A. Drouin [a], J. St-Laurent [c], B. Ghaleb [d]

[a] Géographie and Sciences de l'Environnement, Université du Québec à Trois-Rivières, 3351, boul. des Forges, C.P. 500, Trois-Rivières, Québec, Canada G9A 5H7
[b] GDG Environnement Ltée.,430, rue St-Laurent, Trois-Rivières, Québec, Canada G8T 6H3
[c] Progestech Inc. 795, rue Houssart, Trois-Rivières, Québec, Canada G8T 9C1
[d] GEOTOP, Université du Québec à Montréal, 210 Ave. Président-Kennedy, PK-7150, Montréal, Québec, Canada H2X 3Y7

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ABSTRACT

This study examines the depositional and pedogenic processes observed in reaches affected by periodic flooding in river basins of southern Québec and presents a reconstruction of flood events in this area from 1865 to 2005. This record shows a significant increase in flooding over the last 100 years, and successive overbank flood deposits show evidence for a recent increase in flood frequency in this region. The frequency of flooding leads to fine sediments being regularly deposited on floodplains producing weakly developed alluvial soils. Sedimentological and pedological analyses combined with radiocarbon and ^{210}Pb dating has allowed the determination of floodplain sedimentation rates. The radiocarbon data obtained from organic layers buried in floodplain soils show variable ages over the last 2210 radiocarbon years. Sedimentation rates obtained from radiocarbon dating and both CRS and CF:CS models for ^{210}Pb show average values ranging from 1.0 to 7.6 mm yr^{-1}, 2.1 to 10.7 mm yr^{-1} and 2.6 to 6.0 mm yr^{-1} respectively. This variability can be explained by the models used and depends to a large extent on the geomorphological context and local fluvial dynamics specific to each study area.

1. Introduction

The past few years have seen a growing number of studies examining climate change and its impact on river basin hydrology, especially with respect to the frequency of floods and periods of low flows (Douglas et al., 2000; Yarnal et al., 2000; Middelkoop et al., 2001; Muzik, 2001; Evans and Schreider, 2002; Monirul et al., 2003). The use of certain general circulation climate models based on a doubling of CO_2 show either an increase or decrease in precipitation rates depending on the region, with potentially very significant effects on catchment processes including the frequency and magnitude of flooding. Research has shown that the anticipated climate changes will result in varied environmental responses depending on the areas involved; it is therefore important to consider global change parameters on a local or regional scale in order to better understand their impact on river systems and catchment processes. Several studies have analysed variations in flow regime and the risk of flooding by considering climate change over the past few decades (Douglas et al., 2000; Monirul et al., 2003). A number of researchers have also studied the physical and geomorphological impacts of flooding on the receiving environment (Brakenridge, 1988; Marriott, 1992; Lecce and Pavlowsky, 2004). The morphological and sedimentological evolution of floodplains and river terraces, and the hydroclimatic conditions associated with related fluvial processes have also attracted much attention (Wolman and Leopold, 1957; Anderson et al., 1996; He and Walling, 1996a; Lecce, 1997; Gomez et al., 1998; Macklin, 1999; Biedenharn et al., 2000; Moody and Troutman, 2000; Daniels and Knox, 2005; Baker, 2006; Knox, 2006; Clayton and Knox, 2008).

There are far fewer studies, however, on the genesis of floodplain soils subjected to periodic flooding (Klawon et al., 2000; Daniels, 2003; Phillips, 2004; Benedetti et al., 2007) yet the analysis of alluvial soils and the geomorphological study of floodplains can enhance our understanding of sedimentation processes and the dynamics of river basin systems (Bull, 1990; Bettis, 1992; Autin et al., 1998). Floodplain soils and buried soils provide evidence for phases of stability (Kraus and Bown, 1986; Gerrard, 1987; Bull, 1990; Ferring, 1992; Aslan and Autin, 1998; Daniels, 2003; Daniels and Knox, 2005), while the sedimentological facies and dating frameworks provide important information on depositional environment, sedimentation rate, age and development of the floodplains (Bull, 1990; Woodward et al., 1994; Gomez et al., 1998; Benedetti et al., 2007). Alluvial soils can be sensitive indicators of change in the river system and "provide unique opportunities for interpreting past environmental change because their properties represent an integration of geomorphic and pedological processes" (Daniels, 2003, pp. 226–227). It is therefore

* Corresponding author.
E-mail address: diane.saint-laurent@uqtr.ca (D. Saint-Laurent).

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important to consider both pedological and sedimentological parameters in order to recognise phases of enhanced sediment accumulation in floodplain systems (Saint-Laurent, 2004). This paper presents an analysis of the factors controlling sedimentation rates and soil forming (pedogenic) processes on floodplains in southern Québec. It also presents a new record of historical flood events from 1865 to 2005. A geo-pedological approach has been developed that involves assessment of a range of soil and sediment properties in order to better understand the development of soils subject to frequent flooding (Saint-Laurent and Lavoie, 2004). This has been carried out alongside an investigation of floodplain sedimentation rates in southern Québec based on a combination of radiocarbon and ^{210}Pb dating methods.

The study area is located in the St. Lawrence River basin, from the south shore of the St. Lawrence to northern Vermont, in the United States. This basin includes many rivers whose overbank areas are subject to periodic flooding (Jones, 1998; Saint-Laurent et al., 2001), yet only very limited research has been carried out on the physical and pedological characteristics of this large basin in relation to flooding, especially in terms of the periodicity or severity of the events. The key objectives of this study are: (1) to record and analyse the floodplain soils using morphological, physical, and chemical parameters in order to determine their degree of pedogenic development; (2) to determine the floodplain sedimentation rates using radiocarbon (^{14}C) and ^{210}Pb dating methods; and (3) to reconstruct the recent flood time series of the basin and sub-basins of the study area.

2. Regional settings and hydrological characteristics

The study area is located in the Saint-François River basin of southern Québec (10,230 km^2, MEF, 1996) — the third largest basin on the south shore of the St Lawrence River system (Fig. 1). Situated in both Canada and the United States (northern Vermont), the

Fig. 1. The major rivers of the study area and gauging station locations in southern Québec, Canada (MRNFP, 2000).