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Anthropogenic alluvium: An evidence-based meta-analysis for the UK Holocene

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ABSTRACT

An exploratory meta-analysis of ^{14}C-dated Holocene anthropogenic alluvium (AA) in the UK is presented. AA units were categorized by grain size, catchment area and location, depositional environment, and according to diagnostic criteria linked to recorded types of anthropogenic activity. The oldest AA units date to the Early Bronze Age (c. 4400 cal. BP) and there is an apparent 1500 year lag between the adoption of agriculture (c. 6000 cal. BP) in the UK and any impact on floodplain sedimentation. The earliest influence of farming on UK rivers appears to have been hydrological rather than sedimentological. The mediaeval period was characterized by accelerated sedimentation of fine-grained AA, notably in the smallest catchments. There are some apparent regional differences in the timing of AA formation with earlier prehistoric dates in central and southern parts of the UK.

1. Introduction

In processing the impacts of human activity (which may be regarded as *allogenic*, different from but comparable to the effects of climatic or tectonic transformations), alluvial systems have their own temporal and spatial patterns of *autogenic* activity. Anthropogenically related changes in discharge or sediment supply are routed through catchment systems, which then adjust their morphology and internal sediment storages (Macklin and Lewin, 2008). For deposition, there is a process hierarchy involved: small-scale strata sets representing individual events (laminae for fine sediment), evolving form units (e.g. point bars or levees), architectural ensembles (such as those associated with meandering or anastomosing rivers) and alluvial complexes involving whole river basin sequences. Anthropogenic alluvium (AA) may be seen at one level as simply an extra 'blanket' to a naturally formed channel and floodplain system; at another it is a complex of supplements and subtractions to an already complicated sediment transfer and storage system. AA may alternatively be known as post-settlement alluvium (PSA), although that term is generally applied to any sedimentation that occurs after an initial settlement date, however it was generated (cf. Happ et al., 1940). PSA also forms a sub-category of legacy sediment (LS) derived from human activity (James, 2013), which includes colluvial, estuarine and marine deposits. AA may comprise waste particles derived from industrial, mining and urban sources (e.g. Hudson-Edwards et al., 1999) or, more generally, a mixture with 'natural' erosion products. Accelerated soil erosion resulting from deforestation and farming also introduces sediment of distinctive volume as well as character.

For sediment transfers, UK tracer studies of bed material demonstrate a local scale of channel and floodplain movement from cut bank to the next available depositional site (Thorne and Lewin, 1979; Brewer and Lewin, 1998). However, vertical scour in extreme events without lateral transfer is also possible (Newson and Macklin, 1990). *Fine* sediment behaves rather differently: long-distance transfers in single events, temporary channel storage in low-flow conditions, but longer-term storage inputs highly dependent on out-of-channel flows. In these circumstances, considerable care has to be exercised when interpreting AA transfer and accumulation, and especially in using combined data sets for depositional units that have been processed to arrive on site over different timespans. Fine sediment is most likely to be dispersed catchment-wide during major floods, whilst alluvial

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sediment stored down-catchment may also be locally re-eroded and re-deposited by the same event.

'Connectivity' has been a major theme in UK fluvial research in recent years, particularly in empirical contexts of coarse sediment transfer in upland environments involving gully, fan and adjacent floodplain (Harvey, 1997; Hooke, 2003), and in the transfer of sediment within valleys in the form of sediment slugs or waves (Macklin and Lewin, 1989; Nicholas et al., 1995). These and studies elsewhere have commonly used morphological estimates and budgeting of sediment flux, both from historical survey comparisons (decades to centuries) and from reconnaissance assessments of apparently active erosion or sedimentation sites. On the longer timescale necessary for assessing human impact, whole-catchment modelling involving Holocene sediment routing has also demonstrated how complex and catchment specific these internal transfers may be in response to climatic and land cover changes (Coulthard et al., 2002, 2005). Major elements of UK catchment relief involve variable lithologies, over-steepened to low-gradient slopes, rock steps, alluvial basins, and valley fills inherited from prior Pleistocene glacial and periglacial systems (Macklin and Lewin, 1986). Some of these locally provide what may be called 'memory-rich' process environments. Progressive and ongoing Holocene evacuation of coarse Pleistocene valley fills is of major significance in a UK context (Passmore and Macklin, 2001), and this differs from some of the erodible loess terrains in which many other AA studies have been conducted in Europe and North America (e.g. Trimble, 1983, 1999; Lang et al., 2003; Knox, 2006; Houben, 2008; Hoffman et al., 2008; Houben et al., 2012).

Human activities have greatly modified hydrological systems, and in different ways: in terms of discharge response to precipitation and extreme events, but also in the supply of sediment. For finer sediments (where sediment loadings are generally supply-limited rather than competence-limited), dominant yield events (near bankfull) and sediment-depositing events (overbank) may not be the same. Holocene flood episodes (Macklin et al., 2010) may also be characterized by river incision (Macklin et al., 2013) as well as by the development of thick depositional sequences (Jones et al., 2012), depending on river environment. Fine sediment may be derived from surface soil removal, through enhanced gullying and headwater channel incision, from reactivation of riparian storages, or through the direct human injection or extraction of material involving toxic waste or gravel mining. For a millennium and more, channel-way engineering has also transformed systems to provide domestic and industrial water supply, water power for milling, improved passage both along and across rivers, fisheries improvement, and for flood protection (Lewin, 2010, 2013). These very often retard rather than enhance downstream sediment delivery. The range of anthropogenic impacts is perhaps even more various than the sedimentation systems with which they are involved.

In this paper we set out to analyze the extent of enhanced deposition of material in floodplain environments following human activity, largely through the meta-analysis of a UK data set of Holocene ^{14}C-dated alluvial units. We caution that sedimentation quantities relate both to supply factors (enhanced delivery from deforested or agricultural land, accelerated channel erosion, or as fine waste from other activity), to transportation-event magnitudes and frequency, to sedimentation opportunity (available sub-aqueous accommodation space), and to preservation from reworking (Lewin and Macklin, 2003). None of these has been constant spatially, or over later Holocene times when human impact on river catchments has been more significant and widespread.

The word 'enhanced' also begs a number of questions, in particular concerning what the quantity of fine alluvial deposition 'ought' to be in the absence of human activity in the evolving history of later Holocene sediment delivery. In the UK, there is not always a pronounced AA non-conformity, definable perhaps in colour or textural terms, as in some other more recently anthropogenically transformed alluvial environments, most

Table 1
Criteria for identifying UK anthropogenic alluvium.

Type of evidence	Definition	No. of units	Examples
Colour change	Change in sediment colour resulting from a change in composition or provenance	22	Shotton (1978) River Severn; Hooke et al. (1990) River Dane
Stratification change	Change from massive to layered alluvium or vice versa depending on sedimentary context	15	Caseldine et al. (1988) River Exe; Dinn and Roseff (1992) River Lugg; Howard et al. (1999) River Wharfe; Foster et al. (2008) River Ribble; Foulds et al. (2013) River Swale
Artefacts	Includes objects made or modified by human agency (e.g. fence stakes, pottery) and waste materials (animal bones, charcoal)	10	Durham (1977) River Thames; Needham and Longley (1980) River Thames; Macklin et al. (1991) Coe Burn; Wild et al. (2001) Derwent catchment
Textural change	Abrupt change in grain size and/or organic content; change from peat to mineral sediment; rapid sedimentation	78	Tipping (1995) Kirtle Water; Tipping and Halliday (1994) River Tweed; Smith et al. (2005) River Trent
Biological evidence	Evidence from pollen, mollusca, and coleoptera for anthropogenic modification of the landscape (woodland clearance and cultivation); supported by environmental magnetism and charcoal	66	Brown and Barber (1985) River Severn; Moores et al. (1999) River Tyne; Dinnin and Brayshay (1999) River Trent; Foster et al. (2000) Slapton Lower Ley
Contaminants	Elevated concentrations of pollutants from metal mining (e.g. Pb, Sn) or industry (e.g. coal/coke fragments)	14	Passmore and Macklin (2000) River Tyne; Thorndycraft et al. (2004) River Erme

Table 2
Types of UK anthropogenic alluvium.

AA type	Definition	Evidence	No. of units
1. Deforestation	AA resulting from the removal of forest cover	Pollen, mollusca and charcoal	35
2. Cultivation	AA associated with the cultivation of crops	Pollen or coleoptera	32
3. Engineering	AA associated with engineering works	Description of engineering works (e.g. embankments) at site	1
4. Mining	AA associated with mining activities	Mining pollutants	11
5. Unspecified	AA for which insufficient information is available to assign to 1–4 above	Various	63

N.B. Some dates fall into both the deforestation and cultivation categories.