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THE IMPACT OF FLOODPLAIN DEGRADATION ON FLOODING IN THE UK

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ABSTRACT

A review of floodplain functioning in the north of England following the winter storms of 2015 was conducted using high resolution aerial imagery of the events captured using drone and helicopter survey during and immediately after the flooding. This revealed that for the most part 100% of the floodplain area was inundated. Sediment left across floodplains from the 2015 flood events areas suggest high floodplain velocities (> 1.5 m/s). GIS analysis of land use mapping for valley bottom areas across England reveal part of the cause for these unnaturally high velocities is the near complete loss of natural rough floodplain surfaces, having been replaced by a hydraulically smoother managed arable/grassland mix. The review has revealed extensive and severe degradation of floodplain systems in England and it is highly likely that similar results would be found for floodplains across the rest of the UK, both upland and lowland areas are equally impacted and the result is an almost complete loss of natural floodplain functioning. River restoration remains concentrated on in-channel activity, however, the push for natural flood management offers an opportunity to restore our floodplains with an associated improvement in ecological value and flood driven functionality. The research presented here suggests that it is not lack of floodplain storage space in the upper catchment, rather the decreased efficiency of floodplain areas to retard flow which is leading to increased downstream flood risk. Floodplain reconnection, vegetative naturalization and selective grazing reduction are required to begin to restore upstream floodplain flood function helping alleviate flooding pressure downstream.

Keywords: Floodplains, Flooding, Land Management, Natural Flood Risk Management

1 INTRODUCTION

Natural floodplains have been shown to be among the most biologically productive and diverse ecosystems on Earth (Tockner and Stanford, 2002). This is in a large part due to their dynamic nature forming the transitional ecotone between aquatic and terrestrial environments. Natural fluvial dynamics result in flood-controlled disturbances, encouraging geomorphic processes and successional patterns (Amoros and Roux, 1988; Junk et al., 1989). As a result, floodplains in their natural state exhibit complex dynamic spatial mosaics controlled by the surface and subsurface hydrological regime (Thoms, 2003). These features also reflect past and present geomorphological activity associated with the fluvial system (Nanson and Croke, 1992) with features developing ecologically as connectivity with the main river alters over time.

Mitsch and Gosselink (2000) estimated that globally floodplains cover between 0.8 x 10^6 km^2 to 2 x 10^6 km^2, approximately 1.4% of the land surface, however they contribute around 25% of all terrestrial ecosystem services (Tockner and Stanford, 2002). Recent figures on floodplain state are not known to the authors, however the situation is unlikely to have improved on the status levels reported at the turn of the century when it was estimated that some 80% - 90% of Europe's river floodplains are now cultivated intensively compared to figures of 46% for North America (excluding northern Canada and Alaska) and 11% for African Rivers (Tockner and Stanford, 2002). As such floodplain condition and functionality has been reported as being in a critical situation across Europe (Wenger et al., 1990; Klimo and Hager, 2001).

Longitudinal and lateral fragmentation of large river systems, linked principally to human activities has led to severe and widespread floodplain degradation and this is fundamentally threatening the integrity of running water ecosystems (Dynesius and Nisson 1994; Schiemer 1999). This degradation is closely linked to the rapid decline in freshwater biodiversity, linked principally to habitat alteration through altered land use and flow, flood control, pollution and also to invasive species. Tockner and Sanford (2002) provide the stark statistic that in Europe and North America, up to 90% of floodplains are already 'cultivated' and therefore functionally extinct.

In England and Wales, watercourse and to a lesser degree floodplain alteration and degradation has been quantified as part of the European Water Framework Directive (WFD) with water bodies classified based on their degree of alteration; labelled as artificial, heavily modified and near natural (non-designated). Statistics provided by the Department for Environment Food and Rural Affairs (Figure 1) illustrate the generally poor state of UK rivers with only around 30% of water bodies achieving the required good ecological status/potential. Seager et al. (2012) conducted a stratified random sample of 4,849 River Habitat Survey sites sampled in 1995-1996 and 2007-2008 across England and Wales to assess the general physical character of rivers and streams. From these data they estimated that 11% of river length had a 'near-natural' channel form with a further 14% classed as predominantly unmodified. Bentley et al. (2016) found a similar picture of hydromorphic diversity reduction along an engineered reach of the River Wharfe and their findings suggest that engineering driven changes to morphology, which are common on UK watercourses, have severely degraded system form and function.

Further insight into wider modification to floodplain areas was reported by Heritage et al., (2016) who analyzed floodplain connectivity and land use on eight SSSI rivers in England and Wales. They found that even these high value watercourses have been significantly impacted by current and former engineering and management of the river and valley bottom with intense use of the floodplain along all of the watercourses resulting in a loss of natural habitat to farming. This study extends their analysis further, quantifying land use patterns across all floodplain areas in England with respect to their natural function. The study utilizes GIS based land use data cropped to the 100 year flood zone mapping for the country to reveal the extent and pattern of floodplain degradation.

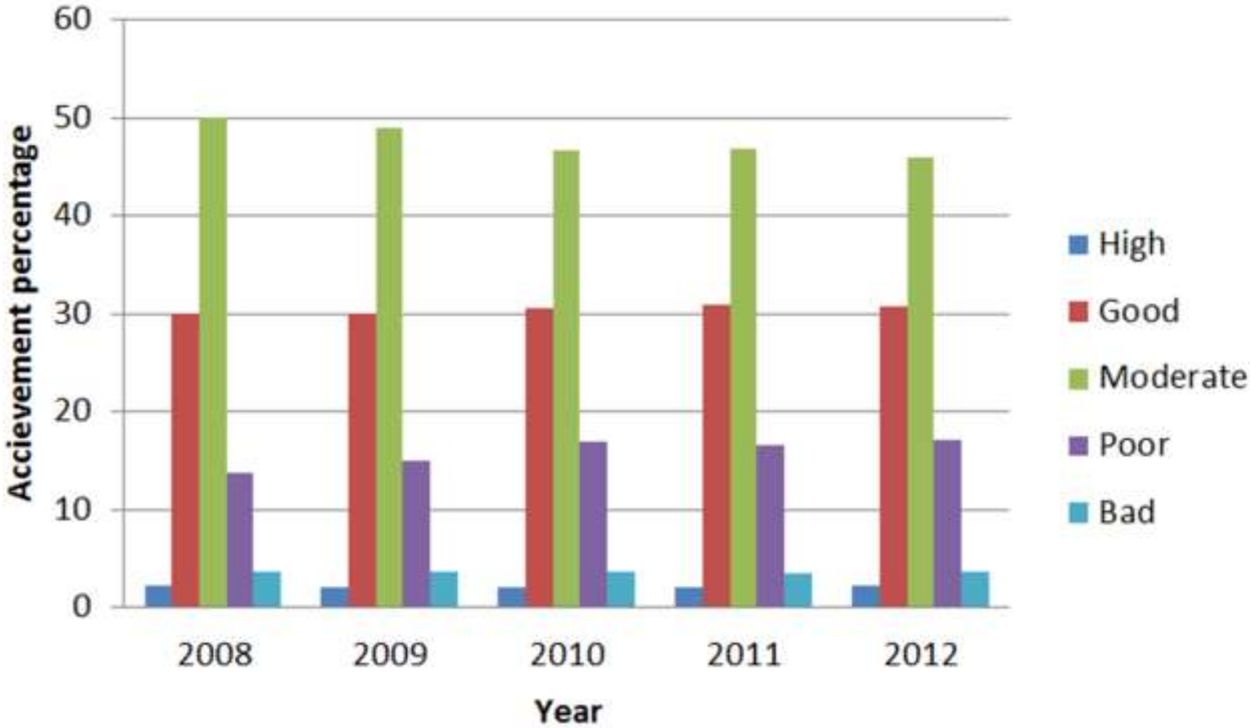

Figure 1. Water Framework Directive status summary for UK Rivers (2008-2012).

2 PROJECT METHOD

Initially the Environment Agency Digital River Network was used to delineate river units across England by main river name; this included all associated tributary units (Figure 2a). Next the Environment Agency Flood zone 2 polygons (equivalent to the 100 year return period flood) were associated with river network (Figure 2b). Each new river floodplain polygon was then intersected with the national land cover map of Great Britain (Centre for Ecology and Hydrology (CEH), 2007) (Figure 3). Areas of each land use type were then extracted and converted to percentage cover by dividing by the total floodplain area for each watercourse network.

This analysis generated data on a total of 555 main river units across England covering just over 6600 km^2 of floodplain area.

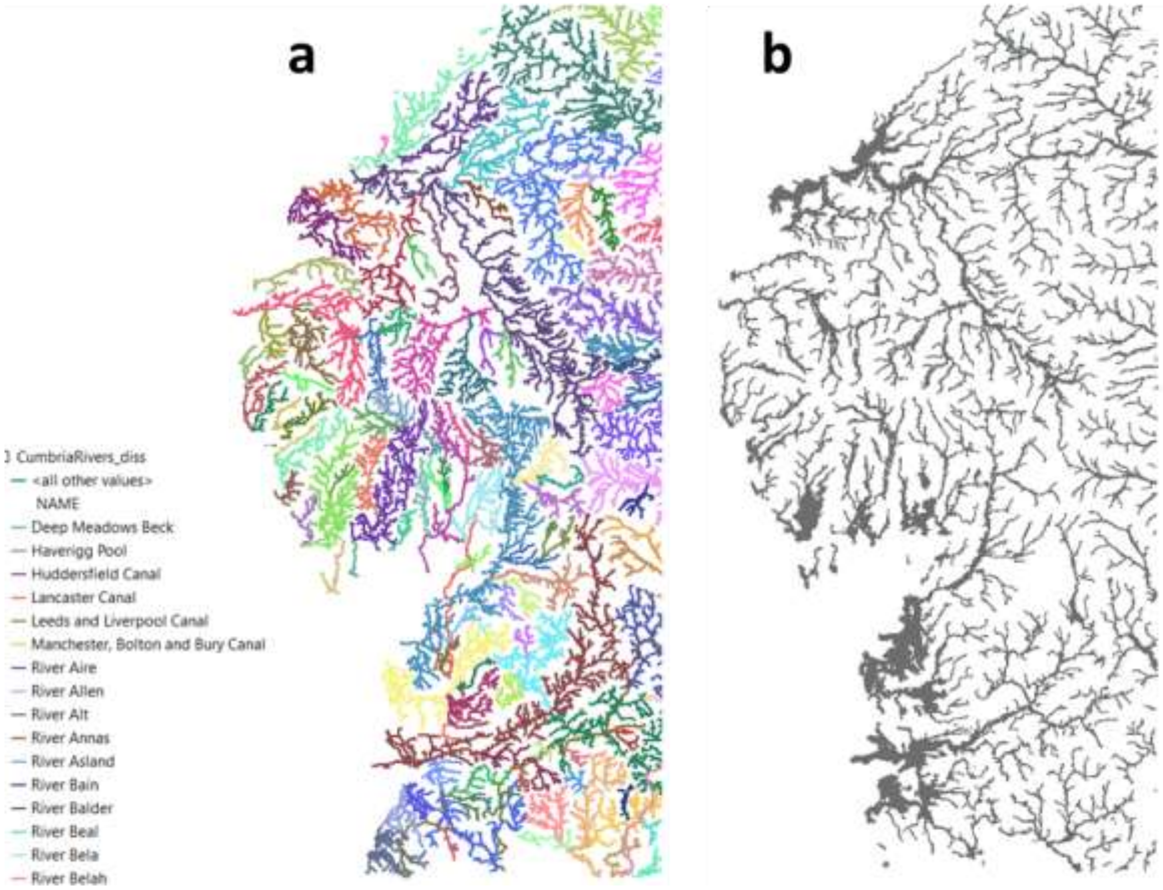

Figure 2. Example area of the river network in England (a), and the associated floodplain areas (b)

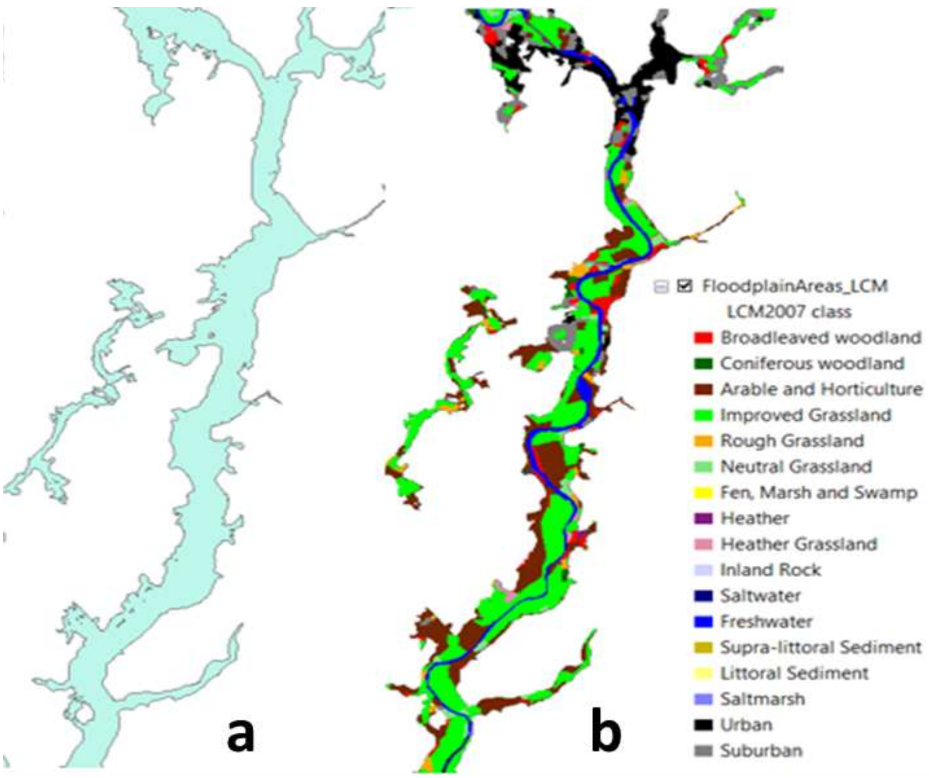

Figure 3. GIS process to define and segment floodplain area and assign land use categories on a river by river basis.

3 RESULTS

A review of the gross area coverage figures for all floodplain in England (Figure 4) reveals that around 65% has been modified extensively due to agriculture with arable, horticulture and improved grazing activities all severely impacting the natural floodplain ecology and functioning. A further 9% has been lost to urban and suburban development. Of the remaining 25%, 4% is occupied by open water. Semi-natural woodland and rough grassland together occupy only 6% of floodplains whilst natural fen, marsh and swamp are reduced to less than half a percent of the total floodplain area.

The spatial patterning of these land use types has been mapped (Figure 5 and 6) using areal dominance classes to reveal both the distribution and dominance of each category across England. Natural Fen, marsh and swamp is an extremely sparse land cover type across the country and is at a low level across all sites where it is present (Figure 5a). Broadleaved woodland shows a better distribution (Figure 5c) with a strong presence in the West Country, even here, however, coverage is generally below 10% of total floodplain area. Coniferous woodland (Figure 5b) is concentrated across higher topography in the north of England at generally low levels. Whilst the distribution of floodplain under arable use is strongly confined to the area around the Wash, Lincolnshire & Humberside, where coverage levels are generally in excess of 75%.

Floodplain rough grassland (Figure 6a) is distributed largely in the north and west of England but is most likely locally patchy with overall coverage levels below 25% of the available floodplain. Urban and suburban cover (Figure 6b) is as expected concentrated around towns and cities, whilst improved grassland (Figure 6c) displays a near ubiquitous distribution exhibiting moderate to high levels of cover (20 - 50%). Areas of heather and heather grassland (Figure 6d) are both rare and at very low concentrations.

A count of the presence of a particular land use type each of the 555 river floodplain systems analyzed (Table 1) backs up the distribution statements made previously. Of note is the very low occurrence of the natural fen, marsh and swamp habitat, which is now seen on only 71 watercourse floodplains, less than 13% of the total present.

Table 1. Floodplain presence statistics of the 555 river floodplain systems analyzed for key land use types for England on a river basis.

Land use category	Occurrence	% rivers
Arable and horticulture	534	96.2
Broad leaved, mixed and yew woodland	541	97.5
Built up areas and gardens	523	94.2
Coniferous woodland	417	75.1
Dwarf shrub heath	335	60.4
Fen marsh and swamp	71	12.8
Improved grassland	545	98.2
Rough low-productivity grassland	501	90.3

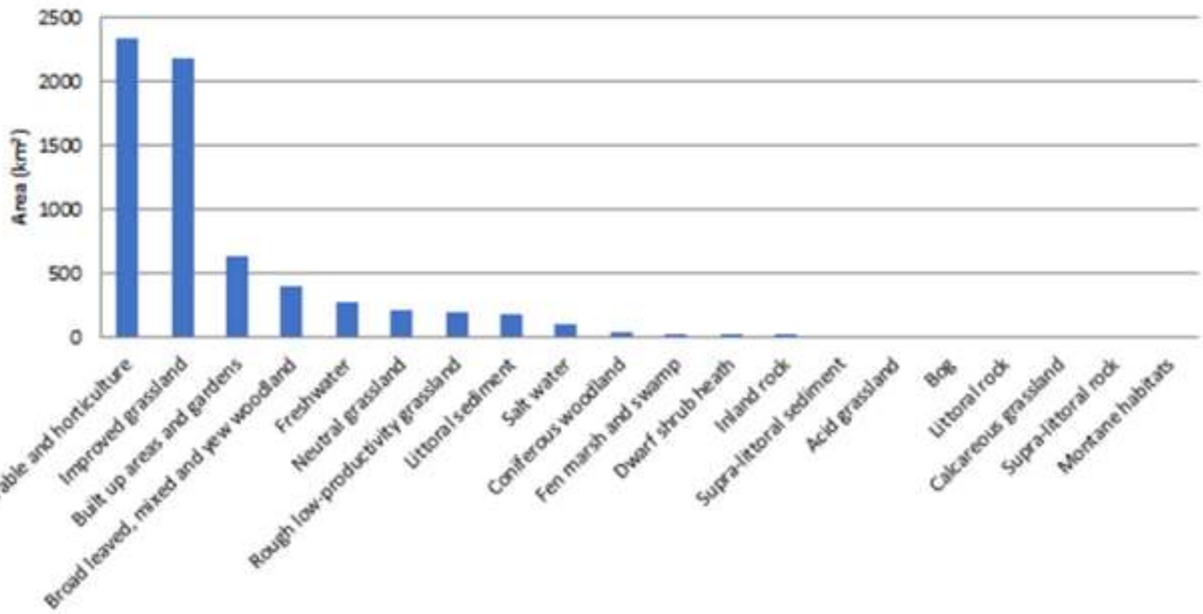

Figure 4. Land use area cover for all river floodplain in England.

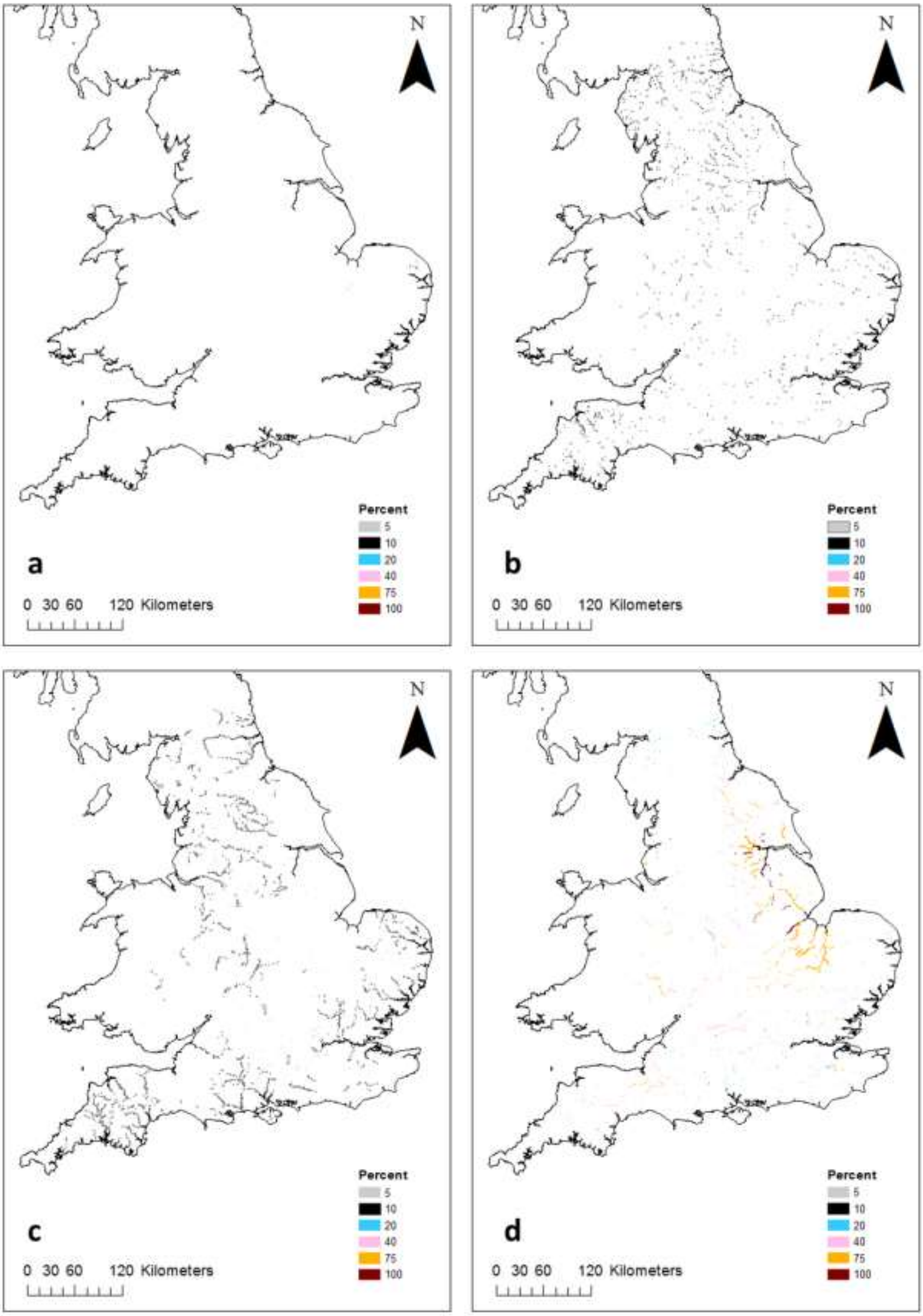

Figure 5. Floodplain land-use maps for England (a) Fen, marsh and swamp, (b) coniferous woodland, (c) Broadleaf woodland, (d) arable and horticulture, (Source, CEH, 2007).

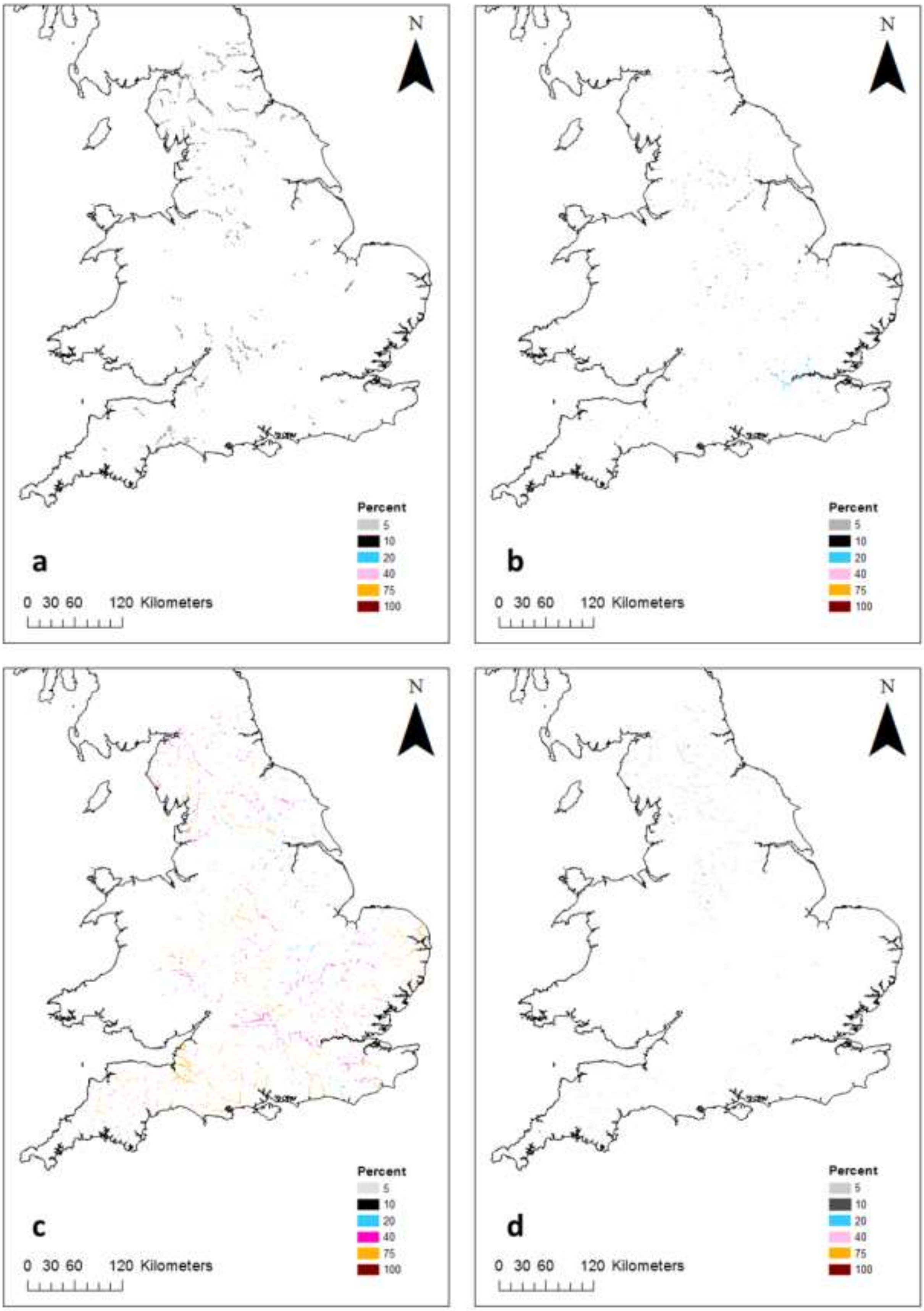

Figure 6. Floodplain land-use maps for England (a) Rough grassland, (b) Urban / suburban, (c) Improved grassland, (d) Heather/heather grassland, (Source, CEH, 2007).

The local dominance of a particular land use type was further examined by extracting the frequency of areal coverage categories across all rivers (Figure 7). It is immediately clear that the majority of fen, marsh and swamp is present at coverages of less than 1% of the overall river floodplain area. Rough grassland is also only generally present at low levels of cover of between 5 and 10%. These figures contrast starkly with the strong dominance of improved grassland and to a slightly lesser degree arable usage which generally occupy 50% to 75% of any floodplain area where they are present.

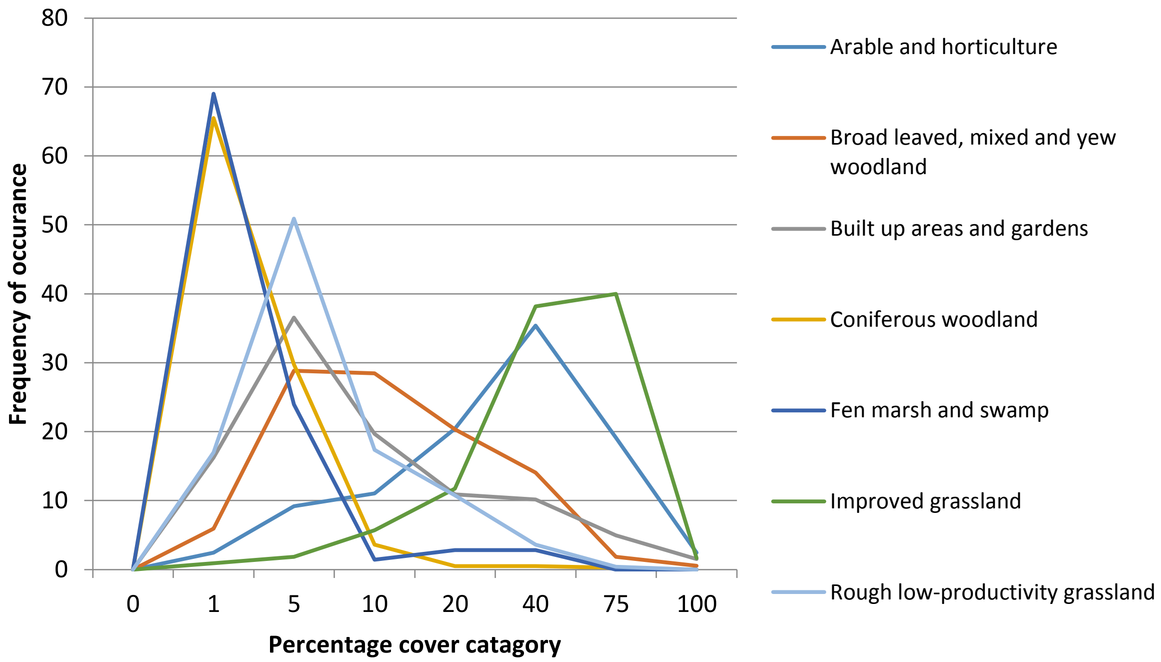

Figure 7. Variation in percentage area for key land use types

4 DISCUSSION AND CONCLUSIONS

This paper presents the first nationwide assessment of floodplain condition for England. It has used land use and floodplain area information together to build a clear picture of the magnitude of change to floodplains away from their natural fen marsh and swamp habitat towards a uniform, heavily managed improved grassland and arable use. It has revealed the near complete destruction of fen, marsh and swamp habitat with only small, isolated remnant areas remaining on less than 15% of watercourses. When this level of natural habitat destruction is linked to earlier studies demonstrating the severe loss of floodplain functionality resulting from anthropogenic modification of the watercourse (Heritage et al., 2016; Seager et al., 2012) the true extent of the destruction of floodplains in England becomes apparent. It is interesting to review this stark reality against the measure of river health currently being used across Europe. The Water Framework Directive standards being used in England largely fail to consider the floodplain at all in any assessment as such rivers water bodies are being classified at good ecological status when almost certainly their floodplain condition and functionality remains degraded. Whilst it is most probably too late to change the assessment criteria being used it should be recognized that efforts must be made to improve the connectivity between floodplain and watercourse and where possible to begin restoring floodplain hydromorphic units to once again see truly functional river and floodplain systems in England with the consequent ecological and downstream. The advantages to taking such action can also be seen in terms of flood benefit. The high floodplain flow velocities approaching 1.5 m/s witnessed on the River Eden, Cumbria during the Storm Desmond extreme event (estimated at a 1 in 200 year return period by the Environment Agency) could be slowed significantly by reintroducing lost rough grassland, fen, marsh and swamp and scrub habitats. This may be simply illustrated by inverting the manning equation to derive average flow velocity from flow depth valley slope and water depth characteristics. Figure 8 illustrates this effect for a typical floodplain surface with a slope of 0.001 under three vegetation scenarios (improved grassland, rough grassland/swamp and scrub with Mannings 'n' roughness values of 0.025, 0.04 and 0.06 respectively (values from Chow 1959). It is clear that significant velocity reductions are likely with consequent flood wave attenuation and downstream flood risk reduction.

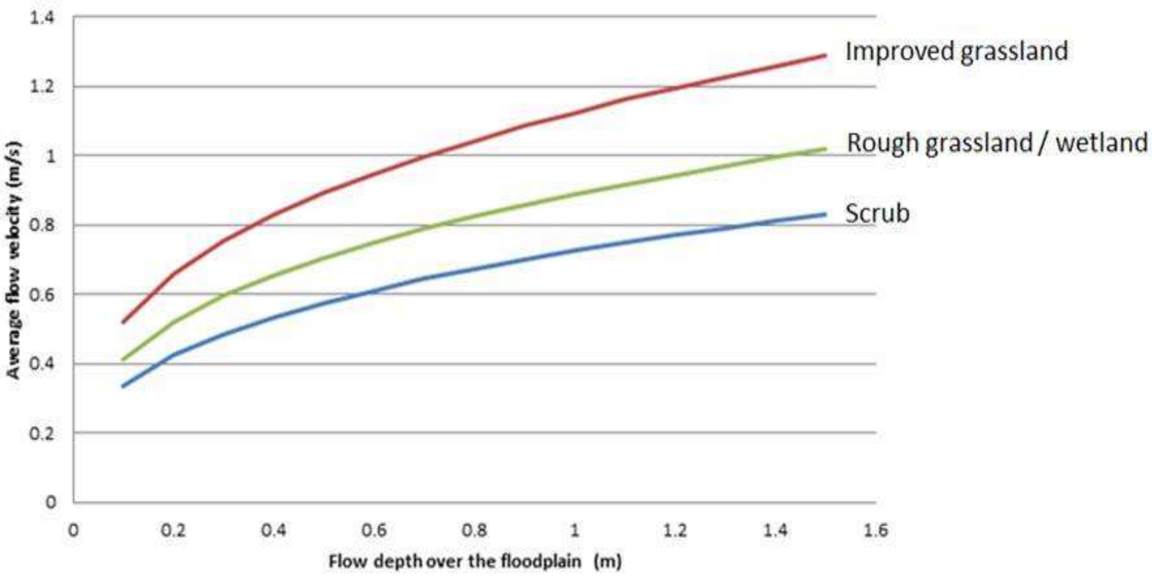

Figure 8. Variation in percentage area for key land use types

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