# Visualising ecosystem services using historical publications

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http://dx.doi.org/10.4324/9781315713373

**Chapter 14: Visualising ecosystem services using historical publications**

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## Introduction

To tackle the concerns of a range of stakeholders involved in landscape management, there is a requirement to understand how ecosystems are, and have been, influenced by human actions and how stakeholders express their valuation of ecosystem services across spatial and temporal scales (UK National Ecosystem Assessment [NEA] 2011; Schröter et al. 2014). Plieninger et al. (2014) believe that conventional ecosystem services assessments ought to be complemented by aspects of socio-cultural attitudes, such as may be found in narratives. Narratives generally present a series of events which may be examined by retrospective analysis to gain an understanding of influencing factors and drivers of actions (Sandleowski 1991). Historical landscape narratives, which highlight natural events and occurrences, are linked to the social values and experiences which were deemed substantial and noteworthy at that particular point in time. So, the historical landscape perspective provides a frame of reference for building an understanding of landscape and ecosystem change (Swetnam et al. 1999; UK NEA 2014).

The examination of historical ecosystem services presents a challenge due to both the complex and often nebulous nature of ecosystem services, and recognition that records are filtered through the prevalent social culture and so subject to various biases (Swetnam et al. 1999). Within the UK, as elsewhere, natural resources have been valued differently over time as a result of changes in population size, societal behaviours and consumption patterns (UK NEA 2011). Disentangling the various aspects of ecosystem services makes the interplay of service and disservice more comprehensible. Consequently, any examination of a specific ecosystem may reflect the changing importance and socio-economic valuing of ecosystem services over time and also illuminate how multiple services are interlaced.

Resulting from the availability of computing tools such as GIS, many researchers have sought to present a visual picture of historical ecosystem changes, assessing the range of species, landscape type and anthropogenic impact (Swetnam et al. 1999; Zu Ermgassen et al. 2012). Source material is assessed for area coverage and retrospective plotting of mapping ranges undertaken (Swetnam et al. 1999; Hendrych et al. 2013). Thus, to enable complex map visualisations, there is a requirement for data which possess high accuracy and resolution, together with professional, skilled computing operators and data translators (Wang et al. 2006; Andrienko et al. 2010). Communicating the outputs of such work is usually done via a series of maps. However, if these do not show trends clearly, or if there are conflicting data, this raises questions around the development of methods to portray historical ecosystem service changes.

The focus here is to examine issues associated with the collection and analysis of multi-dimensional, historical narrative data relating to freshwater ecosystem services within an urbanised area, to present narrative data in a simple visual manner and reflect upon the richness of discovered social values.

## Study area

Urban rivers provide an exemplar which can be used to visualise temporal changes in the social valuation of ecosystem services, otherwise known as ecosystem goods or benefits. As populations grew and urbanisation increased natural processes were influenced, resulting in both positive and negative impacts upon the urban environment (Rakodi et al. 2002). The River Irwell and its tributaries flow from the moors north and east of Manchester, through major urban conurbations of Bolton, Bury, Rochdale, Oldham and Salford to the Manchester Ship Canal, merging into the Mersey River Basin (James et al. 2012). The study area focussed on a 3.8km section of the River Irwell, running southwest from Wallness Bridge (53:29:39N, 02:16:13W), through the City of Salford to Victoria Bridge (53:29:06N, 02:14:46W).

Landscape features and land use documented in historical maps produced during the eighteenth, nineteenth and twentieth centuries, provided basic reference material against which published narrative histories could be compared.

**Methodology**

The methodology aims to identify the valued ecosystem services embedded in historical publications. By comparing ecosystem services identified from historical narratives to fixed-date maps, the method links landscape use to the socio-cultural values contained within the ecosystem services approach. The following method provides a synopsis of services rather than an in-depth study of a particular facet. The advantage of this approach is that it aids stakeholder awareness of both the interconnectedness of ecosystem services and speed of change.

*Classifying ecosystem services*

Ecosystem service terminology was introduced in 1981 by Ehrlich & Ehrlich (Fisher et al. 2007) and incorporated ecological, social and economic factors, all of which are considered in relevant assessments (Pickett and Cadenasso 2002; Harris and Heathwaite 2012). Since the publication of the Millennium Ecosystem Assessment [MA] (2003) the definition of ecological goods and services contained in that publication has been utilised and built on. Examples of such developments include The Economics of Ecosystems and Biodiversity [TEEB] and The Common International Classification of Ecosystem Services [CICES] (Maes et al. 2013). Key categories of provisioning, regulating and cultural systems which established the basis of MA classification, form the backbone of all three typologies.

The overall MA Report (2003) was supported by MA Synthesis Reports which, *inter alia*, highlight specific freshwater ecosystem services (MA 2005a; MA 2005b), and expand on the categories identified by Maes et al. (2013). Social aspects, often referred to as cultural ecosystem services or cultural goods, are defined in the MA (2003, p58) as "the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences". These non-material benefits are intrinsically linked with human health and well-being but are less tangible than the provision of water or flood regulation (Guo et al. 2010). Recently, the UK National Ecosystem Assessment (2014) has reported upon the importance of valuing cultural ecosystem services. Aspects relating to recreational experiences, cognitive skill and capabilities development derived from riverine existence, plus social bequest actions are cultural sub-categories incorporated in this analysis. The expanded categories which underpin the following ecosystem service analysis are identified in Table 14.1.

*Identifying ecosystem services*

The section of the river under study has been formally recorded since 1794, in Green's map of Manchester and Salford. There are a number of published histories with key books by Corbett (1907), Bracegirdle (1973) and records of government proceedings (Greenwood, 1950) augmented by later works and on-line records (Bergin et al. 1989; Dobkin 1990; Greater Manchester Archaeological Unit 1993; Cooper 2005; Nevell 2008; Williams et al. 2010; Manchester City Council [MCC] 2012).

To identify the ecosystem services, each narrative was examined in detail and a note made of any record which referenced the River Irwell ecosystem. From all the published data examined, 151 event records were identified and the date, location, description of each event and ecosystem service, as classified in Table 14.1, was recorded. Earlier research has identified the application of a 'dependency' factor when analysing socio-cultural aspects of water-related use (Feyzi et al. 2011). Therefore, each entry was reviewed to ascertain whether the activity was totally dependent upon the ecosystem, utilised a key aspect, or was independent of the ecosystem. Data was examined to ascertain whether the noted event was recorded in a positive or negative manner, reflective of the values attributed to the ecosystem services.

*Visualisation*

One mark was allocated per noted event irrespective of whether the same event was mentioned in more than one data source. Records were not weighted for magnitude of perceived impact nor calibrated to take into account restricted availability of published sources for earliest dates. Events were reviewed to identify those dependent upon, or which utilised, a key aspect of the ecosystem. Further sub-division isolated the events within the study area which generated positive and negative effects for each of the ecosystem service categories. The result of this process was to identify 88 records for inclusion in the detailed analysis. A net count of events per decade, treating service and disservice entries as positive and negative values respectively, was calculated.

A simple line graph was produced for the key ecosystem service categories of provisioning, regulating, recreational (cultural), cognitive skills (cultural) and bequest (cultural) for those records where the activity can be linked to the study area. Each records the perceived value of ecosystem services as noted at the time and the net change in societal value from the previous decade, so presenting a visualisation of change through time from 1720 to 2013.

*Land use mapping reference*

Natural capital, or ecological capital, is commonly defined as the natural resources and processes needed by an organisation to produce their products, consequently organisations have an impact on the environment by their use of material and through the output of waste goods (Forum for the Future 2009). EU reporting states abiotic outputs and services need to be considered as part of overall natural capital (Maes et al. 2013). The development of urbanisation and industrial growth as captured on historical maps gives a snap-shot of the prevalent socio-environment state and provides a comparator to the narrative from which ecosystem services are identified.

Greater Manchester Archaeological Advisory Service holds and maintain geo-rectified historical mapping on the Greater Manchester Historic Environment Record. Mapping records which cover the study area were reviewed by an expert archaeologist with working knowledge of this area and maps produced at 50 year intervals were selected for the study. The maps used are Green's map of 1794, Ordnance Survey [O.S.] 60" to 1 mile of 1849 (O.S., 1851), O.S. 25 inches m to 1 mile maps surveyed 1905-6 and in 1950 (O.S., 1908 and 1955), plus O.S. Mastermap of 2005.

Historical mapping was enlarged to a consistent scale (1:1000) to allow direct comparison. Structures and features along the river bank were assigned a function based on historical landscape character types as applied in the UK national mapping programme (Greater Manchester Archaeological Unit 2012). The bankside length of these functions was measured to the nearest metre, where there was a point of contact with the river side. The total bank length was calculated by summing the lengths of both sides of the river bank. This exercise was repeated for each of the selected maps. Where maps identified areas of 'waste ground' but contained structural information, a reference by shape, size, and similarity to other named buildings enabled a functional assignment.

**Results**

*Visualising ecosystem services*

The analysis presented here is restricted to those records where the activity can be linked to the area under examination from downstream of Wallness/Frederick Road Bridge to Victoria Bridge, Manchester and where there is a dependency or impact on the ecosystem. From the review of historical documents, 88 records met the selection criteria previously outlined. The plot marker for each decade represents the cumulative net impact of records which possess either a positive (upward movement) or negative (downward movement) assigned value. The movement of the plot line above or below the horizontal axis does not denote any specific status, but is the cumulative change from 1720.

*Provisioning services* - Provisioning services were the least reported of the categories. Expected ecosystem services and goods comprising agricultural water use, fibre extracts for use as biomass fuel and products used in human health treatment were not identified in the historical narratives. Seven records of biodiversity and food benefit were found, along with five reports identifying the use of the river as a power source. Nine accounts of disservice were noted; the majority of reports were linked to the industrial use of the river, with reports on the absence of biodiversity and food goods.

The cumulative change in provisioning ecosystem services is shown in Figure 14.1. Between 1750 and 1820, narratives record the river as a source of food, with fish shoals common. The river is also noted to be a key source of power, with water-powered corn mills (1755) and textile mills (1780s), being remodelled to operate by steam powered engines which require water to operate (1810).

Records of 1830 to 1860 contain reports of continuing industrialisation of the area, so by 1860 waters are contaminated with refuse from dye, chemical and paper works in addition to discharges from cotton factories. The ecosystem impacts are classified as disservices due to a reduction in capacity re provision of clean water and food supply (1850). There is little improvement in the level of biotic life until 1970s when small fish are reported alive in one stretch of the area and ducks are noted to be breeding. The cessation of industrial processes increased the provision of clean water and supported riparian planting schemes in 1980s.

*Regulating services* - A greater number of published events record aspects of regulating ecosystem services. Regulating services linked to hydrological flow and the use of the river to mitigate hazards were well recorded in the published histories, with an equal number of service and disservice events. The river flood plain is a natural feature which mitigates flood water and regulates the flow of water downstream and 18 reports of floods were found, covering the period from 1787 to 1954. The cumulative change in regulating ecosystem services is shown in Figure 14.2. From 1750 to 1850 the hydrological flow of the river is altered by infrastructure developments such as the construction of weirs, water extraction to support industrial processes and the replacement of fords by bridges (1780, 1800, and 1840). The ability of the river to act as a regulator of pollution and disease is compromised by effluent discharges, contributing to the severity of cholera epidemics in 1832 and 1846.

From 1860 to 1940 flood reports indicate that the river is acting as a natural regulating system and actions to address pollution discharge, in conjunction with the decline in heavy industry, enable an improvement in water purification capacity. In the early 20$^{th}$ century regulating disservices were reported as industrial process changed during the period of WWII (1939-45), synthetic textile effluents were discharged (1960s) and a major flood defence scheme was completed removing the capacity for the river to access the flood plain (1970s). Most recently, a programme of sewage discharge improvements have facilitated increased purification capacity (2010s).

*Cultural service* - The majority of the published records are aligned to the cultural ecosystem service framework. Sufficient detail was present in the reports to assign events to the areas of recreational leisure activities, cognitive skill acquisition opportunities linked to industrial and financial growth driven by ecosystem use and bequest values identified through governance and infrastructure management. The majority of leisure and social reports and bequest infrastructure reports are benefit focussed. In contrast, cognitive skill (including economic) reports which are most frequent in the historical documents are twice as likely to be a disservice report rather than a benefit (Figure 14.3).

Social leisure values can be attributed to the physical construction of connecting infrastructure. In the study area, connectivity infrastructure transformed from fords and a medieval stone bridge to a series of road, rail, and foot bridges connecting residential and industrial sites to public parks and recreational sites beside the river. One of England's first public parks, Peel Park was founded in 1846 along a major meander in the river. Angling and rowing societies were also formed in early 1800s but by 1870 activities ceased due to the pollution level in the river water. Recreation activities recur in the narratives from 1930s onward as the river water is less toxic, riparian planting schemes enhance angling and bird watching opportunities, and pollution controls facilitate a charity swim event (1980s).

Bequest values are expressed in narratives through the reporting of legal acts and novel governance structures which aim to restore the resilience of the river, along with infrastructure developments which protect the local population from destructive flow rates. The appointment of River Inspectors in 1867 were forerunners to formal Acts impacting river pollution; prosecutions for illegal discharges followed along with the formation of committees to address water issues. The 20th century saw the formation of river boards (1948), regional water boards with responsibilities to deal with water supply and sewage disposal (1974) and privatisation of water companies. Bequest initiatives continue into the 21st century with the creation of Catchment Partnerships. A major flood defence investment was completed by 1970s ensuring the security of the surrounding commercial and residential developments into the 21st century.

Cognitive skill acquisition opportunities linked to industrial and financial growth driven by ecosystem use are reported from 1720 to 1860 as industrialisation and social mobility increased the population. Disservices in cognitive skill opportunities are frequently reported, as destructive flood events throughout the 1800s and early 1900s destroy industrial sites and drive redevelopment and land-use evolution. The decline of the cotton industry from the 1920s onward not only reduced provisioning ecosystem disservices but also had an impact on the opportunity for linked skills acquisition. Further industrial decline in the latter half of the20th century shifted the social focus to regeneration activities offering greater opportunities for skill development linked to the ecology of the river.

*Land use mapping reference*

Riparian land use was analysed from the mid-1700s through to 2005 for selected map sources. Variations in total lengths between the different census dates are attributed to changes in the course and width of the river, with one notable change occurring due to the infilling of a meander and straightening of the river from 1951 to 1970.

Over the study period, there is a major change in the land use along the river bank (Table 14.2). Agricultural land-use was the dominant land type at the end of the late 1700s but had been totally replaced by the early 1900s. Industrialised lands, including areas classified as waste or open, rose from a low of 11% of the river banks' length in the late 1700s to a maximum of 52% by 1955; by 2005 only 21% remains classifiable as Industrial. In contrast, recreational use rises from 7% classified in 1794 to 71% of the river side land use by 2005, almost doubling from 37% in 1906. This major increase reflects the building of riverside walkways and ecological improvement projects. Residential housing along the bankside saw a peak in the first half of the 1900s at 11% but this has fallen to 7% by the end of the 20th century.

**Discussion**

Over the past 300 years the stretch of the River Irwell under review has been impacted by those people living and working on its banks. Changes in economic drivers, technology innovations and social movement have advanced and relegated the importance of specific aspects of the river to local populations. The visualisation of historical ecosystem change in a closely defined area can take a range of forms. The intuitive methodology outlined here enables temporal changes to be simply visualised for the key ecosystem services of provisioning, regulating and cultural aspects. The methodology utilises historical public data sources which may be considered unsuitable for advanced tools and techniques.

The values placed on the river and reported in historical narratives reveal both similarities and key differences to the observations from infrastructure mapping. The ease of identification of tangible benefits has previously been noted by Guo et al. (2010) and this case study reconfirms this observation. Both narrative analysis and map examination identify a similar sequence of tangible benefits: regulating ecosystem services sustaining an agricultural tradition migrate to provisioning values for powering industrial-based economic development, however, with the decline of industrial infrastructure requiring water use, social values now predominate where the river is seen as a recreational asset for the urban population. This sequence illuminates the interplay of social valuation of ecosystem goods and services

between categories; for example, as provisioning services are more highly valued in the period 1750 to 1820, so regulating disservice reports are noted. Likewise, from 1820 to 1900, the prevalence of provisioning disservice reports are counterpoised against regulating service reports.

The analysis has also found contentions within ecosystem services categories which can be unpicked and made visible by the application of the ecosystem service framework. The prime value of providing water for industrial process in the 1800s is readily identifiable from the construction of mills and weirs along the river channel; however the social impact of pollutant dispersal and contamination of drinking water is not extractable from maps, but may be inferred. Published histories identify the social impact of the cholera epidemic in Manchester in 1832 (Harwood 1895) yet narrative analysis demonstrates how the prime value of the Irwell continued to be a provisioning service supporting industrial processes. Provision of clean water for drinking is critical to the health of the population but is a secondary provisioning value for the Irwell. Through cultural bequest value analysis, the historical social value conflict and method of resolution is illuminated; in this case Manchester and Salford obtained an alternative clean water supply from 1851 which still impacts the hydrology of the Irwell in the 21st century. As demonstrated here, applying the ecosystem service framework to landscape management has the potential to identify conflicts otherwise obscured and so enable solutions to be proposed which alleviate stakeholder concerns.

Those aspects of cultural ecosystem services not explicitly identified on maps and identifiable in this analysis are skill acquisition and bequest values. Cognitive skill acquisition by the population is not limited to employment or schooling opportunities identified from infrastructure maps but also richer social interactions through amenity use. Cultural heritage analysis is noted to place emphasis on the architectural and material aspects of an area (Tengberg et al. 2012). The application of the ecosystem services framework facilitates the identification of cultural values which add a further dimension to landscape assessment. Historical narrative gives greater depth to areas of philanthropy and social justice movements lacking from map function classification. The case study has not sought to identify cultural aspects of spirituality and aesthetic appreciation as the narratives examined do not record these facets. Areas for further study would be examination of aesthetic appreciation deduced from pictorial records, plus existence values of well-being and sense of place through direct interaction with stakeholders. In both cases, the ecosystem service framework would appear to be a suitable method of analysis incorporating the tangible aspects and the emotional responses.

The timeline of ecosystem service interaction and reaction to events has been explored. In the 20th century, concerted efforts were made to address water quality issues in the Irwell. In 1950 a report identified no biotic life present in the Irwell and in 1971 UK Government funds were made available to ‘clean’ rivers in the UK. Over the following ten years restoration actions supported improving water standards, culminating in authorised swimming events. In exposing the timeframe of ecological degradation and recovery, current development plans for the River Irwell may be examined to ensure impact assessments have sufficient depth and breadth.

Historical narrative analysis has been possible for the area under study due to the large number of publications which provide sufficient detail for ecosystem services identification. The applicability of this method to other locations is constrained where such records do not exist, however an alternative application of the ecosystem service framework in the identification of social recollections with local stakeholders could be equally revealing.

**Conclusion**

The interplay of service and disservice may be made more comprehensible to stakeholders through the simple, intuitive, visualisation methodology outlined here. The trade-off between importance of one, or a number, of ecosystem services and impact of social movements may be explored and the multiple layers and conflicts of demands at a given point in time examined. The intuitive method outlined here illuminates the complexity of social values set within a landscape to inform future plans and time frames.

**References**


Andrienko G, Andrienko N, Demsar U, Dransch D, Dykes J, Fabrikant SI, Jern M, Kraak M-J, Schumann H and Tominski C (2010) Space, time and visual analytics. *International Journal of Geographical Information Science* 24(10): 1577-1600.

Bergin T, Pearce DN, Shaw S (Eds.). (1989) *Salford: A City and its Past* (2nd Ed.). Bath, UK: Salford Cultural Services, Adlib Books.

Bracegirdle C (1973) *The Dark River, The Irwell*. Altrincham, UK: J. Sherratt and Sons Ltd.

Cooper G (2005) *Salford: An Illustrated History.* Derby, UK: Breedon Books Publishing Co Ltd.

Corbett J (1907) *The River Irwell*. Manchester, UK: Abel Heywood and Son.

Dobkin M (1990) *Broughton and Cheetham Hill in Regency and Victorian Times* (2nd Ed.). Swinton, UK: Neil Richardson.

Feyzi M, Nejad HH and Seddigh M (2011) Investigating the socio-cultural impacts in redevelopment of the urban coastal areas in Mazandaran Province, Iran. *Asian Social Science, 7*(2): 154-164.

Fisher B, Costanza R, Turner RK and Morling P (2007) Defining and Classifying Ecosystem Services for Decision Making. *CSERGE Working Paper EDM 07-04*. ISSN 0967-8875. Available at: http://www.cserge.ac.uk/sites/default/files/edm_2007_04.pdf [last accessed 30 July 2015]

Forum for the Future (2009) *The Five Capitals Model – a framework for sustainability.* FftF. UK. Available at: http://forumforthefuture.org/project/five-capitals/overview [last accessed 30 July 2015]

Greater Manchester Archaeological Unit (1993) *River Irwell Flood Control Scheme: An Archaeological Assessment.* GMAU, Manchester, UK.

Greater Manchester Archaeological Unit (2012) *Greater Manchester Urban Historic Landscape Characterisation Project (HLC)*. York: Archaeology Data Service. doi:10.5284/1017434

Green W (1794) *A Plan of Manchester and Salford* (reprinted 1982). Swinton, UK: Neil Richardson.

Greenwood A (1950) *River Irwell (Pollution) House of Commons Debate*, 18 April, 474 cc91-106, HANSARD, HMG, UK. Available at: http://hansard.millbanksystems.com/commons/1950/apr/18/river-irwell-pollution [last accessed 30 July 2015]

Guo Z, Zhang L and Li Y (2010) Increased dependence of humans on ecosystem services and biodiversity. *PLoS ONE* 5(10): e13113.

Harris GP and Heathwaite AL (2012) Why is achieving good ecological outcomes in rivers so difficult? *Freshwater Biology* 57 (Suppl. 1):91-107.

Harwood JJ (1895) *History and Description of the Thirlmere Water Scheme.* Henry Blacklock & Co Manchester, UK. Available at: http://www.jdscomponents.co.uk/gates/thirlbook/page19.html [last accessed 30 July 2015]

Hendrych J, Storm V and Pacini N (2013) The value of an 1827 cadastre map in the rehabilitation of ecosystem services in the Kremze Basin, Czech Republic. *Landscape Research* 38(6): 750-767.

James P, Atkinson S, Barlow D, Bates A, Comyn F, Duddy M, Dutton D, Fraser J, Horsfall W, Hothersall A, Hutchinson A, Lowry K, Moore A, Rothwell J, Schofield M, Smith A, Surtees A, Taylor D, Tollitt B, Towers C, Tzoulas K, Whitaker G, Wright A and Causer K (2012) *The Irwell Catchment Pilot: The Rivers Return.* Warrington: The Environment Agency.

Maes J, Teller A, Erhard M, Liquete C, Braat L, Berry P, Egoh B, Puydarrieux P, Fiorina C, Santos F, Paracchini ML, Keune H, Wittmer H, Hauck J, Fiala I, Verburg PH, Condé S, Schägner JP, San Miguel J, Estreguil C, Ostermann O, Barredo JI, Pereira HM, Stott A, Laporte V, Meiner A, Olah B, Royo Gelabert E, Spyropoulou R, Petersen JE, Maguire C, Zal N, Achilleos E, Rubin A, Ledoux L, Brown C, Raes C, Jacobs S, Vandewalle M, Connor D, Bidoglio G (2013) *Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020*. Publications office of the European Union, Luxembourg.

Manchester City Council (2012) *Spinning the Web: The Story of the Cotton Industry*. MCC. Available at: http://www.spinningtheweb.org.uk/overview/ [last accessed 30 July 2015]

Millennium Ecosystem Assessment (2003) *Ecosystems and Human Well-Being: Current State and Trends*. Island Press. Available at: http://www.maweb.org/en/Framework.aspx [last accessed 30 July 2015]

Millennium Ecosystem Assessment (2005a) *Ecosystems and Human Well–Being: Biodiversity Synthesis*, World Resources Institute, Washington. DC. Available at: http://www.MAweb.org [last accessed 30 July 2015]

Millennium Ecosystem Assessment (2005b) *Ecosystems and Human Well–Being: Wetlands and Water Synthesis*, World Resources Institute, Washington. DC. Available at: http://www.MAweb.org [last accessed 30 July 2015]

Nevell M (2008) *Manchester; the Hidden History*. Stroud, UK: The History Press.

O.S. (1851) 60in to 1 mile *Manchester and Salford sheet 23*, surveyed 1849. Ordnance Survey.

O.S. (1908) 1:2500 *Lancashire sheet* CIV.6, revised 1905-6. Ordnance Survey

O.S. (1955) 25" *National Survey* 1950, *Lancashire sheet* CIV.6. Ordnance Survey

O.S. (2005) 1:1250 *Mastermap*. Ordnance Survey. Available at: http://www.getamap.ordnancesurveyleisure.co.uk/ [last accessed 30 July 2015]

Pickett STA and Cadenasso ML (2002) The ecosystem as a multidimensional concept: meaning, model, and metaphor. *Ecosystems* 5: 1–10.

Plieninger T, van der Horst D, Schleyer C and Bieling C (2014) Sustaining ecosystem services in cultural landscapes. *Ecology and Society* 19(2):59.

Rakodi C, Nunam F and McCallum D (2002) *Sustainable Urbanisation: Achieving Agenda 21*. UN-HABITAT and the UK Government Department for International Development (DFID). London, UK. Available at: http://www.dfid.gov.uk [last accessed 30 July 2015]

Sandleowski M (1991) Telling stories: narrative approaches in qualitative research. *IMAGE: Journal of Nursing Scholarship* 23(3):161-166.

Schröter M, van der Zanden EH, van Oudenhoven APE, Remme RP, Serna-Chavez HM, de Groot RS and Opdam P (2014) Ecosystem services as a contested concept: a synthesis of critique and counter-arguments. *Conservation Letters* 7(6): 514-523.

Swetnam TS, Allen CD and Betancourt JL (1999) Applied historical ecology: using the past to manage for the future. *Ecological Applications* 9(4): 1189-1206.

Tengberg A, Fredholm S, Eliasson I, Knez I, Saltzman K and Wetterberg O (2012) Cultural ecosystem services provided by landscapes: Assessment of heritage values and identity. *Ecosystem Services* 2: 14–26.

UK National Ecosystem Assessment (2011) *The UK National Ecosystem Assessment: Synthesis of the Key Findings*. UNEP-WCMC, Cambridge, UK. Available at: http://uknea.unep-wcmc.org/ [last accessed 30 July 2015]

UK National Ecosystem Assessment (2014) *The UK National Ecosystem Assessment Follow-On: Synthesis of the Key Findings.* UNEP-WCMC, LWEC, UK. Available at: http://uknea.unep-wcmc.org/Resources/ [last accessed 30 July 2015]

Wang X, Song B, Chen J, Zheng D and Crow TR (2006) Visualizing forest landscapes using public data sources. *Landscape and Urban Planning* 75:111-124.

Williams AE, Waterfall RJ, White KN and Hendry K (2010) Manchester Ship Canal and Salford Quays: Industrial legacy and ecological restoration, in: Batty LC and Hallberg KB (Eds) *Ecology of Industrial Pollution*, Cambridge: Cambridge University Press, pp. 276-308.

Zu Ermgassen PSE, Spalding MD, Blake B, Coen LD, Dumbauld B, Geiger S, Grabowski JH, Grizzle R, Luckenbach M, McGraw K, Rodney W, Ruesink JL, Powers SP and Brumbaugh R (2012) Historical ecology with real numbers: past and present extent and biomass of an imperilled estuarine habitat. *Proceeding of the Royal Society of Biological Sciences* 279: 3393-3400.

**Figure 14.1:** Cumulative effect of provisioning ecosystem services as relevant to the River Irwell for 1720 to 2013. Provisioning services are the products or goods obtained from the ecosystem such as food, fuel, fresh water, and natural medicines. One mark was allocated per event. The plot marker for each decade represents the cumulative net impact of event records. The movement of the plot line is the cumulative change from 1720, which possess either a positive (upward movement) or negative (downward movement) assigned value.

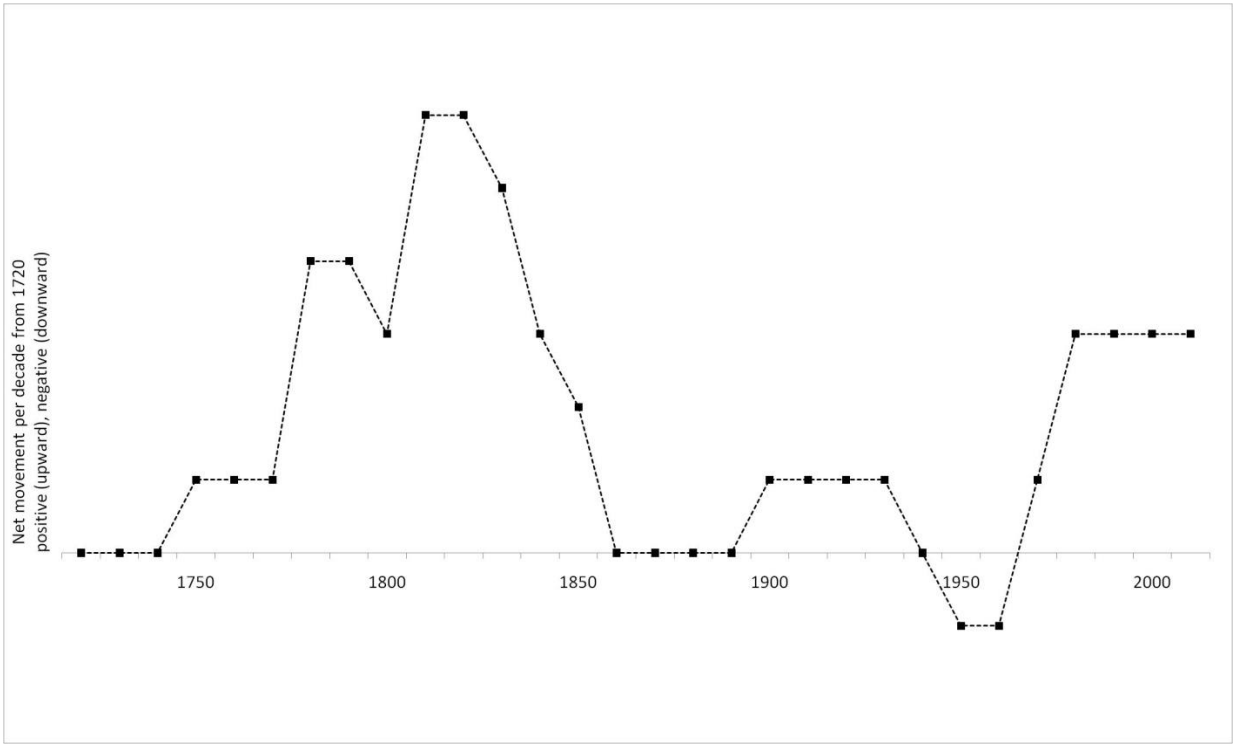

**Figure 14.2**: Cumulative effect of regulating ecosystem services as relevant to the River Irwell for 1720 to 2013. Regulating services include water flow regulation, climate / flood regulation, water purification and disease regulation. One mark was allocated per event. The movement of the plot line is the cumulative change from 1720, which possess either a positive (upward movement) or negative (downward movement) assigned value.

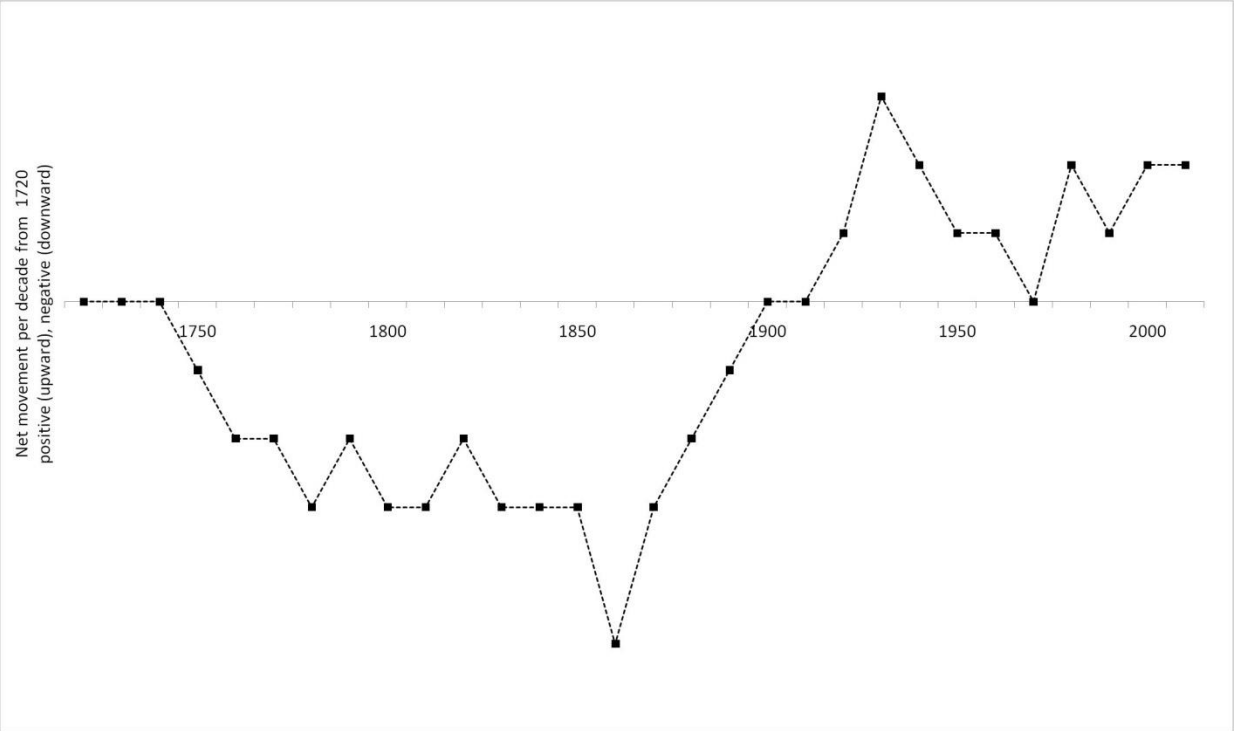

**Figure 14.3:** Cumulative effect of cultural ecosystem services (cognitive skills) as relevant to the River Irwell for 1720 to 2013. Cultural services are those non-material benefits which include spiritual enrichment, cognitive skill developments, social cohesion, aesthetic and recreational experiences. One mark was allocated per event. The movement of the plot line is the cumulative change from 1720, which possess either a positive (upward movement) or negative (downward movement) assigned value.

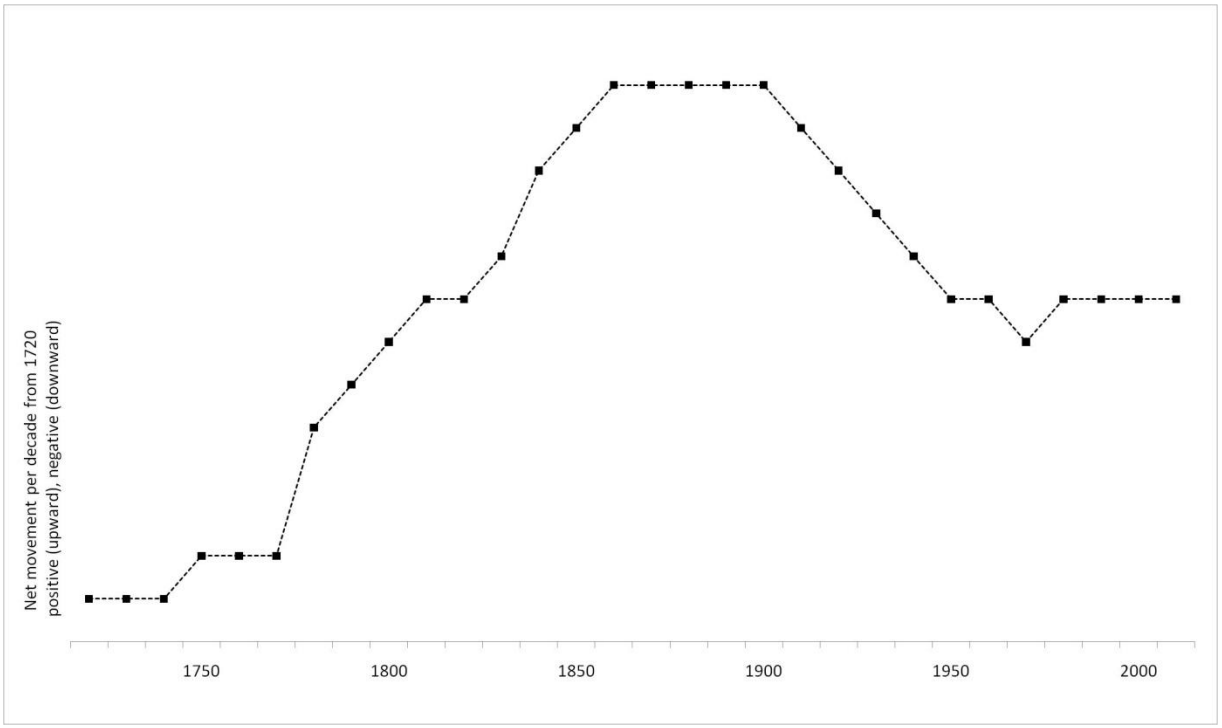

**Table 14.1:** Ecosystem service categories of Provisioning (P), Regulating (R), and Cultural (C) as identified in major mapping typologies, focussing on riverine goods and services. Cultural ecosystem services category incorporates recommendations outlined in the UK National Ecosystem Assessment (2014).

| Ecosystem Service Category | | Riverine Goods & Services |
|---|---|---|
| P | Provisioning | Food – nutrition source for human (fish, waterfowl).<br>Food – nutrition source for animal.<br>Drinking Water – human use.<br>Drinking Water – animal use.<br>Clean Water – agricultural use, irrigation.<br>Clean Water – provision of habitat supporting biodiversity.<br>Non-Drinking Water Use – resource for washing, industrial processes.<br>Non-Drinking Water Use – resource for mechanical power (water).<br>Non-Drinking Water Use – resource for mechanical power (steam).<br>Fibres & Timber – biomass power source, fuel supply.<br>Fibres & Timber – food source for animal based power.<br>Bio-medicinal – products used in healthcare, medicinal uses. |
| R | Regulating | Water Purification – waste water cleansing – dilution service.<br>Water Purification – waste water cleansing – biotic waste assimilation.<br>Water Purification – waste water cleansing – reed beds, wetland filtration.<br>Water Flow – mediation of flow, stable liquid flow rate and patterns.<br>Water Flow – moderation of extreme flow rate.<br>Erosion Regulation – moderation of destructive flow rates.<br>Pest Regulation – control of invasive species.<br>Habitat & Gene Pool – lifecycle requirement (pollination, nursery, dispersal). |
| C | Cultural | Recreation – physical interactions, experiential opportunities, connectivity.<br>Knowledge & Skill development – cognitive opportunities derived from riverine existence<br>Bequest – governance to ensure resource passed to descendants<br>Bequest – existence, sense of place, appreciative values<br>Religious Values - spiritual reflections<br>Aesthetic Values - art and appreciative opportunities.<br>Cultural Inspiration – diversity linked to river. |

**Table 14.2:** Percentage of measured riparian land attributed to differing land uses. Major categories are Agricultural (AG), Industrialised (IN), Recreational (RC) and Non Industrial Build (BI). Major land uses >30% per map year noted in bold.

| Percentage of river bank attributed to different land uses (%) | | Year | | | | |
|---|---|---|---|---|---|---|
| | | **1794** | **1849** | **1906** | **1955** | **2005** |
| AG | **Agricultural** | **79.0** | 23.0 | 1.0 | 0.0 | 0.0 |
| IN | **Industrialised** | 10.5 | **49.5** | **51.0** | **51.5** | 21.0 |
| RC | **Recreational** | 7.0 | 26.5 | **37.0** | **38.0** | **71.0** |
| BI | **Non Industrial Build** | 3.5 | 1.0 | 11.0 | 10.5 | 7.0 |