Int. J. of Sustainable Water and Environmental Systems
Volume 4, No. 1 (2012) pp. 35-41

Building a common understanding of natural resource management and use within a catchment community - the Eye Brook, England

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Abstract

Water quality and availability are inextricably linked with landuse and climate change. Public understanding of these issues, of differing attitudes towards them, and of how different members of catchment communities can address them is low. This paper describes a four-year (2006-2010) project in the 67km^2 Eye Brook catchment in central England and takes an innovative and inclusive social learning approach that recognises messy problem situations and differing social norms. The aim is to improve natural resource management, especially that of water, to benefit local people, resource users and regulators. The project recognises, values and capitalises on three differing knowledge cultures: scientific, local and historical, through professional inter-disciplinary research, public events, a newsletter, group and individual research, a teaching pack and a book. The project improved farmer's engagement with environmental issues, increased public awareness of agri-environmental processes associated with water quality and availability, and provided a valuable reality check for researchers and experts. Locally, the work has extended to practical evaluated management, while nationally it has influenced the development of new landscape scale community-led projects. The principles are widely applicable to other sites and circumstances.

Keywords: *Biological indicators, catchment management, climate change, community engagement, natural resources, participatory research, water quality*

1. Introduction

The sustainable management of natural resources requires an understanding of multiple integrated issues and conflicting objectives, but is increasingly important, given current pressures of population growth, increased consumption, demographic change and resource depletion. For example, multiple objectives for land management and increasing impacts of climate change have major influences on the quality and availability of water resources for domestic use, crop production, and for wildlife [1]. In the case of water, management of other relevant resources must be considered at the catchment scale, especially management of land for food production. In considering the resolution of climate change impacts on water, there is also a need to recognise the strong linkages between climate change adaptation and mitigation [2].

Education, regulation, and market intervention aim to address these issues at a range of scales and science-based technological advances such as new developments in insulation, photo-voltaic panels, anaerobic digestion, and precision agriculture contribute increasingly to climate change mitigation. The EU Water Framework Directive is a strong regulatory driver for behavioural change at a range of scales across Europe, with for example, a major influence on land use change. Education at a range of levels, from industry to individual households, promotes such sustainable approaches and their public benefits, in part through identifying or stimulating associated immediate socio-economic benefits to the individuals responsible for them. Despite this combination of science, industry, incentive and regulation, adoption of sustainable development is slow. This may be because the approach involves top-down knowledge transfer, rather than knowledge exchange which also builds on the knowledge of, and accounts for the different cultural circumstances between and within individual communities.

It is increasingly recognised that cultural aspects such as perceptions, feelings, attitudes and values have a role to play in determining the rate at which adoption of sustainable

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DOI: 10.5383/swes.04.01.004

technology or practices takes place. They also interact with each other, and with other influences; attitudes influence behaviour, but how they do so may depend on local circumstances. For example, individual farmers cannot by assigned to typologies in terms of environmental practice, but express different attitudinal typologies according to what part of the farm they are considering for environmental management [3]. Social norms and peer pressure also play an important part. Farmers who demonstrate control of nature gain cultural capital amongst their peers [4]. However, different groups perceive the same issue in different ways and draw on different knowledge cultures [5, 6]. Scientific knowledge may differ from local or experiential knowledge for example, through differing approaches to evaluation of processes, and differing local cultural and bio-physical contexts. Both scientific and local knowledge contribute to the work described in this paper.

Understanding differing attitudes to environmental issues and knowledge cultures within communities, and mutual acceptance of those differences, may be crucial to developing plans for addressing them. Environmental issues, including those discussed in this paper, are often characterized by uncertainty, conflict about problem definition, subject to unpredictable changes, and can be highly context dependent, features that classify them as 'wicked problems' [7]. Flexible negotiating packages ('boundary objects') have been advocated for such circumstances to facilitate the mutual development of more defined and formulated plans [8]. The implementation of different management approaches, with successful 'communities of practice' is characterized by sharing sustained mutual relationships and shared ways of engaging in doing things together [9]. Group affiliation and identity with a common cause has been shown to strengthen individual behavioural change through establishment of new social norms [10, 11].

In practice of course, there may be conflicting objectives in the management of natural resources. Such trade-offs are made explicit through the language of ecosystem services [12,13]. One example is the trade-off between the need to produce affordable food through profitable crop production and the need for clean water for drinking and a healthy aquatic ecosystem which may be compromised by runoff from arable land. Non-farming residents also influence water quality and ecology through discharge of nutrient-enriched waste water from private septic tanks [14]. Such water-related issues therefore involve a range of people and organizations interested in a common resource, including farmers, other rural residents, anglers, water companies and regulators.

The value of knowledge embodied in local communities is increasingly accepted in terms of its contribution to, and interpretation of science [15]. Social learning [16] is based on the inclusive participatory involvement of a range of people and their associated knowledge cultures from within a community with a common 'issue' but disparate or even conflicting objectives. It is concerned, not with the 'rational' basis for choice, but with the processes that lead to choice. It brings together scientific and local knowledge cultures and may involve a common focus for discussion such as participatory GIS that enables experiential knowledge to be incorporated into debate alongside scientific data for example. It is particularly well suited to 'messy' problem situations where multiple processes interact [17, 18]. The management of an agricultural catchment to meet objectives for water quality and availability, alongside multiple other demands on natural resources, and alongside climate change influences, provides an example of such a situation. The social learning approach has previously been applied to a number of European catchments through the SLIM project [19], and this work has informed the approach described in this paper.

The project reported here is concerned primarily with issues associated with water as a resource within a primarily agricultural catchment in lowland England. Specifically, the project is concerned with the problem perceptions of regulators applying the Water Framework Directive, those of local farmers producing food, and those of other local residents. The project addresses the issue of agriculturally derived sediment and associated nutrients in watercourses and the numerous interrelating functions of the catchment. The approach combines scientific, local and historical knowledge with a view to informing future sustainable management of land and other natural resources within the rural catchment community. . The inclusion of historical knowledge, alongside scientific and local knowledge, is based on the premise that an understanding of the history of land and other natural resource management and use can enhance local identity and 'ownership' of environmental problems and opportunities. The aim is therefore to focus on water, but to develop a shared understanding of the relationship with other related objectives, with a view to improving the sustainability of resource management and use in future through behavioural change in both the farming and non-farming members of the community. As well as being relevant locally, the process is relevant to regulators of environmental quality, and to policy makers interested in community engagement on agri-environmental issues.

1.1. The Study Area

The Eye Brook catchment is a tributary of the river Welland in the East Midlands of England. It is 6,750 ha in area and is predominantly agricultural, comprising arable land and permanent pasture grazed mainly by sheep, with some beef cattle. Arable crops are mainly wheat and oilseed rape, with beans and oats also being grown. Soils are predominantly heavy clay over ironstone and crops are therefore mainly autumn-sown. Although the area of woodland is not high, much of the catchment is within Leighfield Forest, a remnant medieval hunting forest now comprising a series of semi-natural woods which are designated Sites of Special Scientific Interest (SSSI) because of their rare woodland plants. The Eye Brook flows into Eyebrook Reservoir at its lower end and this is also designated an SSSI for the migratory wintering birds that occur there. The reservoir was built in 1940 to provide 18,000m^3 of water per day for steel works in the nearby town of Corby but only 2,000m^3 of water per day are now used as the steel works has closed. The reservoir is now managed as a trout fishery.

The river Welland fails Water Framework Directive targets on account of high phosphate concentrations and poor ecological status on account of sedimentation. Phosphate is derived from agricultural sources (adsorbed to sediment) and domestic sources (sewage treatment works and septic tanks). Sedimentation causes impoverishment of the fish and invertebrate communities, increased flood risk, and reduced reservoir storage capacity, while phosphate causes eutrophication and increases drinking water treatment costs. There are additional issues associated with concentrations of some agricultural pesticides exceeding EU drinking water limits.

The Game & Wildlife Conservation Trust's 'Allerton Project' www.gwct.org.uk/research__surveys has been managing a 333 ha research and demonstration farm at Loddington, in the middle of the Eye Brook catchment, since 1992. The Trust runs a farm business and a research programme, as well as hosting visits from up to one thousand agricultural professionals each year. Environmental objectives of the research and farm management include an improved understanding of agricultural ecology and wildlife conservation, reduced greenhouse gas emissions, improvement of water quality and aquatic ecosystems, and the development and implementation of management practices to achieve these [20,21] . Some of the management practices researched and developed at Loddington are now incorporated into the UK Government's agri-environmental schemes which fund farmers to adopt similar management on their own land. The Trust therefore aims to meet the environmental, social and economic objectives of sustainable rural development through improved understanding and use of natural resources.

The scientific knowledge is developed in partnership with other research organisations from a wide range of academic disciplines, and with other key players such as national agencies responsible for implementing government policy regionally (e.g. Environment Agency and Natural England). Local knowledge is represented by farmers and other rural workers, local naturalists, historians and others. Historical knowledge comes from members of the catchment community, including elderly residents with memories of a largely pre-fossil fuel economy, and from academics outside it. The underlying premise is that improved knowledge of natural resource use history enhances local identity and increases popular awareness and 'ownership' of environmental problems and opportunities.

2. Activities

2.1. Science

Scientific knowledge is associated mainly with the Allerton Project research and demonstration farm at Loddington in the centre of the catchment where scientific research into environmental issues such as catchment management, soil and nutrient management, water quality, and wildlife conservation has been carried out in the context of agricultural business. The scientific research involves universities and other UK research organisations.

2.1.1. Soil and Nutrient Management

The potential role of reduced tillage to minimise crop establishment costs while simultaneously meeting environmental objectives such as reduced surface runoff has been studied in some detail through a number of projects. An EU funded project, 'SOWAP' (www.sowap.org) compared cropping, runoff, soil fauna such as earthworms microbial communities, and use by birds in reduced tillage and conventional plough based tillage systems. These studies identify the potential of increased soil organic matter, earthworm density and microbial biomass for increasing the capacity of the soil for water retention and attenuating flood peaks during storms, while maintaining soil moisture during drought. The potential benefits to soil and cropping arising from application of digestate by-product from an anaerobic digestion plant is currently being investigated at the replicated plot scale. A UK government funded project, 'MOPS' [22] compared runoff in reduced tillage and plough based systems, cultivation direction and in-field barriers. The management of tramlines (tractor wheelings) in arable fields is currently being investigated to reduce runoff and associated transport of sediment, nutrients and other pollutants to watercourses. The project includes development and testing of new technology, including low ground pressure tyres and surface disrupters.

2.1.2. Land Use, Households and Water Quality

A Defra-funded research project, 'PARIS' [23] explored the relationship between land use and sediment and nutrients in water in the upper Eye Brook. Suspended sediment and associated total phosphorus concentrations tended to be higher in arable than grassland catchments and peaked during storm events when the difference between land uses was greatest, except during exceptionally intense storm events when grassland soils became saturated. However, the project also identified domestic septic tanks associated with private households as locally and seasonally important sources of phosphorus and other nutrients associated with eutrophication in headwater streams, especially under low flow and drought conditions. Nutrient concentrations in the stream were up to ten times higher downstream of houses than upstream [14].

Water turbidity was highly correlated with suspended sediment and total phosphorus, and turbidity measures from 22 catchment tributaries during storm events were used to assess the relative impact of the tributary catchments on the main stream. This made it possible to identify the tributaries carrying highest sediment loads with a view to targeting those for subsequent management. Suspended sediment in agricultural catchments used for food production was up to ten times that in mature woodland representing near pristine conditions. Other research investigates the potential of field edge and field corner constructed wetlands to minimise diffuse pollution through sedimentation and retain water on farms longer into the summer so as to benefit terrestrial wildlife and attenuate flooding (www.lec.lancs.ac.uk/research/catchment_and_aquatic_processes/mops.php).

2.1.3. Wildlife

Brown trout *Salmo trutta* and other fish have been surveyed in the stream. Brown trout represent an iconic species that is valued by local people and is affected by sedimentation of the stream bed spawning habitat as a result of increased erosion of agricultural land. Although the species is present along the entire length of the stream, productivity is low and breeding is restricted to a small number of sites. Ecosystem services provided by wildlife have been investigated. Predatory beetles control aphid crop pests and beetle banks have been developed and implemented to minimise the need for summer aphicides in arable crops [24]. Local research has shown that naturally occurring pollinating insects are essential for fruit-set in some hedgerow shrubs [25] and habitat is being introduced for nesting and alternative foraging so as to increase the abundance of these pollinators for wild shrubs and cultivated fruit trees.

Such habitat creation can have multiple benefits that contribute to water quality improvement and climate change mitigation, as well as enhancing biodiversity and associated ecosystem services, and wildlife conservation can be a motivator for farmers' land use change. To be effective at the catchment scale, collaboration between farmers may be necessary. In a survey of 34 Eye Brook catchment farms, 37% of farmers collaborated on farming activities for their businesses, 30% collaborated on game bird shoots, but only 7% collaborated through Environmental Stewardship agreements for wildlife conservation. 30% had noticed effects of climate change on their own farms, mainly through water related issues such as drought-stressed crops.

2.2. Individual and Group Research

2.2.1. Local History

Local historians, both professional and amateur, collected a wide range of historical data on management and use of land and other natural resources in the area. This included archaeological evidence, historical documents, and landscape features. This work highlighted considerable change in the local landscape, from pre-Neolithic woodland to dispersed farmsteads, to nucleated settlements and feudal 'open field' farming systems, followed by private enclosure of land for livestock, and ultimately by an increase in the arable area since the Second World War (1939-1945). GIS software was used to map the distribution of cultivated and uncultivated land at three points in history so as to present these results to local residents in a meaningful way. Management of natural resources was more integrated and localised in the past than it has become in recent decades with greater use of hydro- and wind-power, and animal traction fuelled by grass and crops. Low crop yields in the medieval period demanded a large cultivated area to feed the population, but crop yields have increased considerably in the past century in response to increased inputs derived from fossil fuels, such as pesticides and fertiliser. Historical data also demonstrated a substantial increase in population size, with half of this increase occurring during the period of high fossil fuel dependency in the past century.

GIS maps of land use in the medieval period, the 1840s and the present day were developed for four parishes, based respectively on aerial photos of 'ridge and furrow' evidence of medieval cultivation, historical land use maps, and direct observation [26]. These were used as a focus for discussion about historical changes in water quality with six experts. There was consensus that water quality was previously influenced by management of riparian land and that the influence of the wider catchment has increased through history as a result of increased hydrological connectivity associated with field drainage, domestic waste water treatment, and an increase in the arable area. Based on this analysis of local evidence by regional experts, the appropriateness of WFD 'Good' status was questioned, as there was no historical benchmark against which to judge current chemical and ecological status.

2.2.2. Oral History

Elderly members of the rural community grew up in the 1930s and '40s, a period of rapid transition into the current fossil-fuel based economy. Fourteen elderly residents were interviewed and their verbatim accounts of the use of land, woodland, water, and wildlife were used to illustrate to other members of the community the changes in management and use of these resources. With the exception of a railway line introduced in the 1870s and powered by coal, and some coal used in domestic houses, energy was generally derived from local renewable sources until this period (e.g. timber for household heating, and grass and oats produced for horses). The replacement of horses by tractors in the 1940s marked a major and symbolic change to a fossil fuel based society. Improved sanitation increased hydrological connectivity between houses and watercourses during this time. Mains sewerage was introduced in two villages, and septic tanks were adopted for individual houses, removing the need for pans and earth closets. Eyebrook Reservoir was built near the base of the catchment in 1940, providing a focal point for water as a resource within the catchment.

2.2.3. Household Energy Use

A local environmental group, 'Tilton Green' carried out a survey of energy use for domestic heating and lighting, and for travel, with data drawn from forty households in the village of Tilton on the Hill. Energy use varied considerably between households. The data were used to estimate the area required to produce energy locally for household use (based on wood chip production from short rotation coppice willow), and for transport (based on biodiesel from oilseed rape). The areas were mapped in a GIS to create a graphic image that was locally relevant. Assuming current consumption and production rates, the area needed to meet the needs of the Tilton community would be 110% of its available land area associated with the village. If energy consumption data for the lowest consuming households are used in this analysis, then the necessary production area is reduced to about 30% of the available land area. This exercise illustrates (to residents and researchers alike) the need to use energy more efficiently, and the limitations of biofuels as a source of energy. The exercise was repeated (using national consumption data) for food, illustrating the 'land hungry' foodstuffs such as meat and dairy products which have a major influence on the land area needed to feed the local population.

2.2.4. Future Land Use

108 residents in the upper Eye Brook catchment took part in a questionnaire survey about future land use, carried out by an MSc student [27]. Residents were asked to comment on the relative merits of maintaining the *status quo*, biofuels production, 'rewilding', and water resource protection. GIS maps of the local area were used to make the study locally relevant. Statements below are based on statistical significance at $P<0.05$. The biofuels scenario was the least favoured at a personal level, but the most favoured for the community as a whole. Rewilding was most favoured at a personal level but ranked in third position for the community as a whole. Men, especially those under 55, preferred the rewilding option. Younger respondents (under 55) favoured the biofuels scenario more than older ones did. Older women ranked biofuels last and the water quality scenario first, while the reverse was true for younger women. Respondents with farming links favoured the status quo and biofuels options. The water quality scenario was generally neither strongly favoured or rejected, potentially providing common ground between farming and non-farming respondents, and an opportunity for developing a strategy that meets multiple objectives. In practice, a multifunctional landscape is likely to be the most acceptable to a wide range of residents and the most resilient to future uncertainties associated with climate change and volatile crop prices.

2.2.5. Biological Indicators

Records of wildlife species that had been collected by local naturalists were used to illustrate changes in local wildlife communities at the landscape scale, especially those associated with climate change. Little egret *Egretta garzetta* has become established at Eyebrook Reservoir since the 1980s as part of its range expansion northwest from southern Europe. Nuthatch *Sitta europaea* has also become more widespread in recent years, initially occurring only in large ancient semi-natural woodlands, but more recently also in small farm woods. Five species of orthoptera (grasshoppers and crickets), a damselfly and a bumblebee have colonised the area in the past two decades as part of their range expansion, including species that colonised the UK from southern Europe only recently. Some of these species are clearly identifiable and prominent indicators of climate change. Data on lichen communities were also collected by local amateur naturalists and served as indicators of terrestrial nutrient enrichment and air pollution arising from fertiliser application for food production and increased road transport by local people and others passing through the area.

2.3. Knowledge Exchange and Dissemination

2.3.1. Events

Four events were held each year from 2007 to 2010, covering a range of topics including farming, sewage treatment, reservoir management, woodland management, wildlife conservation and local land use history. They took the form of site visits and evening talks. Attendance reflected the local population in terms of the proportion of agricultural residents attending, with most being from non-farming backgrounds, and with younger residents mainly participating in site visits, rather than talks. The events provided an opportunity for local people to share their knowledge with experts in the various issues, with a facilitator maintaining the focus on relevance to water quality and availability and climate change. For example, a village tour focussing on the occupations of village residents in the 1880s highlighted the low arable area, the lack of mobility, and the dependence on local natural resources at that time, emphasising the implications for water quality and climate change of the way of life today. A visit to the reservoir provided a focus for discussion about catchment scale processes and the influence on water quality of historical changes in land use.

An annual newsletter, 'The Eye', was distributed to every household (about 1,000) in the catchment, providing information on forthcoming events and other activities. Local people, students and Allerton Project staff all contributed information for articles on the past and present issues associated with the management and use of natural resources in the Eye Brook catchment. The newsletter was also used to provide information on the correct management and use of domestic septic tanks to reduce residents' impact on headwater streams.

2.3.2. Teaching Pack

A primary school teaching pack was designed and produced to be compatible with the national history syllabus but specifically as a means of teaching issues associated with future use of natural resources. The aim was to raise awareness of issues associated with land and water resource use amongst pupils and their parents and proved to be popular with teaching staff and pupils. For example, the teaching pack material highlighted the historical dependence on locally sourced energy (wood, grass and oats for horses, and wind and hydro-power), timber for construction of buildings and vehicles, and food. It also provided information on past and present household use of water, with information on changes in toilet use proving to be popular with pupils

2.3.3. Book

A 144 page book [28] was published in order to make the results of the project accessible to local residents, as well as to people much further afield, and was subsequently made available as a pdf (www.gwct.org.uk).

3. Outcome and Conclusions

3.1. Community Engagement

This project has demonstrated that data collected by volunteers can be combined with data from professional sources to improve shared understanding of environmental change. Wildlife provides an indicator of climate change and deterioration in air and water quality for example, and energy consumption data from individual households has been used effectively to demonstrate the energy demand footprint of an individual community, ensuring relevance to its members. Similarly, interviews with elderly members of the community about life in a pre-fossil fuel society proved to be a popular approach to improving understanding of issues associated with resource use today. GIS maps of the local area were also popular, for example providing a locally relevant visualisation of past or future land use change. The results of the future land use survey confirmed that there are differences in opinions between various members of the community, according to their age, gender and involvement in farming. Acknowledging and accepting these differences is essential to any plans that might be made for the future.

Through the book, the project has been widely acknowledged by UK policy makers and other high profile commentators as making a valuable contribution to the development of approaches to improve catchment community scale sustainable development. The broad principles of the project have been incorporated into UK government plans for community led projects to improve water quality and other environmental aspects of land management in other parts of the country.

3.2. Future Direction of the Project

Improvement of water quality and aquatic ecology at the river basin scale is important given the targets set by the Water Framework Directive and the likely increase in frequency of extreme storm events associated with climate change. The issue of diffuse pollution by sediment, nutrients and pesticides is being addressed with the help of volunteers who carry out assessments of sedimentation sources (in-field evidence) and impact (in-stream assessment) throughout the catchment, and adjacent tributaries. The assessment of impact adopts a simple application of turbidity measures of water disturbed from the stream substrate. The resulting information will be used to guide mitigation measures with support from the government's Environmental Stewardship scheme and other initiatives.

In the headwaters of the Eye Brook and two adjacent catchments, this process is being implemented more rigorously, with two years of detailed baseline data followed by negotiation with farmers about the introduction of targeted mitigation measures, and subsequent monitoring of outcomes. The project has been initiated by the Allerton Project researchers but has been facilitated by the activities described in this paper, raising collective awareness and acceptance of the issues associated with water quality and availability, land use and climate change. Farmers have become more willing to discuss environmental issues amongst themselves, with other residents, and with researchers than was the case before the project started. At the base of the catchment, two farmers who became involved in the project are now leading an initiative with other farmers who own land adjoining the main river Welland to improve management of riparian pasture to benefit birds, fish and water levels.

Nutrient enrichment of water by domestic sources remains more difficult to address as headwater streams are not the subject of targets set by the Water Framework Directive, there is no private benefit associated with mitigation, and little guidance and no financial support is available for improving water treatment technology at household level. The activities described here attracted interest amongst farmers (to whom phosphate in water is normally attributed) and other rural residents and have led to the development of plans for a demonstration project on domestic waste water phosphate reduction in one village.

Climate change adaptation and mitigation issues are the focus of two new approaches, one working with arable and livestock farmers to assess greenhouse gas balances for their businesses, and making recommendations for change (especially where these have multiple benefits), and one working with the local environment group, 'Tilton Green', to stimulate behavioural change at the household and community level. This initiative now has an established plastics recycling facility to which a large proportion of the village contribute. The Tilton work is linked to another research project investigating rural communities adapting to, and living with climate change (http://www.relu.ac.uk/research/projects/Fourth%20Call/Phillips.html). All of these activities build on the foundation established by the work described in this paper.

3.3. Wider Implications

This project provides a clear illustration of public engagement and involvement in strengthening the knowledge base and foundation for behavioural change at individual, household, farm and landscape scales. As such it is in line with current UK Government policy for greater involvement of local communities and non-government organisations in addressing major issues such as natural resource use, and climate change adaptation and mitigation that have traditionally been the focus of top-down approaches. The enthusiasm with which the project has been received, and the momentum of local activity, provide support for the concept of greater integration of bottom-up community-led approaches, combining different knowledge cultures, with traditional mechanisms such as regulation, education and market intervention.

Acknowledgements

The work described in this paper is the result of collaboration with numerous research organisations and local residents of the Eye Brook catchment.

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