Restore WP4a20 (3) Interim summary report:

Measuring Ecosystem Services of Restored Quarries

Introduction

Throughout Europe, the natural environment continues to be pressured by urbanization and industrialisation. For example, new road and buildings require raw resources gained from mineral extraction sites (quarries), which are common features of landscapes throughout Northwest Europe. After an active extraction phase, most quarries are subject to a choice of after-use restoration. The choice of after-use options depends on physical, geographical and financial considerations, and may include reinstatement of agricultural land, management for biodiversity conservation, or the creation of forestry plantations (Singh *et al.*, 2002; Tischew and Kirmer, 2007). Quarries restored to wildlife habitat can provide benefits for biodiversity/nature conservation because they provide different habitats than surrounding agricultural or urban landscapes. Previous studies have demonstrated that quarry habitats can support a range of rare species with high conservation value (Davis, 1979; Beneš *et al.*, 2003) and the importance of nature conservation to the public is a driver to adopt restoration strategies that produce new wildlife habitat (e.g. Santoul *et al.*, 2004).

Quarries restored for nature conservation may also provide wider societal benefits through the delivery of ecosystem services (ES) such as recreational opportunities, climate regulation through carbon sequestration and storage, and water regulation (Balmford *et al.*, 2002). However, the value, spatio-temporal distribution, and beneficiaries of ES provided by mineral sites restored for nature conservation are not always well understood (Damigos and Kaliampakos, 2003; Lienhoop and Messner, 2008); in particular how different restoration strategies compare, or how these may vary relative to the wider landscape. Exploration of these issues would enable the development of restoration policies that provide more socially-optimal ES provision (*sensu* de Groot *et al.*, 2010). Recent calls for practitioners to demonstrate how ecological restoration can improve human well-being (e.g. Aronson et al., 2010) illustrate the need to better understand the social and economic benefits provided by mineral sites restored for nature conservation beyond their inherent conservation value.

The Restore project seeks to address this research gap using a field-based approach to collect primary ecological and socio-economic data to quantify ecosystem service delivery at former mineral extraction sites restored for nature conservation, and explore how these sites contribute to human well-being. The specific objectives of the project were as follows:

1. To identify the primary ecosystem services (ES), and key beneficiaries, provided by nature-based site restoration strategies from a variety of sites and locations across Northwest Europe.
2. To quantify marginal ES benefits provided by the nature-based restoration strategies by assessing ES delivery against plausible alternative restoration strategy for each site.
3. To understand the wider societal importance of a nature-based site restoration strategy within a landscape context.

Ecosystem Service Assessment Methods

The TESSA (Toolkit for Ecosystem Service Site-based Assessment) approach described in Peh *et al.* (2013) provides a rapid, low-cost methodological framework to quantify a variety of services, and was used to assess ES provision at each site, specifically making a comparison between:

a) the current state, in which a site is managed for nature conservation;

b) a likely alternative state, referred to here as a counterfactual, which varies by site but generally is representative of conversion to another land use such as agriculture.

Assessing levels of ES provision between states enables examination of the marginal gains or losses in ES provision as a consequence of restoring the site for nature conservation rather than an alternative use, and is often considered to be more useful to decision-makers than quantifying gross benefits (Balmford *et al.*, 2011). Discussions with key stakeholders, such as site managers, government/regional authorities, and conservation organizations identified the key ES provided by each site, and TESSA provided guidance in measuring those which are considered practical for assessment: carbon storage and sequestration, nature-based recreation, agricultural production, harvested wild goods, and water services, including flood risk mitigation. These can then be used to make economic evaluation of associated benefits to people, such as socio-cultural fulfilment, reared animals and harvested goods, adequate resources, benign physical and chemical environment, and water services. Ecosystem services were quantified for the current and counterfactual states of each site using the TESSA service-specific approaches as described below.

Carbon Storage and Sequestration

Global climate change mitigation is dependent on CO_2 emission rates and the amount of carbon sequestered in vegetation and soil including: above and below ground biomass, litter, and soil organic carbon (SOC) stocks. To determine this, vegetation habitat compositions were derived based on the current restored or planned restoration state for each site. Then, habitat-specific carbon storage and greenhouse gas (GHG) flux estimates were calculated and applied to the habitat composition of each site and those assumed for the counterfactual.

Above-ground biomass (AGB) was measured on site by sampling the vegetation present, either by measuring the size of trees along transects, or sampling quadrats of grass and heather. Below-ground biomass (BGB) and litter carbon stocks were calculated using published values. Soil organic matter (SOM) is the largest component of total C storage for many landscapes (Schmidt *et al.*, 2011), and were determined from primary field data collection. Soil were sampled in the habitats present and measured for C content using the loss-on-ignition method. Net greenhouse gas (carbon dioxide, methane and nitrous oxide) fluxes from grassland areas were taken from published values (eg Allard *et al.* 2007 for grassland, and Kayranli et al. 2010 and Couwenberg and Fritz 2012 for wetlands). Marginal global climate change mitigation benefits provided by the nature-based restoration strategy were determined by subtracting carbon storage and greenhouse gas fluxes of the site in its counterfactual state from those of the current state.

Nature-based recreation

The recreational value of each site was assessed using a travel-cost method (Peh et al. 2013) to estimate the value that visitors derive from the site; i.e., determining how much visitors paid per visit to a site. Visitor questionnaires were conducted in person at each site between 2013-2015, typically at trail head car parks or other high visitor traffic locations, and were distributed over both weekdays and weekends. To calculate the value in the counterfactual scenario, visitors were asked how often they would visit the site if it had been converted to the alternative state, and the proportional change in visitation rates was multiplied by the visitor value to determine the counterfactual value. A value of zero was assigned to sites without public access.

To quantify the marginal recreational value of the nature-based restoration strategy, the proportional change in visitation rate in the alternative state was multiplied by the visitor spend to determine the value of the counterfactual scenario and subtracted from the visitor spend of the restored state. In addition to the revealed preference approach of the travel-cost model, stated preference methods were used at the Wenduine and ENCI sites to better understand the motivations for respondents choosing to visit the sites, and to provide more information about the role of nature-conservation restoration sites in providing societal services.

Agricultural production

The value of farm income for the agriculture scenarios were estimated using farm business information. Where possible this included local farm data, although these were frequently unavailable due to commercial sensitivity. Therefore, regional farming statistics were obtained for as local a scale as possible from the appropriate government agencies (e.g. Farm Business Reporting in the UK, Flemish Land Agency database) to calculate the net farming income per site if it was restored to agricultural production similar to neighbouring farming practices.

Water services

Where water services, such as flood risk mitigation and filtration were considered important and likely to differ between scenarios, these were assessed using hydrological models. This approach measured elements such as water-holding capacity, and the likely time for the capacity to be filled in case of flooding.

Harvested wild goods

Harvested wild goods provision generally had a small contribution towards total ES provision at sites. However, in some cases this category of ES was present; eg recreational fishing, and assessment took the form of information on fishing licence applications, and/or interviews with individuals who harvested wild goods.

Study sites and counterfactual scenarios

The study focussed on a variety of partially and fully restored mineral extraction sites, including sand, gravel, clay and limestone/marl quarries that were situated throughout North Western Europe in the UK, Belgium, and the Netherlands (Table 1).

Table 1. Study sites

Site Name	Location	Mineral	Size(ha)	Restoration date
Curfs Quarry	Limburg Province, The Netherlands	Limestone	41	Restoration began 2009
ENCI Quarry	Limburg Province, The Netherlands	Limestone	135	Active extraction in 135 ha till 2018, restoration in progress on 70 ha.
Meertens Quarry	Limburg Province, The Netherlands	Limestone, Marl	8.7	Extraction ended 1974, used as motorcross track till restoration began 1985
't Pompje	West Flanders, Belgium	Clay pit	66	Extraction ended 1940, restoration began 2008.
Wenduine	West Flanders, Belgium	Clay pit	12	Unknown extraction end date, restoration began by Flemish Land Agency 2011.
Mechelse Heide (Hoge Kempen NP)	Limburg Province, Belgium	Gravel and Sand pit	144	Extraction on 100 ha, 44 ha has been restored to heathland/woodland mix.
Whitesands Loch	West Lothian, UK	Sand and Gravel	100	Extraction ended 2007 Partial Restoration began 2007.
Middleton Lakes	Staffordshire, UK	Gravel	160	Extraction ended 2006. Restoration began 2007.
Ouse Fen	Cambridgeshire, UK	Gravel	700	Extraction continues on 550 ha. Restoration began 2002 on 153 ha
Fen Drayton	Cambridgeshire, UK	Gravel	311	Extraction 1950-1997. Restoration began 2007.

Curfs Quarry is located northeast of Maastricht between Houthem and Maastricht. The quarry was restored following the end of extraction in 2009, and is managed by Limburg Landschap as a nature reserve. The vegetation has re-colonized quickly and the site now contains several species of conservation interest, including the yellow-bellied toad whose habitat is managed in part by IKL. Goat grazing is used to manage excessive vegetation growth in some areas. A perimeter fence surrounds the site, which is closed to the public, although a viewpoint overlooks most the site and Limburgs Landschap organizes guided tours for visitors on a regular basis. The most likely alternative state for Curfs quarry is for it to be left as an unmanaged wildlife, recreation, woodland area with public access.

ENCI quarry is situated south of Maastricht, near the Belgian border. The active limestone quarry is 135 ha, of which 70 ha has already undergone some restoration. Extraction will end in the remaining quarry in 2018. In 2009, a transformation plan was developed by ENCI, the city of Maastricht, the Province of Limburg, Vereinigung Natuurmonumenten and a representation of local neighbouring communities: the Sint. Pietersberg Adembenemend. In 2010, these five stakeholders established the ENCI Development Foundation for the ENCI area. The restoration plan will convert the quarry to a managed nature conservation area with public access and include the re-establishment of a historical foot trail. The alternative restoration scenario for the ENCI quarry is to leave it to natural colonization with no management and no public access.

't Pompje is a 66 ha restored clay pit site along the Ostend-Bruges canal amidst the low lying farmland of the Polder region of West Flanders. Clay extraction began here at the turn of the century with a brickworks built on the Canal. Extraction ended in the 1940s and the military subsequently installed an antennae array and have managed water levels and restricted public access until the present. However, from 2008 to 2011, the Flemish Land Agency (VLM) dug and re-profiled scrapes, ditches, and ponds to provide a diverse mix of young and mature reed beds, open water and wet meadow habitats. VLM continues to manage the site, which now provides important habitat for overwintering birds, as well as breeding habitat for wetland species in the spring and summer free from visitor disturbance. The most likely alternative scenario for the site would be to fill in ponds and use the area for agricultural production.

Wenduine clay pits are located in the Polder area of West-Flanders, amidst coastal low lying farmland. Clay extraction was abandoned soon after the war and converted for use by a commercial angling club. In 2011 and 2012 VLM restored the site to a wetland area with 12 ha of reedbeds and shallow water, and 1 ha of shrubland. Management work consisted of digging scrapes, clearing ditches, cutting poplar stands, planting scrub trees, and building a bird hide. The management of the site was handed over to Natuurpunt, a Flemish nature conservation NGO in 2013. The site now provides important habitat for wintering and breeding birds. The most likely alternative scenario would be for the site to be filled in and used for agricultural production/grazing.

Mechelse Heide is a 143 ha quarry located between Genk and Maasmechelen, within the Hoge Kempen National Park. High grade white sand has been excavated since 1961 from Mechelse Heide, and the development and restoration planning of the site has been closely linked through a partnership between the park authority: Regional Landscape Kempen and Maasland (RLKM), SCR-Sibelco, and the government Agency for Nature and Forest. Currently 45 ha of the extraction site has been restored, with about 100 ha currently within the extraction phase. Heathland restoration has been accomplished through a mix of natural re-generation and management, which provides a diverse patchwork of heath species supporting many important species of flora and fauna. There are visitor facilities, a cafe and campground, and well developed hiking trails through the restored half of the quarry, with walking and cycling trail links to the rest of the Hoge Kempen park network. The most likely alternative scenario for the site would be conversion to agricultural production (grazing and/or cereals).

Meertens Quarry lies close to the Geul river between Maastricht and Valkenberg with the Bergse Heide nature region. The 8.7 ha quarry was first used as a motorcross track after limestone-marl extraction ended in 1975. Restoration work began 1985 onwards by the Limburgs Landschap Foundation, and the quarry now contains a mix of tree covered and bare slopes, with shrubs and grass on the bottom. There is one large clay-lined pond and two smaller ponds with rushes. The quarry provides important habitat for wildlife, including protected species such as the Yellow bellied toad (*Bombina variegate*) and the Common Mid-wife toad (*Alytes obstetricians*). The alternative scenario for Meertens quarry would be to fill it in and convert it to farmland for cereal production or grazing.

Middleton Lakes is situated on the floodplain of the River Tame and Hanson UK extracted Gravel there until 2006. The Staffordshire county council originally planned to create a public amenity country park containing walking and cycling trails, bridleways, play areas for children, and a small nature reserve. However, in 2007 the RSPB acquired the land and modified the plan to restore it to a nature reserve with open lakes, reedbeds, grassland and wooded areas. The site is an important bird watching location in the area with approximately 30,000 people visiting each year. A small cattle herd is used to manage grassland areas.

Ouse Fen was a gravel extraction site for Hanson UK since 1994. It was originally planned to be restored to agriculture post extraction, however, this plan was later changed to a nature conservation scheme. Restoration work began in 2002 and consisted of re-profiling the gravel pits to create shallow areas and planting reed beds. During this study, the post-extraction site was 153 ha, however, once extraction activities end, the restored nature reserve will be about 700 ha. The RSPB manages the reserve and it currently consists of four habitat types: open water, reedbed, with grassland, and scrub woodland between the reed beds. The reserve already contains several bird species of high conservation value, including bearded tit (*Panarus biarmicus*), bittern *(Botaurus stellaris*), and marsh harrier (*Circus aeruginosus*). Cattle grazing is used to manage grassland areas, and a path network is being created.

Fen Drayton Lakes were created during gravel extraction between 1950 and 1997. The early post-extraction sites were left to colonise naturally leaving deep gravel ponds with fringing vegetation. Ponds extracted later have received more nature-focused restoration that included re-profiling basins to provide shallow areas and reed beds with particular emphasis on attracting species of high conservation concern. The site therefore consists of a mix of non-intervention (older) and biodiversity conservation (newer) areas. The RSPB acquired the site in 2007 and have implemented biodiversity-sensitive management, including grazing by sheep and cattle to maintain wet grassland areas. The Lakes have an extensive path network to provide visitor access to both the older and newer areas.

Whitesands Loch is a limestone quarry located near Dunbar on the Southeast coast of Scotland and has been operated by Lafarge-Tarmac since 1963. Extraction on the 100 ha northwest section of the quarry ceased in 2007 and the quarry restoration scheme initially envisaged a multi-user "country park" with a lake, trees, foot/cycle paths and horse-trails. Landscaping is mostly complete, however, decisions about access and infrastructure were left outstanding. The RSPB and Lafarge signed a Memorandum of understanding in 2013 to devise a strategy to create a regionally important wetland ecosystem with associated habitats for the benefit of people and the local economy. The restoration will include breeding and wintering habitat for migrant birds, and provide a natural space for local people and tourists. The quarry consists of a 30 ha deep-water lake, with scrub, grassland, arable and rough grazing, and woodland habitats, however, public access is currently restricted.

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