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Farmers as water managers in a changing climate – can we turn sustainability research into outcomes?

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Abstract: How well does research-derived knowledge on sustainability translate into practical improvements in the sustainability of land and water management? This paper reflects on progress being made through the lens of the "Aquarius - Farmers as Water Managers" project part of Interreg IVb. This project seeks to use research-derived knowledge to aid the specification, delivery and evaluation of a flood alleviation scheme that uses natural flow management measures. The paper sets out previous research on the definition of outcomes and places these in the context of the specific criteria being used within the Interreg programme. Interreg provides an opportunity for researchers interested in translating research into outcomes to be part of large scale interventions that are beyond the scope of research studies. The paper details the research approach being adopted; a variant of adaptive management schemes intended for use in complex coupled social-ecological systems. The base line studies that characterise the bio-physical and socio-economic systems and the framework of stakeholder issues have been completed. These have emphasised the contested nature of the causes of, and responsibilities for, flooding and its future management in a changing climate. The paper also reports the central role of computer-based modelling in the statutory cost-benefit analyses. Going beyond these statutory processes the paper reports an analysis of the levels of compensation needed by land managers to offset the loss of income from temporary flooding. This amounts to <5% of the annual damage and presents an opportunity for financial solutions based on insurance or public support for regulating ecosystem-service provision. The paper concludes by reflecting on progress against the Interreg outcome criteria and notes that the research-practice-policy partnerships are working well and that international cooperation has been successful in promoting innovative engineering, financial, governance and policy options.

Keywords: farmers; water-managers; climate-change; Aquarius

1 INTRODUCTION

How well does research-derived knowledge on sustainability translate into practical improvements in the sustainability of land and water management? This paper reflects on progress being made through the lens of the "*Aquarius - Farmers as Water Managers*" project, funded by the European Regional Development Fund (ERDF) as part of the Interreg IVb programme in the North Sea Region (NSR).

1.1 Defining outcomes

Outcomes are most simply defined as effects that occur beyond the walls of the research organisation. The authors have previously argued that it is useful to differentiate between *process effects* and outcomes [Matthews et al., 2010]. Process effects are changes to *how* things are done, for example improved efficiency or capacity. Outcomes on the other hand are changes to *awareness*, *attitudes* and *actions* of stakeholders. The former have the potential to be transformative beyond the research and development environment while the latter actually cause verifiable change. Outcomes can thus encompass a wide range of changes. In Interreg IVb the outcomes they are seeking are defined through the promotion of three ideals that together aim to improve to quantity of life and protection of the environment of the NSR. The three ideals are – *innovation, inclusion* and *implementation*. Innovation seeks to improve on current practice, (providing an opportunity to use existing research derived knowledge, tools and approaches). Basic or strategic research *per se* is explicitly excluded since the focus of Interreg is on process and the delivery of outcomes. Inclusion supports the building of cross-sectoral partnerships and networks: locally, regionally and internationally (research-practice-policy linkages). Finally implementation means demonstrating how good practice works through building and evaluating pilot projects (a form of action research). These ideals combine to provide opportunities for researchers who are interested in seeing their research result in improvements in the sustainability of land and water management.

1.2 Evaluating outcomes

Even when outcomes are sought, the criteria by which they are to be evaluated are often unclear. Within Interreg IVb, however, projects are evaluated against explicit outcome criteria, summarized as the 5 L's.

- **Linkage**, building on existing knowledge (including research) from previous Interreg or research programs.
- **Longitude**, ensuring strong cross-sectoral partnerships (research, agencies, government, NGO and publics).
- **Latitude**, partnerships between regions to share expertise.
- **Locality**, or how to ensure that any intervention includes the issues of overriding importance to local stakeholders.
- **Legacy**, or how to create structures, capacity and outcomes that can be sustained beyond the lifetime of a particular program.

This paper reflects on how well the Aquarius project is progressing towards the outcomes sought by Interreg using the 5'Ls as criteria. The paper also seeks to draw some more generic conclusions on the nature of the challenges that confront researchers seeking to turn sustainability research in to sustainability outcomes.

1.3 AQUARIUS

Aquarius is a transnational project (7 partners in 6 countries across the region) and is part of the ERDF intervention "Adapting to and reducing the risks posed to society and nature by a changing climate" within the wider objective "Promoting the sustainable management of our environment". The overall aim of Aquarius is to identify and overcome the barriers to farmers contributing positively to addressing water management issues (e.g. in flooding, water shortage and water quality)[1]. Farmers are seen as crucial actors for a wide range of water management issues (e.g. mitigating flooding, avoiding damaging low-flows and controlling diffuse pollution). Many of these issues are likely to be exacerbated by climate

[1] The particular mix of interests varies between partners but all are concerned with multifunction land-water systems.

change and there is a recognition that existing approaches to their management are either inadequate, cannot be sustained financially or result in undesirable unintended consequences. Particularly important for Aquarius is the promotion of partnership between land managers, competent authorities and researchers. This made Aquarius an appropriate case study within which to develop and test research derived approaches to sustainable land and water management.

Each regional partnership is undertaking a pilot/demonstration project addressing the most important local issues (in addition to transnational or bilateral exchanges of knowledge between the Aquarius partners via expert networks, partner meetings and reports). For Scotland the partners are Aberdeenshire Council (as the competent authority) the Macaulay Land Use Research Institute (land, catchment management and socio-economic research groups) and a local environmental consultancy (LandCare NE). There are also a significant number of direct and indirect stakeholders[2].

The Scotland pilot is being undertaken in the Tarland Burn catchment (a sub-catchment of the River Dee in Aberdeenshire – see
Figure 1. Aquarius is informing the specification and implementation of the Tarland Flood Prevention Scheme (TFPS), intended to relieve flooding pressure on the villages of Tarland and Aboyne. While the primary focus is on flood alleviation the pilot partners aspire to go beyond hard engineering approaches, to take a systemic, multi-scale approach and to include in the evaluation of intervention options a wider range of criteria so as to provide a more rounded assessment of their sustainability.

The intervention options being considered are "natural" in that they seek to restore or enhance the storage capacity within of river systems (e.g. re-meandering, (re)stablishing wetlands or flood storage basins) rather than building defences that while locally effective simply move the problem downriver. For AC more natural flow management options are being considered since these have the potential to be undertaken as partnerships with land managers, rather than requiring the compulsory purchases of land (incurring substantial legal and other costs) and requiring subsequent maintenance. More conventional interventions, such as a by-pass channel for Tarland village are not being ruled out but are recognised as at best partial solutions as they simply move the locus of impacts.

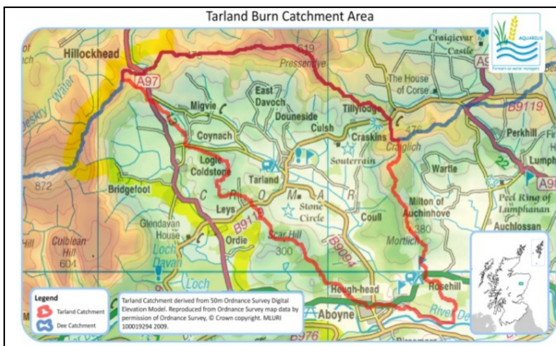

Figure 1: Case Study Catchment

The process of generating the Aquarius proposal and undertaking the project is providing a wealth of insights into the practical, institutional and research challenges that remain to be overcome in translating research derived knowledge, methods and tools into practical improvements in the sustainability of land and water management. This paper reports on progress to date in responding to these challenges and assesses how successful we have been in translating sustainability research in to improvements in outcomes for land and water management.

2 MATERIALS AND METHODS

2.1 Aquarius Tarland Case-Study

[2] Direct stakeholders are involved in the project, beyond these stakeholders are consulted and/or informed.

Aquarius started in March 2009 and has four phases (A-D). Phase A (March 2010 to March 2011) has established a system-baseline: current conditions, climate change scenarios and the key land-water management issues as seen by stakeholders (farmers, local residents, land-owners, statutory agencies, fishery interests etc). The aim of this phase was to fully understand the barriers to farmers acting as water managers. Phase B (from March 2010 to 2011) will asses scenarios of potential interventions (online and offline storage) using empirical and simulation-model derived data and experience from transnational partners. This analysis will explore the series of trade-offs required e.g. between cost of the intervention, its effectiveness (for flood alleviation), and the impacts on the existing land management regimen. The analysis also seeks to highlight and where possible quantify synergies between water management and other services such as enhanced bio-diversity; water quality or landscape character. With stakeholders the intention is to investigate how payment for environmental services or for the maintenance of key public infrastructure could contribute positively to participating farm businesses. In Phase C a pilot demonstration and monitoring site will be built. Phase D will assess and evaluate the project in terms of its implications for planning processes, construction impacts, maintenance and acceptability.

2.2 Research Processes

The approach being adopted by the Aberdeenshire Aquarius partners draws its inspiration from those developed and applied by Kay et al. [1999]. These adaptive management approaches for complex systems recognise that there is the need to generate baseline system descriptions and a framework of visions and preferences for the future. The systems baseline includes both biophysical and socio-economic components and the choice of scale and detail is guided both by the nature of the system (e.g. a catchment for a water focused issue) and the preferences and concerns of the key stakeholders identified in the issues framework. It is particularly important to generate explicit (if not agreed) definitions of the issues otherwise the research will be neither salient nor credible and this will undermine the legitimacy of the whole process.

The information generated by the baseline analysis for the Tarland case study is intended to 1) increase the project Partners understanding of the nature of the land-water management issues, 2) underpin assessments of the feasibility and acceptability of possible interventions, 3) identify the key barriers to active land-water management by farmers (particularly financial and/or institutional) and 4) inform government of possible policy measures. Table 1 presents the baseline analyses undertaken by the Aquarius Scotland partners. It can be seen from the number and variety of activities considered necessary (and given the resources available to the Aquarius project the list is in no way exhaustive) that there is little prospect of tangible improvements to the sustainability of land and water management though single–disciplinary, science led initiatives alone.

Table 1: Baseline Analyses in Aquarius

Baselines	Components	Data, methods and tools
Geographical	land cover, use, ownership, holding size & tenure, stocking, employment	Field, holding and business databases, GIS mapping [Matthews et al., 2008a].
Climate	Agro-meteorological indicators for current and 2070-2100 period	UK Meteorological office datasets and regional climate models [Matthews et al., 2008b]
Economic	Output, added value, assets, liabilities & subsidies,	Review of regional economic summaries [SG RERAD, 2009]
Ecological	Water quantity, quality and river morphology	WFD water body characterisation from 3DeeVision[3]
Sociological	Farmers as water managers Authorities and Advisers views Farmers and Factors views	Questionnaires, Interviews and Workshops.

[3] 3DeeVision website http://www.3deevision.org:78/

Legal	Applicable policies, support mechanisms, planning regulations	Review of published sources – governance mapping.

Statutory processes

The research being undertaken by the authors is designed to complement the work being undertaken as part of statutorily defined processes. These statutory processes include strategic environmental assessments (SEA, undertaken for the Council by environmental consultants) and site specific environmental Impact Assessments (EIA) for particular activities on chosen sites. The SEA has been ongoing since a strategic decision was taken by elected members of AC that there needed to be an investigation of intervention options following significant flooding in the village of Aboyne in 2002. The initial identification of potential sites suitable as temporary flood storage basins was undertaken by Aberdeenshire Council staff on the basis of visual survey of suitability (see Figure 2).

Hydrological and hydraulic modelling was conducted by consultants to Aberdeenshire Council. A 1-d hydraulic model for the catchment was constructed using InfoWorks[4] (1000 node). Input hydrological data was available from four hydrographs. The overall topography of the catchment was defined using 1m resolution digital elevation model derived from LIDAR[5]. The model has 25 km of watercourses consisting of a main channel and principal tributaries. Cross channel and riparian profiles were defined by topographical survey at 399 locations. The model recognises 385 spill units (parts of floodplains). The model also contains 37 key infra-structures that affect flow e.g. bridges and culverts. Seven point inflows and nine lateral inflows provide inputs to the rainfall-runoff relationships defined using UK Flood Estimation Handbook (FEH) methods [Centre for Ecology and Hydrology, 2008].

The model was calibrated for four events between 2005 and 2008. Full calibration was restricted to the Scottish environmental Protection Agency (SEPA) Aboyne hydrograph at the bottom of the catchment, with the Aberdeenshire Council Tarland site used for stage and the Macaulay sites at Tarland (top of the upper catchment) and Coull (at the end of the Tarland floodplain) used only for the timing of the flood peaks. Particular issues were found in calibrating the model to reproduce observed events: the need for high values for the rainfall to runoff coefficient, the need for different soil wetness values across the catchment and timing of events (ensuring that the peak flow was not too slow to reach Tarland village in the upper catchment nor too slow to reach Aboyne). These issue were overcome and frequency and volumes of peak flows were then calculated using statistical estimation procedures of the FEH. These values were then used to scale the outputs of the InfoWorks model deriving maps of the median, 5, 10, 25,100 and 200 year inundation events and a 200 year + 20% event (the standard simulation of climate change).

The validation of the modelling process was undertaken by SEPA but this does not evaluate the quality of the results obtained. Informal validation has been carried out through contacts with land managers at Aquarius workshops backed by historical "trash line" surveys recorded after major events. Given the relative ease of identification using remote sensing (standing water being particularly distinctive) the Macaulay team intend to pursue this as a more systematic way of evaluating the effectiveness of the model for particular events. The issue of course is the availability of satellite coverage for the largest events that occur during periods of significant rainfall and thus cloud cover.

The inundation maps are the key factor used in the calculation of damage to property and infrastructure. The entities affected are identified by overlaying the inundation maps with asset registers for public and maps of housing. The depth of inundation is used to asses whether the waters have passed floor level (a key threshold) and the cost of damage assess [Penning-Rowsell, 2005]. Strictly the budget for any works is the damage assessment (discounted over 100 years) minus any limitation in the effectiveness of measures (e.g. they may only be effective 1 in 100 instead of the standard 1 in 200). Informally it is also

[4] InfoWorks website http://www.wallingfordsoftware.com/uk/products/infoworks/index.asp
[5] LIDAR – LIght Detection And Ranging derived elevation data.

possible to argue that if there are secondary benefits that can be assessed as resulting from the intervention then these maybe included in the assessment, particularly if they are likely to provide a resource stream for maintenance or capital build.

RESULTS

2.3 Overall Characterisation

The overall characteristics of the Tarland catchment are reported in the Baseline Report[6] and it is only possible to briefly summarise key highlights here. The area of the catchment is 7300 ha, and has an elevation range of 620m to 109m. This means that the catchment is on the margins of the more intensive agriculture (cropping and rotational grass). Arable and rotational grassland makes up 42%, permanent grassland 18% and forestry 30%. Most land is rented on long term tenancies (76%), with median holding size of 38 ha. There is a complex mosaic of ownership and management (see Figure 3 where the candidate basins are overlaid with land ownership, note especially the woodland areas which are managed directly by the tenant's landlord.

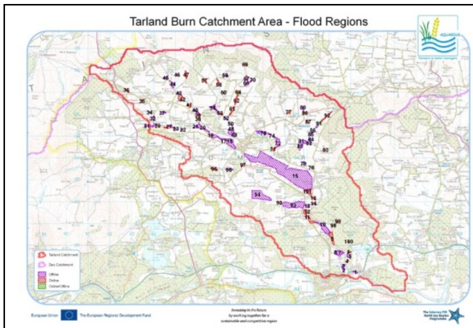

Figure 2 - Storage Basins

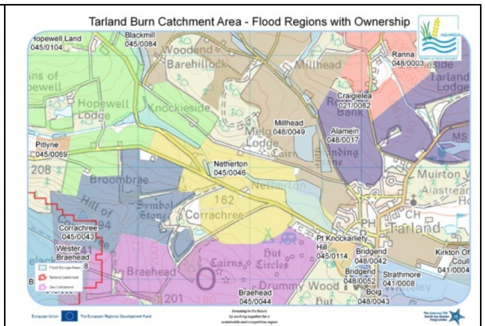

Figure 3 Basins and Ownership

The mix of enterprises means the farm types are dominated by mixed farming (41%) and upland sheep and cattle rearing (36%). Farm incomes have risen over the period 2003 to 2008 but are still heavily dependent on subsidy. Only 89 FTE are employed in agriculture in Tarland. Regionally agricultural employment is ~3% and 1.8% of regional Gross Value Added. The villages have a significant role as dormitory towns for Aberdeen and the provision of local services. The watercourses are designated under the Habitats' Directive for fish and invertebrate species, and are currently failing to meet good ecological status because of morphology (excessive canalisation) and diffuse pollution (phosphorous).

2.4 Flood volumes, extents and cost-benefit analysis

The consultants' modelling has indicated that that the likely volume that any intervention will need to deal with to alleviate flooding in Aboyne is 950,000 m^3. The first option being considered is constraining the maximum flow permitted with the excess diverted into temporary flood storage basins. This means, assuming a mean depth of 1m is achieved, 95 ha of temporary flood storage beyond those areas already inundated. The budget for such an intervention is constrained by a cost-benefit analysis. Accepting that the outputs of the hydraulic model are an adequate representation of the flooding extent a preliminary cost-benefit analysis has been undertaken. For Tarland village, see **Error! Reference source not found.**, the inundation mapping when combined with property mapping estimates that 21 properties are affected, 7 above floor level, in the 25 year event and 30 properties are affected, 14 above floor level in the 200+climate change year event. Using standard inundation-to-damage functions this means average annual damage of £25k to £30k and total benefits of £800k for 100 years. Initial assessment are that this is unlikely alone to justify constraint and basin works but a bypass channel may be added for local protection

[6] Aquarius website – Tarland report

with increased storage further down the catchment. It may be possible, however, to make the argument for other "natural" flow management measures due to their reduced capital and administrative costs (through cooperation with land managers). For Aboyne the flooding is more significant with the modeling and mapping identifying 72 properties as affected, 18 above floor level in the 25 year event and 101 properties affected, 36 above floor level in the 200 year + climate change event. Using the same inundation-to-damage relationships this means an average annual damage of £90k to £95k and total benefits of £2,400,000 for 100 years[7]. This is a more substantial sum to justify alleviation works but the geography of the catchment makes it very difficult to get sufficient area of sites close to Aboyne since the river is much incised. This will limit the flow that can be captured by any interventions reducing effectiveness and thus the budget for the intervention.

Figure 4 - example inundation map - Tarland, 200 year + CC

Beyond the (largely) capital costs considered by the cost-benefit analysis is the issue of acceptability, and this will depend on the degree of compensation available for loss of income or provision of additional services. Table 2 shows a simplified analysis of the "value" of the main land uses present in the Tarland catchment.

Table 2: Land manager opportunity costs of 95 ha TFPS

Land Use	Land Cover	GM/ha[8]	Subsidy/ha	All/ha	% Use	£ per Use	% damage	Opp cost/y
Finished Cattle	Grass < 5 y	£155	£224	£379	24%	£3,498	25%	£874
	Grass > 5 y	£124	£179	£303	8%	£932	25%	£233
Store Cattle	Grass < 5 y	£74	£224	£297	24%	£1,661	25%	£415
	Grass > 5 y	£59	£179	£238	8%	£442	25%	£111
Hill Sheep	Rough Grazing	£12	£14	£26	10%	£112	10%	£11
Cropping	Spring Barley	£317	£200	£517	12%	£3,639	25%	£910
	Spring Oats	£307	£200	£507	12%	£3,528	25%	£882
	Winter Barley	£443	£200	£643	1%	£510	25%	£128
	Winter Wheat	£442	£200	£641	1%	£508	25%	£127
						£14,830		£3,691

The income figures are 10 year average gross margins (GM) per ha per year. GM exclude rent, labour and other fixed costs but are a generally accepted metric for the income generating potential of land. For grassland there needs to be assumptions made on the nature of the livestock system and two alternatives are used (finishing and store cattle with a 50:50 mix). Note the significant proportion of income derived from subsidy that need not be affected (or could even be enhanced) by the use of the land of temporary storage of flood waters. The mix of land uses affected by a real scheme would depend on the fields chosen but for this analysis we are assuming the 95 ha has the land use/cover mix identified for all the basins. This gives a maximum opportunity cost to land managers (assuming loss of all GM income) of £14,830 per annum. The real opportunity costs will be less since frequency and degree of inundation will vary. This is reflected in a simple damage function (% damage per year). These initial estimates of damage are speculative but they do provide a

[7] Note that in both cases the estimates are highly sensitive to the assumptions made on discount rates for future costs. Particularly when dealing with climate change historical assumptions on the appropriate rates may no longer hold , see Stern [2009].

[8] [Scottish Agricultural College, 2009]

first order estimation of real opportunity costs ~£3,700p/a. It is important to note that opportunity cost is less than 5% of the annual damage estimated for Aboyne, but that particular businesses may suffer larger business viability effects beyond the loss of GM income for particular fields. This estimation opens up the possibility of cost effective public or private (insurance based) compensation since it is significantly cheaper to compensate farmers than house owners. The wider framing of the issues and the acceptability of the interventions is further discussed in the results of the Issues framework below.

2.5 Issues Framework

The sociological baseline, the adviser and authority workshop, the farmer and factor workshop and informal meetings have revealed flood alleviation using natural approaches as a complex and contested issue. There are strongly held and basic disagreements on what flooding is, what causes flooding and who should deal with it. Flooding to land managers is a drainage issue – particularly the restriction placed on them from dredging or deepening ditches. This is now a controlled activity and there is a presumption against as this can be detrimental to protected species of fish and invertebrates covered by the EU Habitats Directive. However, even were it not prohibited the increasing the capacity of the channel simply moves the problem elsewhere and indeed may increase the speed to and consequently size of the peak flow. This is recognised but seen as an issue of mismanagement elsewhere. There is particular criticism of the failure by the planning authority (Aberdeenshire Council) to prevent (in the past) development of housing on sites likely to be flooded. These sites may, however, have been preferentially sold precisely because of their wetness. The idea of farmers as water mangers does however have strong acceptance. There is an idea that they have always been water managers, responding to previous policy and public pressures to increase production by draining and otherwise improving land. There is perhaps a growing recognition that in addition to accepting regulation to ensure negative externalities are avoided there is the potential to argue for mechanisms (market, insurance or publicly funded) that reward the provision of an ecosystem service of flooding alleviation[9].

3 DISCUSSION AND CONCLUSIONS

The Interreg ideals and evaluation criteria provide a useful framework against which to assess progress of projects that seek to achieve outcomes in terms of improving the sustainability of land and water management. These have shaped the Aberdeenshire Aquarius project and there has been significant progress made. There are, however, serious challenges that remain. In terms of innovation, Intereg provides an incentive for competent authorities to go beyond standard best practice, indeed this is a prerequisite for Intereg funding). This provides and supportive environment to demonstrate and test research based approaches and to refine these so that they can fit with the reality of the situated internal practice of the non-research partner(s) particularly in terms of project timelines and priorities. The Intereg funding model of 50:50 can, however, be challenging for some research organisations with limited matching budgets. Inclusion through partnerships and deliberative or participatory processes with direct and indirect stakeholders is highly rewarding by ensuring salience, building credibility and enhancing legitimacy. There is a significant cost, however, in the overhead of communication, both in learning about issues beyond a disciplinary specialism and in defining project governance. The opportunity to undertake action-research though implementing pilot or full-scale infrastructure gives researchers a unique opportunity to in effect experiment with large scale eco-social systems that would normally beyond the scope of academic research.

The expectation of linkage with previous and existing projects was easily met for the Aquarius project since the work build s on 3DeeVision and Interreg IIIB project addressing

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[9] Indeed one could make the case that all the existing land that is inundated during flooding events is a service provided at no cost to householders/local authorities. If the land were further protected from inundation then flooding would be much worse in settlements.

diffuse pollution issues in a variety of circumstances. This linkage does, however, depend on the maintenance of institutional memory in key individuals and this can be challenging in the face of staff turnover, which can be more rapid in agencies and local government than in some academic organisation. Aquarius is seen as leading the way in generating a Scottish evidence base for natural flow management policy at both local and national government level and has fed back in to the research agenda and funding – the locality criteria for Intereg. A particular challenge is the latitude criteria – for strong transnational partnerships. Since many of the issues that NSR Interreg seeks to address require interregional cooperation (e.g. marine pollution) trans-nationality in delivery is now insisted on. Transnational exchanges between researchers, authorities and stakeholders have proven highly influential in Aquarius but insistence on shared ways of working and common outputs in terms of guidance and best practice have been divisive and unproductive so latitude needs to be considered carefully. The longitude criterion has largely been covered by the ideal of inclusion but the emphasis here is on cross sectoral partnerships. As noted above these partnerships have the potential to be highly productive but do require significant upfront investment in team building. The final criterion of legacy is often seen as difficult to deliver since it aims for outcomes beyond the lifetime of the project. As researcher's influence on continuing practice and policy is increasingly valued by some research funders and Interreg provides and explicit opportunity to invest time in ensuring that these sustainability outcomes occur.

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