**Water quality benefits**

**Introduction**

Targeted planting of woodland on pollutant sources and delivery pathways have been shown to reduce diffuse nutrient, pesticide and sediment delivery to watercourses (Nesbet et al 2011 in FR 2014).

The mechanism for pollution delivery can vary according to the type of pollutant and its source, and so too can mechanisms of mitigation. Two key mechanisms are central to the delivery of many agricultural (eg organic matter, nitrates, phosphates, pesticides) and other pollutants:

* Soil erosion and transport can also deliver large quantities of pollutants within the soil matrix into watercourses. EXAMPLE
* High surface water runoff can transport many water-soluble(?) pollutants. For example, EXAMPLE.

Soil loss is cited as a direct reason for failure of river waterbodies to reach a ‘good’ status in >10% of cases in England and as a detrimental factor in many drinking water sensitive zones (ref?). It is also likely to play an important role in many other causes for watercourses failing to achieve a ‘good’ status. GET A TABLE FOR CORNWALL CATCHMENTS REASONS FOR FAILURE?

Landcover and uses that reduce bank erosion and soil loss along watercourses or that slow water flow, can contribute to mitigating detrimental effects on water quality. Landcover type and use will also influence the quality of watercourse habitats and ecosystem functioning that in turn can bring benefits to water quality.

**Identifying dependencies on water quality – potentially vulnerable areas**

1. Vulnerable Activities

In addition to a potential impact on biodiversity and ecosystem function, any reduction in water quality can bring significant economic and social costs. We identified key industries and activities highly dependent on suitable water quality as:

* Drinking water abstraction
* Aquaculture
* Tourism via bathing water quality

The main location of these areas and the catchments draining into them were located using a variety of geographical data sources (see Table \*).

1. Vulnerable waterbodies and catchment areas

Additional designations and information, concerning the quality of watercourses, can be used to identify catchment areas vulnerable to a range of threats. River waterbodies that have been rated as possessing ‘not good’ quality status (Water Framework Directive classification REF) are identified as priority areas for improvements to water quality. Existing land designations associated with threats to watercourses such as nitrate and phosphate sensitive areas also indicate priority areas for the mitigation of pollution affecting water quality.

Vulnerable ‘not good’ catchments where the reason for failure is identified as a ‘diffuse pollution’ source are considered areas where mitigation of pollutants affecting water quality was particularly valuable. This amounted to 74 of the 116 waterbodies that did not achieve “Good” overall quality. For opportunity mapping these areas are considered priorities where an increase in pollution mitigation value from a change in land cover would be particularly welcome.

Separate weightings for each type of vulnerable areas (drinking water abstraction, aquaculture, bathing water, ‘not good’ waterbody) can be applied in prioritisation and opportunity mapping.

**Estimating potential mitigation value**

The methods chosen to estimate water quality service benefits focus on the two key delivery mechanisms of pollution outlined above, namely (i) soil erosion and transport and (ii) agricultural surface water runoff.

*i. Soil loss (RUSLE\_calcs.R)*

Estimates of factors affecting soil erosion across Europe produced using the RUSLE2015 model (Panagos et al 2015 [The new assessment of soil loss by water erosion in Europe](http://www.sciencedirect.com/science/article/pii/S1462901115300654" \t "_blank)) have been adapted to provide an estimate of soil loss mitigation due to landcover.

The factors used in the estimation, namely K-Factor (Soil Erodibility), R-factor (Rainfall erosivity) and the LS-factor (Slope Length and Steepness), provide an estimate of potential soil loss (RUSLE.base) independent of landcover.

**RUSLE.base = K-factor + R-factor + LS-factor**

To estimate soil loss under existing (or hypothesized landcover types) requires the addition of factors representing landcover type, management (C-factor) or support practices (P-factor).

Instead of using the ESDAC C-factor, which was derived from Corine landcover data, tailored landcover values were used based on CEH 2015 landcover classification. Values were derived from previous studies as reviewed by Panaglos et al (2015) although the difference in the C value for improved grassland and arable land was explicitly reduced to reflect the potential of these uses to vary between years (see table 1 for the values assigned to land classes). The P-factor is most often used to capture the effect of tillage and use of cover crop to reduce erosion. With a lack of reliable information on cultivation practices, we have instead added a P-factor based on the total hedgerow length (ERCCIS data ref) within each cell (see Table 2).

The custom C and P layers were used to derive a modified RUSLE estimation of current soil loss due to water erosion under current landcover.

**RUSLE.lc = K-factor + R-factor + LS-factor + C-factor + P-factor**

The soil loss mitigation value was calculated as the normalised difference between RUSLE.lc and RUSLE.base.

|  |  |
| --- | --- |
| **Landcover** | **RUSLE C-factor** |
| Coniferous woodland | 0.001 |
| Broadleaf woodland | 0.001 |
| Semi-natural grassland | 0.04 |
| Wetland | 0.01 |
| Heath / Moor | 0.05 |
| Inland Rock | 0.0 |
| Maritime cliff | 0.08 |
| Littoral Rock | 0.0 |
| Supralittoral sediment | 0.0 |
| Littoral sediment | 0.0 |
| Water | 0.0 |
| Arable | 0.2 |
| Improved grassland | 0.1 |
| Urban | 0.0 |

**Table** 1: landcover C factor used in RUSLE calculations

|  |  |  |
| --- | --- | --- |
| **From** | **To** | **RUSLE P-factor** |
| 0 | 25 | 1 |
| 25 | 150 | 0.95 |
| 150 | 300 | 0.9 |
| 300 | 600 | 0.75 |
| 300+ | (max = 2742) | 0.5 |

**Table 2:** P-factor based on sum of hedgerows length (in metres) within 100m2 cell

***Surface water runoff and transportation*** *– mass flux modelling*

The RUSLE-derived soil loss mitigation value provides an estimation of the service provided by existing landcover to mitigate potential soil loss. It provides a static map of potential soil loss but does not offer any modelling of soil transportation to the river/water network or the potential of landcover to intercept or otherwise influence this transportation. Furthermore, it takes no account of pollution associated with surface water runoff, independent of soil erosion. The water quality mitigation benefits of landcover can not only function by reducing soil erosion but also by reducing the likelihood of soil or water-based pollutants reaching the water network.

An alternative approach is offered by applying a simple dynamic model that captures the transportation flux of sediment / pollutants transported by overland flow to the watercourse network *ie* a simple mass-flux model. Such a model will include a loading parameter, but also a transportation or interception factor that reflects the probability or amount of the pollutant transported by the flow to the river network.

We have adopted the approach of Scimap (ref) in using topographical wetness index (Bevan & Kirkby 1979) as an indicator of overall flow-connectivity and in assuming any temporal variability in connectivity will reflect spatial variability in TWI. The likelihood of surface water borne pollutants reaching the watercourse network (assumed to have constant year-round flow) is therefore determined by the lowest TWI along its flow path.

An unfortunate implication of using TWI as the sole indicator of connectivity can be that any factor increasing soil wetness, such as vegetation cover, should increase connectivity and thereby risk of pollution from upstream areas. In reality, vegetation cover is as likely to reduce pollution risk, by reducing flow velocity and improving soil infiltration, particularly during heavy rainfall events when soil wetness if unlikely to be the limiting factor determining pollution connectivity. EXAMPLE – FIELD POLLUTION TRIALS

We therefore adopt a connectivity value, representing the probablility of water-carried pollutants being transported along an overland flow pathway, calculated from TWI and flow velocity, the latter calculated using a modified Manning’s equation which incorporates a landcover effect of velocity:

Connectivity = twi \* flowvelocity

An estimate of mitigation from runoff interception will be attained by the difference in connectivity calculated where flow velocity is calculated with and without consideration of landcover (constant mannings value of 0.02). High mitigation values will correspond to areas where these is a high mass flow accumulation *and* where land cover reduces connectivity.

The direction and flow of pollutants carried by surface water is modelled using standard flow direction and accumulation models derived from a digital elevation model. Several studies suggest (eg Kopecky et al 2010), that particularly for soil wetness applications, the superiority of adopting a multi-directional rather than single direction flow indicator.

The effect of vegetation parameters on soil wetness (Timimi et al 2010)

The potential of landcover to intercept and reduce pollution carried by overland flow is captured by applying a modifier to the TWI values

Calculate TWI on basis of multiple flow direction algorithms

Hydrodem processing

Dinfinity method

(replaces simple riparian zone if run on flowacc?)

Q add SPR to TWI???

**Mine works pollution sources**

* Of the xx river catchments across Cornwall assessed under the Water Framework ??, ?? were classified as of ‘not good’ quality and mining was identified as a reasons in ?? cases.
* Methodological limitations and alternatives

**Notes on alternatives**

* Role of deposition – advocates of RUSLE suggest low deposition outside of watercourses
* The relative importance of the different mechanisms involved in the transportation of pollutants will vary between different types of pollutants. FOR EXAMPLE
* Good land management / farming practices are not captured in this methodology
* Hedgerows
* Sediment loss has been shown to be strongly related to overland flow levels (Henshaw 2005)

**R code**

Vulnerable Activity Data

Extract EA waterbody data functions

RUSLE calculations = RUSLE\_calcs.R

SCIMAP type approach – scimap\_functions.R

**References**

[Beven, K.J.](https://en.wikipedia.org/wiki/Keith_Beven); Kirkby, M. J. (1979). "A physically based, variable contributing area model of basin hydrology". *Hydrolological Science Bulletin*. **24** (1): 43–69. [doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1080/02626667909491834](https://doi.org/10.1080%2F02626667909491834).

Nesbet et al 2011 in FR 2014

Scimap ref

Vegetation parameters and TWI - Temimi et al 2010 doi:10.1016/j.jhydrol.2010.04.021

Flow direction algorithms, twi and vegetation https://www.jstor.org/stable/40927821?seq=1#metadata\_info\_tab\_contents