**Flood mitigation benefits**

**Introduction**

There is growing evidence supporting the role of landcover to the mitigation of downstream flood risk. Key mechanisms by which the type of landcover can influence flood risk include the interception of rainfall and evapotranspiration, improved soil infiltration and reduced surface water runoff, and the slowing and interception of overland surface flow. Each of these mechanisms can increase the time and reduce the magnitude of downstream peak flows. Soil erosion is also highly influenced by landcover and can magnify the risk and/or cost of surface water flooding by reducing the effectiveness flood mitigation measures such as drainage ditches.

**Identifying potential vulnerable areas**

Potentially vulnerable areas (PVAs) were determined from where existing built-up areas, or areas assigned to an allocation zone, fell within Environment Agency flood risk zones for surface water or rivers/seas flooding corresponding to a risk greater than 0.1% per annum. A ‘PVA’ value was assigned to each of these cells equal to the percent of the cell that is built-up or assigned to an allocation zone (the latter given a constant 50% value).

**Estimating mitigation values**

To assist calculation, different mechanisms by which landcover can mitigate the flood risk of potentially vulnerable areas were considered:

1. Mitigation of surface water runoff draining directly to a PVA.
2. Mitigation across the wider upstream catchment area that reduces the contribution of surface water runoff to peak river flows affecting PVAs.
3. Mitigation of flow velocity and improving soil infiltration across floodplain.
4. Mitigation of flow velocity along water courses.
5. Mitigation of soil loss and transportation.

*i. Mitigation of local catchment on surface water runoff*

Only areas directly upslope of PVAs were considered to have a mitigating value on surface water flooding. Areas draining to a PVA along a permanent watercourse were *not* included. The surface water flood mitigation potential of each cell *x* is calculated as:

*PV* = sum of the PVA value of all cells along the flowpath from cell *x* that are vulnerable to SW flooding (>0.1% per annum). Flowpath only extended as far as the first permanent watercourse downhill from cell (*ie* excludes river/stream flow).

*Rainfall* = rainfall erosivity (units) as a proxy of rainfall amount and intensity.

*SPR* = Standard Percent Runoff from soil HOST class (0 to 100%).

*SWmitig* is expressed as a normalised value between 0 and 100.

*ii. Mitigation of upstream catchment on river and stream peak flow*

The flood mitigation of a cell through its effect on downstream peak flow was calculated by estimating its contribution to peak flow to downstream river nodes prone to flooding. Each node was weighted by the sum of all nearby PVA cells.

The peak flood mitigation potential of each cell *x* (*Rmitig*) is calculated as:

*n* = the number of vulnerable downstream river nodes.

*CP* = contribution of cell *x* to the peak flow at node *i.*

*PV* = risk value at node *i*.

Rainfall = rainfall erosivity of cell *x.*

SPR = Standard Percent Runoff of cell *x*.

*Rmitig* was expressed as a normalised value between 0 and 100.

In terms of its calculation, the following analytical steps were followed:

* All PVA cells were assigned to their nearest river/stream node (defined as a branch in the watercourse network) with the risk value of each node equal to the sum of the PVA values of assigned cells.
* The upstream catchment area for each PVA node was calculated using a D8 flow direction method.
* The contribution to peak flow at each PVA node is modelled across the upstream catchment area using spatial data on topology and landcover MORE ON CALCULATION.

*iii. Mitigation across floodplain*

The floodplain was defined as all cells that fell within a river or sea flood zone of 0.1% or higher. All floodplain cells were given a constant potential mitigation value:

FPC = floodplain constant of 0.5.

*iv. Mitigation along watercourses*

All cells corresponding to an aboveground, open watercourse were given a constant potential mitigation value:

WCC = riparian constant of 0.5.

*v. Mitigation of soil loss*

Soil loss estimates estimated from 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)) were used as the basis for this mitigation value, normalised to a value between 0 and 1.0.

**Application to prioritisation and opportunity mapping**

The combined flood mitigation potential, *FMP*, was calculated as:

*FMP* = (*SWmitig* + *Rmitig*) + ( (*SWmitig* + *Rmitig*)\*(*SLmitig*+*FPmitig*+*WCmitig*) )

With the resulting *FMP* normalised to between 0 and 100

FMP corresponds to a potential flood mitigation value of a cell. The combined effect of floodplain, riparian and soil loss mitigation mechanisms is therefore limited to a theoretical maximum of twice the combined surface water interception and peak flow mitigation effects. In most cases the combined effect of these three factors will be less than that of the two primary factors *SWmitig* and *Rmitig*.

For **opportunity mapping** the potential flood mitigation values for cell *x* was calculated as:

*SLmitig* was calculated without consideration of existing landcover.

For **prioritisation mapping** the flood mitigation service value (*FMV*) of each cell *x* was estimated as:

*SLmitig*,was determined from the difference in soil loss under existing landcover and a baseline value.

*LC* = landcover flood mitigation value (0 to 1.0) from (i) cell habitat type and (ii) cell hedgerow lengths (normalised between 0 and 0.2) – see table \* .

**Calculation of underlying layers**

Factors used in the calculation of flood mitigation benefits include:

**Standard Percent Runoff:** estimates the % of rainfall that contributes to quick response runoff. High SPR soils are prone to rapid runoff or pathways to streams (*eg* naturally wet soils) and at risk of sealing/compaction. A SPR>25% is often associated with seasonally water-logged, flashy soils (Packman 2004). SPR was derived from the HOST value of soil layers (CEH data REF) at a resolution of 1km and then interpolated by a thin spline method using the surface elevation as an additional interpolation parameter.

Several methods (*eg* Forestry Commission Woodlands for Water mapping) have used SPR to identify priority areas for woodland creation with a revised SPR value of >50% (Broadmeadow et al, 2014) considered high priority area for flood risk management and used as a threshold for Countryside Stewardship grants to target the wettest soils (26.8% of England). However, it is recognized that woodland creation on the many soil associations with revised SPR values of <50% can also contribute to reducing flood risk management as a result of improved soil texture and enhanced soil infiltration.

NOTE: investigate the use of the Soilscape data or National Soil Inventory Data (LandIS REF) to derive SPR or other suitable values at finer resolution. In most cases however, such data is itself interpolated from underlying data of a similar resolution as that used by the CEH HOST data.

**Rainfall erosivity:** was derived from ESDAC rainfall data (Panagos et al 2015 [10.1016/j.scitotenv.2015.01.008](http://www.sciencedirect.com/science/article/pii/S004896971500011X)) that provides a multi-annual average index that measures rainfall's kinetic energy and intensity.

NOTE: Various other sources of data are possible although unlikely to significantly affect the results. There is the possibility of including a canopy interception factor (eg higher for deciduous compared to broadleaf woodland) but this is considered included in the Landcover intercept values.

**Landcover** flood mitigation values: the habitat class and the sum of hedge lengths within each cell was used to derive a surface water intercept value between 0 and 1.0.

|  |  |
| --- | --- |
| **Landcover** | **Flood mitigation value (LC)** |
| Coniferous woodland | 1.0 |
| Broadleaf woodland | 0.85 |
| Semi-natural grassland | 0.2 +HRF |
| Wetland | 0.4 +HRF |
| Heath / Moor | 0.3+HRF |
| Inland Rock | 0 +HRF |
| Maritime cliff | 0.2 +HRF |
| Littoral Rock | 0 +HRF |
| Supralittoral sediment | 0.2 +HRF |
| Littoral sediment | 0.2 +HRF |
| Water | 0 +HRF |
| Arable | 0 +HRF |
| Improved grassland | 0.05 +HRF |
| Urban | 0 +HRF |
| HRF = Hedgerow factor | 0 to 0.2 |

**Table \*:** Flood mitigation values for landcover

It is recognized that these values reflect a range of different mechanisms by which landcover can mitigate downstream flooding. The effect of landcover on surface water and channel flow is integrated directly into the calculation of contribution to peaks through the Manning’s coefficient.

**Manning’s roughness coefficients**: used in the Manning’s formula to calculate flow in open channels, the values describe the resistance of land cover to water flow. The formula is adapted as an estimate of overland as well a channel flow in determining the contribution of cells to peak flow.

|  |  |
| --- | --- |
| **Landcover** | **Manning’s Roughness Coefficient** |
| Coniferous woodland | 0.12 |
| Broadleaf woodland | 0.12 |
| Semi-natural grassland | 0.03 + HRF |
| Wetland | 0.05 + HRF |
| Heath / Moor | 0.05 + HRF |
| Inland Rock | 0.01 |
| Maritime cliff | 0.03 + HRF |
| Littoral Rock | 0.01 |
| Supralittoral sediment | 0.03 |
| Littoral sediment | 0.05 |
| Water | 0.04 |
| Arable | 0.02 + HRF |
| Improved grassland | 0.02 + HRF |
| Urban | 0.02 + HRF |
| HRF = Hedgerow factor | 0 to 0.02 |
| Permanent watercourse | 0.035 |

**Soil erosion** estimates were calculated following the RUSLE2016 model described by REF (also used in the calculation of water quality benefits).

NOTE: investigate possibility of using a soil transfer model to estimate soil deposition and affect on drainage channels theoretically possible but complex.

**Hydrologically-corrected digital elevation model**: were used for the determination of the catchment areas. The hydrological elevation model was calculated by stream burning (REF) the watercourse network described by the Ordnance Survey Mastermap Watercourse network into the original digital elevation model to ensure hydrologically coherent flow paths. Without stream burning, flow paths will not correspond to known watercourses due to artefacts of the DEM, particularly at lower resolutions. Typical artefacts include road crossings over watercourses and other stretches of covered flow that are not reflected in the uncorrected elevation model.

**Methodological limitations and issues**

* Environment Agency flood zones take no account of 'Areas Benefitting from Flood Protection' or 'Flood Storage Areas'.
* The effect of land management practices are excluded from the estimation of risks and mitigation values.
* Watercourse characteristics affecting roughness coefficients for the calculation of contributions to peak are not accounted for. SOLUTION: investigate use of OS Mastermap water network layer to give indications of channel width and derived depth from estimating volume of water from flow accumulation.
* Stream burn using watercourse vector file not open rivers?
* Soil HOST data was downscaled from 1km raster to 100m raster.
* Effect of normalisation – reduces effect of outliers / extreme values.
* No correction for the size of the catchment area of PCA cells is made for SWmitig or RSmitig values.
* Contributions to peak flow – used to rate potential flood mitigation areas -no negative effect – potential that slowing flow can contribute to higher peaks. Interdependance of landcover change effects across a catchment area not accounted – therefore large scale land cover change effects area NOT captured
* Hedgerows – act as break on flow or as channel?
* Blocking of drainage channels can have beneficial as well as detrimental effects?

**R code notes**

Calc\_flood\_layers.R

Inputs:

* HydroDEM, Stream network, Flow direction and accumulation
* Nrd, allocation zones, built up cells
* Rai erosivity, RUSLE, HOST SPR

Calculates: each mitigation layer for:

* Floodplain mitigation
* Watercourse mitigation
* SW mitigation
* R catchment mitigation

From which a single flood mitigation potential raster produced with values 0 to 1.

Zonation\_dataprep\_protect & Zonation\_dataprep\_wood

Uses outputs of Calc\_flood\_layers.R for:

* Priority mapping through multiplying by a landcover mitigation value
* Opportunity mapping as an indicator of potential flood mitigation value of creating woodland.

**References**

Manning’s coefficient ref:

<https://www.engineeringtoolbox.com/mannings-roughness-d_799.html>

<http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm>

Panaglos

Whitebox

Scimap

**Data**

EA flood risk vectors

EA NRD

EA RRCs

CEH landcover

CEH HOST

OS DEM

OS OpenRivers etc

OS builtup

ERCCIS Hedges

Panaglos layers