ECOSYSTEM SERVICE MODELLING

RULE-BASE DEVELOPMENT – SUGGESTIONS FOR USER

Contents

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Water quantity regulation (i.e. surface water flows)				
CICES Ecosystem Service Typology				
Section	**Division**	**Group**	**Class 1**	**Class 2**
Regulation and Maintenance	Mediation of flows	Liquid flows	Hydrological cycle and water flow maintenance	Flood protection / Storm protection
Water Quantity description	Water quantity regulation is a key ecosystem service which affects everyone. Excess water in a natural system can cause flooding events which can lead to severe social and economic consequences. Conversely, too little water over a long period causes drought conditions and water restrictions (Taylor, et al., 2009). The regulation of water is complex and is affected by obvious factors such as climate (and rainfall in particular), but also less obvious ones such as soil, vegetation (Crockford & Richardson, 2000) and land cover type (especially sealed surfaces, such as concrete and tarmac).			

Factor 1a - Soil	
Soil Types	At its simplest, soil temporarily stores water that falls as rain as it percolates through the system towards rivers and streams, or into the groundwater resource. The ability of soil to perform this function depends on its texture, depth and organic matter content, as well as the overall context of the soil in the landscape (Brady and Weil, 2002; Farmer, et al., 2003).
Mineral	The role of mineral soils in water regulation depends very much on the clay content within both the topsoil and subsoil horizons. Clay soils impede the percolation of the water through the profile, leading the surface of the soil to become waterlogged quickly. When these soils are subject to heavy rainfall the water flows overland and very rapidly reaches the rivers leading to problems caused by flash flooding events. Conversely, sandy soils have very effective drainage and consequently hold little water and are prone to drought events. When they are underlain by clay rich sub-soils they are able to store water as aquifers. Soils with high silt content can become 'capped' by an impenetrable layer of particles when they dry out and this again can lead to higher overland flows, even when the soil is not fully at field capacity (Quisenberry & Phillips, 1976).
Organo-Mineral	Organo-mineral soils can act as either a water store or a water-shedding resource depending on the subsoil clay content, the water inputs to the system and slope. Heavy clay soils with unstable soil structures resist infiltration and encourage run off (Brady and Weil, 2002).
Organic	Organic soils are highly absorbent. They have a large capacity to store water after a rainfall event which reduces the amount of run-off, and slows the progress of water to water courses (Brady and Weil, 2002). This cycle occurs until the soils are fully saturated at which point they cannot contain any more water and additional rainfall water will flow over the land surface.
Soil Systems	Wetland systems tend to be peat based and are able to absorb large amounts of rainfall can be absorbed, thus reducing the amount of run-off until the peat system is saturated and additional water inputs run-off the soil surface (Bain et al., 2011). Mineral soil systems are very dependent on particle size, organic matter content and compaction. Mechanical and biological soil management practices which improve the structure of the soil, allowing more air into the system, reduce compaction and allow the soil to store more water (Brady and Weil, 2002). Where the volume of the soil is limited by an impermeable layer this will also affect the soils capacity to absorb and retain water.
Factor 1b Geology	
	The underlying geology affects the soil type as it is the parent material, which determines the mineral composition and particle size of the soil. This is directly related to the water holding capacity of soils (Gupta & Larson, 1979). The geology also has an effect on the shape of the topography, the course of rivers and within rock through flow characteristics; which drive the drainage cycle and determine whether it is an aquifer (Fetter, 1994).

Factor 2 - Habitat		
Biophysical Properties of habitats		Habitat, through its link to vegetation type and soil type, has an important influence on water quantity. This is linked largely to the structure of the vegetation present. At one end of the spectrum, mature woodland provides an important water quantity regulation role, through: • The interception of rainfall before it reaches the ground (Crockford and Richardson, 2000,; Teklehaimanot, *et al*., 1991), slowing its arrival at the ground and increasing its chance of being absorbed by the soil. • The dissipation and slowing down of water through the system by tree growth and evapotranspiration. • The retention of water in the soil through enhancing organic soil content from leaf litter. • Reducing the pressure on urban drainage systems. Mature woodland provides the most vegetative benefits to water quantity regulation. At the other end of the spectrum of vegetated land cover, improved grassland has only a small influence on water quantity regulation, linked solely to soil type and underlying geology. Improved grassland provides only a modest potential for evapotranspiration to occur, no discernible interception and no enhancement of the soil organic content (Cheng, *et al*., 2003). Other habitat types have a varying influence on water quantity regulation according to the structure of the vegetation present. Wetlands provide flood control and drought prevention due to their physical characteristics and by the presence of plants which impede water movement, such as *Sphagnum* (Mitsch and Gosselink, 2000). Mire has traditionally been viewed as having a high storage capacity for water but more recent publications have highlighted that this is only true until they are saturated, at which point they only have a limited flood storage potential (Holden, 2005). Generally the taller and more complex the vegetation the greater the influence. In many areas an increase in built up infrastructure (namely concrete or tarmac surfaces), unable to absorb rainfall, has resulted in the alteration of water flow and increase the risk of surface water flooding (Bolund and Hunhammar,1999; Woodland Trust, 2010). A greater proportion of rainfall becomes surface water run-off, resulting in increased flood discharges. Gardens which are not paved over and which contain plants and trees can help reduce surface water flow by intercepting intense rain, slowing run-off and reducing the pressure on urban drainage systems (Pauleit and Duhme, 2000).
Below ground physical features	**Root depths**	The distribution of roots in the soil profile determines how different vegetation types absorb soil water (Brady and Weil, 2002). Deep rooted plants, such as in mature semi-natural woodland, are able to effectively slow water movement (Calder *et al*., 2008). The root system opens the soil structure, creating a large capacity for water storage. Shallower rooted species, such as annuals, have little effect on water holding capacity.
Below ground biological features	**Species richness**	Macro fauna, especially earthworms, have a strong influence on soil water holding capacity by aerating the soil and maintaining an open structure which is more effective at storing water. Habitats which support these species therefore have a higher water holding capacity on mineral soils.
Above ground	**Biomass/ Canopy**	The biomass and canopy height are important influences on water quantity. Generally, the higher the canopy the more levels of vegetation structure there

physical features	**Height**	are and the higher the interception rate and transpiration potential. Additionally with trees, the efficiency of water use is influenced by leaf area; which declines with old age (Haycock *et al*., 1993; Viramontes and Descroix, 2003). Bracken and Heather have high rates of interception due to their fine branch and leaf structures, although as their transpiration rates are lower (Calder *et al*., 2008) they have a lower bearing on water quantity provision than woodlands.
Above ground biological features	**Species Richness**	Above ground species richness of vegetation can result in varying rooting depths present in an area and therefore influence the soil water storage potential. Species diversity can also mean a varied structure of the vegetation present within an area, which can affect how water is used and stored. In broadleaved woodland structural diversity increases aerodynamic roughness and evaporation. Trees with lighter canopies, such as ash, intercept less rainfall compared to oak and beech species (Harding *et al*., 1992).
Other effects (How other data can be used as a proxy indicator of functionality)		Sealed surfaces are generally well mapped by OS MasterMap, especially urban areas and roads. Other areas of bare ground can be mapped using satellite imagery and the NDVI (Normalized Difference Vegetation index) calculation.

Factor 3 -– Landform	
	Landform has an influence on water quality regulation. Of particular importance is slope. Steep slopes shed water more rapidly than shallow slopes. Steep slopes are also more likely to be in the upper reaches of catchments and are characterised by small streams with rocky banks, which in times of heavy rainfall can quickly rise (Hanna, *et al.*, 1982). In the lower reaches of the catchment, where the land is relatively flat or gently sloping, rivers are generally wider and the flow rate of the water is slower. When flood waters arrive in this region of the catchment the banks of the river can be breached, and the water inundates the surrounding flood plains. Certain habitats, such as large areas of ecologically functioning wetlands, provide a range of potential benefits for flood risk management. These include water storage, slowing down the movement water and reducing the chance of a surge or flood peak and creating opportunities to direct flooding away from population centres (Brown and Edwards, 2006). The drainage density of an area is significant for the speed with which water travels through the system. This is described as the distance to water courses or water bodies from a point of interest, the further the distance the longer it takes water to move through the habitats. Simple barriers, such as hedgerows, can have a profound effect on the speed at which water moves through the hydrological cycle. Sealed surfaces (ones which are paved or compacted) on steep slopes can contribute towards a significant increase in run-off and the possibility of surges of water into the system.

Factor 4 - How it is managed	
Negative Management	Negative management, leading to reduced water quantity regulation include: • Paving over of gardens and other areas creating larger areas of sealed land surfaces (Perry and Nawaz, 2008) • Drainage of peatlands and other wetlands used as water storage areas (Holden *et al.,* 2004) • Felling of woodlands • Increased agricultural activity, especially on steep slopes in high rainfall areas
Positive Management	Positive management, leading to increased water quantity regulation includes: • Maintenance of gardens and other areas of natural soils in urban areas • Restoration of peatlands and other wetlands used as water storage areas • Planting of woodlands, especially on steep slopes (Nisbet *et al*, 2011) • Less intensive agricultural activity, especially on steep slopes in high rainfall areas and close to rivers and water courses

References

Bain, C.G., Bonn, A., Stoneman, R., Chapman, S., Coupar, A., Evans, M., Gearey, B., Howat, M., Joosten, H., Keenleyside, C., Labadz, J., Lindsay, R., Littlewood, N., Lunt, P., Miller, C.J., Moxey, A., Orr, H., Reed, M., Smith, P., Swales, V., Thompson, D.B.A., Thompson, P.S., Van de Noort, R., Wilson, J.D. & Worrall, F (2011) IUCN UK Commission of Inquiry on Peatlands. IUCN UK Peatland Programme, Edinburgh.

Bolund, P., and Hunhammar, S (1999) Ecosystem services in urban areas, Ecological Economics, **29**, 293-301

Brady N.C., and Weil, R (2002) The Nature and Properties of Soil, 13th Edition Prentice Hall

Brown, C, F., Edwards, A (2008) Identification of priorities for wetlands, flood risk and diffuse pollution control within future high tier targeted Agri-environment schemes. Report 06/13.

Calder, I, R., Harrison, J., Nisbet, T, R., Smithers, R, J (2008) Woodland actions for biodiversity and their role in water management [online] Available at: http://www.woodlandtrust.org.uk/SiteCollectionDocuments/pdf/woodswater26_03-08.pdf [Accessed 6th August 2012]

Cheng, G, J. M., Wan, H. E., Wang, J., & Yong, S. P. (2003). Soil Water Regulation of the Natural Grassland of Semi-Arid Loess Hilly Region [J]. *Acta Agrestia Sinica*, *4*, 004.

Crockford, R. H., & Richardson, D. P. (2000). Partitioning of rainfall into throughfall, stemflow and interception: effect of forest type, ground cover and climate. *Hydrological Processes*, *14*(16-17), 2903-2920

Farmer, D., Sivapalan, M., & Jothityangkoon, C. (2003). Climate, soil, and vegetation controls upon the variability of water balance in temperate and semiarid landscapes: Downward approach to water balance analysis. *Water Resources Research*, *39*(2).

Fetter, C. W., **1994**, Applied hydrogeology. (4th Ed) Upper Saddle River: Prentice Hall. *691p*

Gupta, S., & Larson, W. E. **1979**, Estimating soil water retention characteristics from particle size distribution, organic matter percent, and bulk density. *Water Resources Research*, **15**(6), *1633-1635*.

Hanna, A. Y., Harlan, P. W., & Lewis, D. T., **1982**, Soil available water as influenced by landscape position and aspect. Agronomy Journal, **74**(6), *999-1004.*

Harding, R. J., Hall, R. L., Neal, C., Roberts, J. M., Rosier P.T.W., and Kinniburgh, D. K., **1992**, Hydrological impact of broadleaf woodlands: Implications for water use and water quality". *Institute of Hydrology, British Geological Survey Project Report 115/03/ST and 115/04/ST for the National Rivers Authority, Institute of Hydrology*: Wallingford, UK

Haycock, N. E. and G. Pinay (1993) "Groundwater nitrate dynamics in grass and poplar vegetated riparian buffer strips during the winter". Journal of environmental quality, 22, issue 2, pp. 273-278

Holden, J. (**2005**). Peatland hydrology and carbon release: why small-scale process matters. Phil.Trans.R. Soc. A. **363**: *2891-2913.*

Holden, J., Chapman, P. J., & Labadz, J. C. (**2004**). Artificial drainage of peatlands: hydrological and hydrochemical process and wetland restoration.*Progress in Physical Geography*, **28**(1), *95-123*

Mitch, W, J., Gosselink, J, G, **2000**, The value of wetlands: importance of scale and landscape setting, Ecological Economics, **35**, *25-33*

Nisbet, T., Silgram, M., Shah, N., Morrow, K., & Broadmeadow, S. , **2011**, Woodland for water: woodland measures for meeting Water Framework Directive objectives. *Forest Research Monograph*, ***4***, 156.

Pauleit S, and Duhme F., **2000**, Assessing the environmental performance of land cover types for urban planning. *Landscape and Urban Planning* **52**: *1–20*.

Perry, T., & Nawaz, R. (2008). An investigation into the extent and impacts of hard surfacing of domestic gardens in an area of Leeds, United Kingdom.*Landscape and urban planning*, *86*(1), 1-13.

Quisenberry, V. L., & Phillips, R. E., **1976**, Percolation of surface-applied water in the field. *Soil Science Society of America Journal*, **40**(4), *484-489*.

Taylor, V., Chappells, H., Medd, W., and Trentmann, F., **2009**, Drought is normal: the socio-technical evolution of drought and water demand in England and Wales, 1893–2006. *Journal of Historical Geography*, **35**(3), *568-591*.

Teklehaimanot, Z., Jarvis, P. G., and Ledger, D. C., **1991**, Rainfall interception and boundary layer conductance in relation to tree spacing. *Journal of Hydrology*, **123**(3), *261-278*.

Viramontes, D. and Descroix, L., 2003, Changes in the surface water hydrologic characteristics of anendoreic basin of northern Mexico from 1970 to 1998. *Hydrological Processes*, **17**, *pp. 1291-1306*

Woodland Trust (2010) Policy Note: Greening the Concrete Jungle [online] Available at: http://www.woodlandtrust.org.uk/en/planting-woodland/Documents/woodland-trust-greening-the-concrete-jungle.pdf [Accessed 17th December 2012]