ECOSYSTEM SERVICE MODELLING

RULE-BASE DEVELOPMENT – SUGGESTIONS FOR USER

Contents

Water quality regulation			
CICES Ecosystem Service Typology			
Section Regulation and Maintenance	**Division** Mediation of waste, toxics and other nuisances.	**Group** Mediation by ecosystems.	**Class** Filtration/sequestration/storage/ accumulation by ecosystems.
Water Quality Regulation description	Water quality is a key ecosystem service that effects human health and wellbeing and can have significant economic consequences (Gleick, 1993). Water quality is influenced by both natural processes and human activities.		

Factor 1a - Soil	
Soil Types	Soil temporarily stores water that falls as rain and subsequently releases it to rivers and streams, or adds it to the overall groundwater resource. The ability for soil to perform this process depends on texture, depth and organic matter content and the overall context of the soil in the landscape. During its percolation through the soil, water can interact with the soil chemistry and any deposits from human activity taking place on the soil surface; which can influence the water quality (Arya and Paris, 1981).
Mineral	In general soils provide a filtration function for water, improving quality (i.e. removing particulate matter from drinking water). However soils can also add pollutants to water where the soil itself is naturally high in certain metals or contaminated by human activity. The role of mineral soil in water quality regulation depends on the mineral type and concentrations within the topsoil and subsoil, as well as the pH of the water. Clay soils impede water movement, leading to a slow rate of percolation of water through the profile and quickly become waterlogged. When waterlogged, water will run off the surface of soils and collect any surface pollutants, which are then incorporated directly into the soil system and water cycle. Sandy soils drain quickly, and hold little water, but can have a useful filtration effect and form the best aquifers. However, clay soils have greater capacity to adsorb charged particles from water than sandy soil due to the presence of ion exchange sites. Neutral soils have the highest capacity to reduce water pollution as it filters through soil horizons, as at this pH there is a high ion exchange capacity. The underlying mineralogy of the soil has an effect on filtration rates as the mineral proportion of the soil acts as an ion exchange site. Groundwater is often of high quality where it has been filtered through many layers of soil and rock.
Organo-Mineral	Organo-mineral soils can act as either a water store or a water-shedding resource, depending on the subsoil clay content (which influences the water holding capacity) and the amount of rainfall in the area. Acid soils are less effective as water purifiers as they have a low ion exchange capacity. The peat component of the top soil can also be a source of suspended solid particles, which are released into the water. Although these are not deleterious to human health, they are now perceived as undesirable and extra effort is needed to remove them from potable water.
Organic	Organic soils absorb a large quantity of water and act as a water store, when they are not at full capacity. However, in prolonged rainfall events when the peat is saturated, water will run off of the soil surface. In eroded systems, or where there is an incomplete Sphagnum layer, the suspended solid component of the water running through and off the peat can be significant (Lucas and Davis, 1961).
Soil Systems	The health, or functional capacity, of soil systems has an influence on water quality. Soil systems which have active microbial and geochemical interactions are able to react with particulates, metals and nutrients from the water, incorporating them into the soil (Fetter, 1994).
Factor 1b - Geology	
	The solid and drift geology provides parent material to the soil and drainage properties effect conditions and subsequently soil development. This therefore affects the water quality regulation capability of soils. The reactivity of the main minerals that form the rock and the natural pH of the systems will drive the filtration effects. (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 quality. This is largely linked to the structure of the vegetation present. Some species of plants assist with water purification. Several mechanisms allow plants to take up extra metals and impurities from water. Certain wetland plants (e.g. *Phragmites australis)* have microbial species associated with their roots that provide oxygen into the system which creates conditions that assist metal uptake by the plants and therefore enhances the natural purification process (Armstrong, et al., 2000; Shutes, 2001).
Below ground physical features	**Root depths**	Below ground features will have a positive impact on water quality, especially where roots and their associated microrrhizae communities remove unwanted nutrients and organic content from water (Virginia, et al., 1986).
Below ground biological features	**Species richness**	Below ground communities will have an impact on water quality. The microrrhizae associations and the macro and micro fauna in mineral soils influence oxygen concentration levels. Increased oxygen availability allows more particulates, metals and nutrients to be taken up by the plants and increases the level of purification. Therefore, the greater the below ground biodiversity, the more likely the system will bolster purification (Boulton, et al., 2008; Mommer, et al., 2010).
Above ground physical features	**Biomass/ Canopy Height**	Geochemically, the above ground vegetation is less important than the below ground physical features and has a specific effect on water quality in a limited number of situations. Some species of conifer have leaves which are coated in a substance which inhibits growth of competitive species in the area around the tree. Conifer needles also degrade to create acidic mulch. These characteristics can affect the quality of any water that comes into contact with the soil. Additionally above ground vegetation holds the surface of the ground together protecting it from erosion, and therefore aids in water quality regulation.
Above ground biological features	**Species Richness**	Generally species rich communities above ground, will have a similarly species rich soil community below ground. These species rich systems are actively functioning and aid in water purification. In some aquifers, feeding, movement and excretion by diverse assemblages of groundwater species have the potential to enhance groundwater ecosystem services such as water purification (Boulton, 2008).
Other effects (How other data can be used as a proxy indicator)		Where habitats are located on peat based substrate, information on the quality of the bog surface can be used to proxy erosion risk. Where habitats are located on mineral soils, the species richness of the community can be used to indicate possible erosion risk. Land cover types, such as arable fields, which leave soil surfaces bare, or involve manmade inputs into the soil, increase the risk of pollution and can therefore be considered to have a negative effect on water quality by leading to increased pollutant inputs (Heathwaite *et al*., 2005). Reed beds can be regarded as a positive resource as they collect particulate matter from the water.

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. The water has higher energy and is able to carry more particulate matter within it, picked up from the land surface. 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). When these steeper streams meet less steep reaches of the catchment, or join with other water courses, the energy of the water changes and suspended particulate matter can be deposited and river banks can be scoured. 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 floodplains. This flood water can contain high levels of sediment and pollutants from upstream and pick up additional materials from the flood plain and any urban areas, these pollutants return to the river when flood waters recede.

Factor 4 - How it is managed	
Negative Management	Negative management, leading to reduced water quality regulation include: • Overstocking and poor animal management in upland areas leading to soil erosion (Curtis, 1983) • Poorly managed use of chemicals in grassland for livestock management • Drainage of peatlands and other wetlands used as water storage areas (Holden *et al*., 2004) • Extensive use of chemicals in arable and cereal production, especially at sites adjoining water courses (Hallberg, 1987)
Positive Management	Positive management, leading to increased water quality regulation includes: • Restoration of peatlands and other wetlands used as water storage areas • Good animal management in upland areas • Well managed use of chemicals in arable and cereal production, especially at sites adjoining water courses (and the use of buffer strips)

References

Armstrong, W., Cousins, D., Armstrong, J., Turner, D. W., & Beckett, P. M. (**2000**). Oxygen distribution in wetland plant roots and permeability barriers to gas-exchange with the rhizosphere: a microelectrode and modelling study with *Phragmites australis*. *Annals of Botany*, **86**(3), *687-703*.

Arya, L. M., & Paris, J. F., **1981**, A physicoempirical model to predict the soil moisture characteristic from particle-size distribution and bulk density data. *Soil Science Society of America Journal*, **45**(6), *1023-1030*.

Boulton, A. J., Fenwick, G. D., Hancock, P. J., & Harvey, M. S., **2008**, Biodiversity, functional roles and ecosystem services of groundwater invertebrates. Invertebrate Systematics, **22**(2), *103-116*.

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

Code of Good Agricultural Practice for the Protection of Soil (1998) MAFF, Countryside matters

Curtis, S. E., **1983,** Environmental management in animal agriculture. *Iowa State University Press.*

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

Gleick, P. H., **1993**, Water in crisis: a guide to the world's fresh water resources. Oxford University Press, Inc. Chicago

Hallberg, G. R., **1987**, Agricultural chemicals in ground water: extent and implications. American *Journal of Alternative Agriculture*, **2**(1), *3-15*.

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.

Heathwaite, A. L., Quinn, P., F., and Hewett C., J., M., **2005**, Modelling and managing critical source areas of diffuse pollution from agricultural land using flow connectivity simulation." *Journal of Hydrology* **304**.1. *pp446-461*.

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

Lucas, R. E., and Davis, J., **1961**, Relationships between pH values of organic soils and availabilities of 12 plant nutrients. Soil Science, **92**(3), *177-182.*

Mommer, L., Van Ruijven, J., De Caluwe, H., Smit-Tiekstra, A. E., Wagemaker, C. A. M, Joop Ouborg, N., Bögermann, G, M., Van Der Weerden, G, M., Berendse, F. & De Kroon, H., **2010**, Unveiling below-ground species abundance in a biodiversity experiment: a test of vertical niche differentiation among grassland species. *Journal of Ecology*, **98**(5), *1117-1127.*

Shutes, R. B. E. (**2001**). Artificial wetlands and water quality improvement. *Environment international*, **26**(5), *441-447*.

Virginia, R. A., Jenkins, M. B., and Jarrell, W. M., **1986**, Depth of root symbiont occurrence in soil. Biology and Fertility of Soils **2**.3, *127-130*