CL:AIRE INSPIRATION bulletin

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CL:AIRE's INSPIRATION bulletins describe practical aspects of research which have direct application to the management of contaminated soil or groundwater in an agricultural context. This bulletin describes the development and application of a freely available decision support tool to mitigate nutrients in drainage waters.

A decision support tool to select media to mitigate nutrients in farm drainage water

1. Background

Agricultural land is often artificially drained. Drainage systems affect both the hydrologic and water quality responses on agricultural landscapes. Any nutrients dissolved in water as it travels along surface and subsurface pathways can travel along a drainage system to a receiving water body. In many countries such as New Zealand, USA and in the UK engineered structures have been designed and installed along the drainage network to intercept nutrients and attenuate them before reaching rivers. The choice of a medium or media to facilitate this attenuation depends on many factors. For example where nitrate is discharging from a farm, woodchip is the medium of choice in structures called denitrifying bioreactors. It is now known that discharge waters may contain mixed nutrients. Therefore a medium that treats nitrate converting it to a benign gaseous form may be no good for phosphorus attenuation and vice versa. Therefore nitrate (NO_3^-), ammonium (NH_4^+) or indeed dissolved reactive phosphorus (DRP) specific media must be considered. A simple water sample analysis will identify the nutrients of concern. Matching a water quality issue with a filter medium or media is the first step to protect water quality. However, this decision is difficult as there are so many different materials and some of which are not locally available. A decision support tool (DST) called FarMit (Farm mitigation tool) was developed for this purpose. This tool is open source and freely available via Ezzatti *et al.* (2019).

2. Methods and Approach

2.1 The FarMit tool structure

As can be seen from Figure 1 the structure of the DST brings together information on the nutrients needing mitigation at a given site and the database of media, which produces a list of media possibilities in a quick timeframe.

For the media database a systematic review of the literature was conducted, which considers the following steps: *Step 1: Framing questions for a review, Step 2: Identifying relevant work, Step 3: Assessing the quality of studies, Step 4: Summarising the evidence and Step 5: Interpreting the findings.*

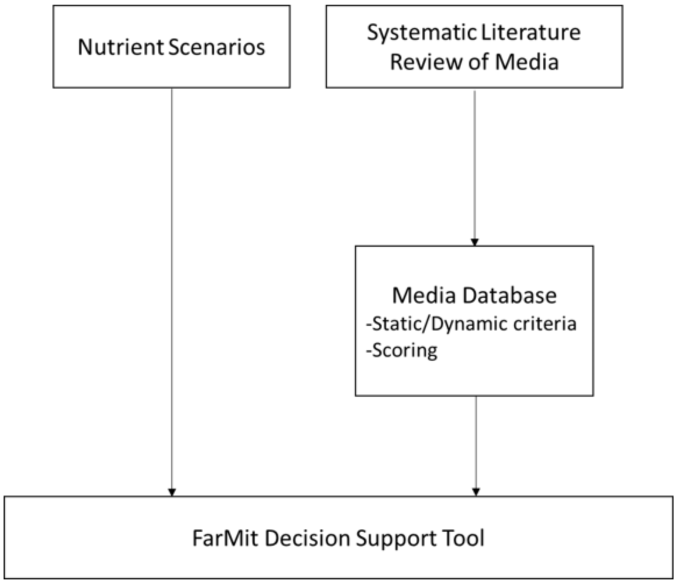

Figure 1: The steps taken to create the decision support tool - FarMit.

Initially 150 media-based water treatment studies published over the past 20 years were included in the study. This eventually led to a "media database" on 75 distinct media types. The database was further categorised into different types as follows: wood-based, vegetation/phytoremediation and inorganic materials. The database contains information on nutrient, biochemical oxygen demand (BOD) and chemical oxygen demand (COD), pesticide, oil, metal, coliforms and suspended solid attenuation capacity. In addition, information was collected on the hydraulic conductivity of the media, the reported period of operation before saturation, the potential for pollution swapping, and possible requirement for expensive pre-treatments. To develop the nutrient scenarios, the literature was also collated with specific emphasis on land drainage studies. This research activity enabled various worldwide farm pollution scenarios to be developed, which could be used to select and filter the full media database only presenting a shortened top 10 list for the given water quality issues at a site. These nutrient scenarios consisted of nitrate only, DRP only, ammonium only or a combination of DRP and a nitrogen species.

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Inspiration

2.2 Static and dynamic criteria

From this systematic review process seven static scores (which do not change) were assigned to each of the 75 media. Media were then assigned nine criteria (seven static and two dynamic), based on the literature review (see Table 1), and a corresponding score system was developed for each criterion. In the static component, these criteria were NO_3^-, NH_4^+ and DRP removal capacity, removal of other pollutants of concern, hydraulic conductivity, lifetime of media before saturation, and negative externalities such as emission of greenhouse gases (GHG), contaminant leaching or the presence of other pollutants in the final effluent (Table 1). For example, Criterion 1 is nitrate removal rate (% concentration reduction) with a score range of -1, 0, 1, 2, 3, 4 corresponding to < 10%, 10-30%, 30-50%, 50-70%, 70-85% and >85% reduction of nutrient concentration, respectively. Although many studies report % removal, there are of course other factors that affect this criterion, such as hydraulic residence time in denitrifying bioreactors and contact time in P-sorbing filters. Therefore, for this criterion % removal is only a contributing factor when comparing studies/media results and other criteria should be consulted at the final ranking stage. The corresponding scoring system for the static criteria is presented in Table 1. In the dynamic component, media were ranked according to geographically-based criteria such as availability and delivery cost to the treatment site or farm. These criteria are country/region-specific and will change over time. As the amount of media needed will vary depending on the drainage flow and composition at the site of concern, local knowledge is required and the end user can obtain the most appropriate ranking of media by only assigning scores to these two components. The score ranges for these two final dynamic criteria are presented in Table 1.

2.3 Tool interface and example

Figure 2 shows the user interface of the tool which enables the user to click on the water quality issue that they are concerned with. This immediately brings up a list of potential media based on the nutrients selected and the static criteria. As an example if nitrate is elevated at a particular site the DST user would click "nitrate". A table of the top ten media based on static criteria are presented. The user can now insert the dynamic categories based around local availability and cost (Figure 3). The final list is re-shuffled and a final selection is presented (Figure 4).

Figure 2: FarMit interface for the selection of the nutrient of concern or combination of nutrients.

Table 1: Static (1-7) and dynamic (8-9) criteria and corresponding scoring ranges (Adapted from Ezzati *et al.*, 2019).

Criteria	Condition pertaining to score	Score
Static scores based on an average performance reported		
1- NO_3-N removal rate	NO_3-N concentration reduction > 85%	4
	NO_3-N concentration reduction: 70-85%	3
	NO_3-N concentration reduction: 50-70%	2
	NO_3-N concentration reduction: 30-50%	1
	NO_3-N concentration reduction: 10-30%	0
	NO_3-N concentration reduction < 10% and increase in concentration	-1
2- NH_4 –N removal rate	NH_4-N concentration reduction > 85%	4
	NH_4-N concentration reduction: 70-85%	3
	NH_4-N concentration reduction: 50-70%	2
	NH_4-N concentration reduction: 30-50%	1
	NH_4-N concentration reduction: 10-30%	0
	NH_4-N concentration reduction < 10% and increase in concentration	-1
3- DRP removal rate	DRP concentration reduction > 85%	4
	DRP concentration reduction: 70-85%	3
	DRP concentration reduction: 50-70%	2
	DRP concentration reduction: 30-50%	1
	DRP concentration reduction: 10-30%	0
	DRP concentration reduction < 10% and increase in concentration	-1
4- Removal of other pollutants of concern	Removal of other nutrient/pollutant> 80%	2
	Removal of other nutrient/pollutant< 80%	1
5- Hydraulic conductivity	Very good: > 4 cm/h	3
	Good: 1.5-4 cm/h	2
	Acceptable/depending on compactness: <1.5 cm/h	1
6- Lifetime	Lifetime >10 years	2
	Lifetime : 5-10 years	1
	Lifetime <5 years	0
7- Negative externalities	GHG emission	-3
	Contaminant leaching/other pollutants in effluent	-2
	Expensive pre-treatment	-1
User Selected dynamic scores. (subject to change based on geographical region)		
8- Scale of Availability	Scale of Availability: farm scale	4
	Scale of Availability: local/country scale	3
	Scale of Availability: EU/continent scale	2
	Scale of Availability: International scale	1
9- Cost	Cost (low)	3
	Cost (medium)	2
	Cost (high)	1

Nitrate

	Media	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Total
Woodchip	1	4	0	0	0	3	2	0			9
Vetiver grass	2	3	0	0	2	2	2	0			9
CocoPeat	3	3	0	0	2	2	1.5	0			8.5
Crushed glass	4	2	0	0	1.5	3	1	0			7.5
Sand	5	3	0	0	1	2	1	0			7
Cardboard	6	4	0	0	0	3	0	0			7
Zeolite	7	1	0	0	2	3	1	0			7
Granular actuivated carbon	8	3	0	0	1	3	0	0			7
Immature compost	9	4	0	0	0	2	0	0			6
Barley straw + (native) soil	10	4	0	0	0	2	0	0			6

Figure 3: Nitrate example with the top ten media options based on the static criteria.

Criterion 8	Score
Scale of Availability: farm scale	4
Scale of Availability: local/country scale	3
Scale of Availability: Continent scale	2
Scale of Availability: International scale	1

Criterion 9	Score
Delivered Cost (low)	3
Delivered Cost (medium)	2
Delivered Cost (high)	1

Nitrate

	Media	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Total
Woodchip	1	4	0	0	0	3	2	0	1	3	13
CocoPeat	3	3	0	0	2	2	1.5	0	2	1	11.5
Vetiver grass	2	3	0	0	2	2	2	0	1	1	11
Zeolite	7	1	0	0	2	3	1	0	3	1	11
Granular actuivated carbon	8	3	0	0	1	3	0	0	3	1	11
Crushed glass	4	2	0	0	1.5	3	1	0	2	1	10.5
Immature compost	9	4	0	0	0	2	0	0	3	1	10
Sand	5	3	0	0	1	2	1	0	1	1	9
Cardboard	6	4	0	0	0	3	0	0	1	1	9
Barley straw + (native) soil	10	4	0	0	0	2	0	0	2	1	9

Figure 4: Nitrate example with the top ten media options re-shuffled due to inclusion of dynamic criteria scores. Criterion 8 gets a score of 4 if it is local but 1 if it needs to be imported into the area. The highest score ranks as the best media across all 9 scores.

3. Take Home Message

The FarMit DST has been made available for free on the INSPIRATION ITN website. It is hoped that in future the DST will be developed further and is capable of housing data on other materials used to mitigate nutrients in drainage waters.

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For more information on the INSPIRATION Project, please visit: www.inspirationitn.co.uk

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