Interceptor phases – catching nutrient losses at key points on the landscape

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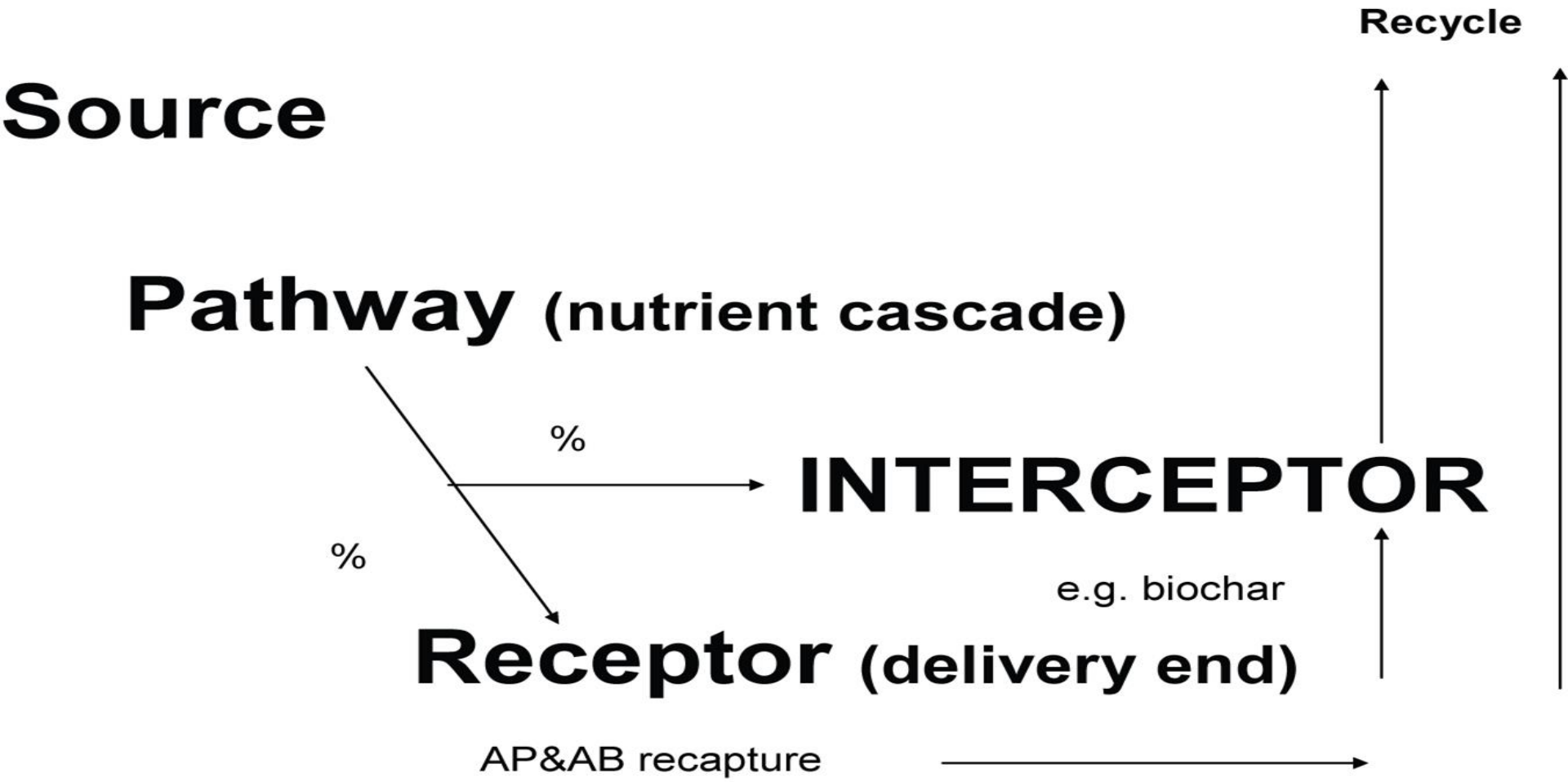
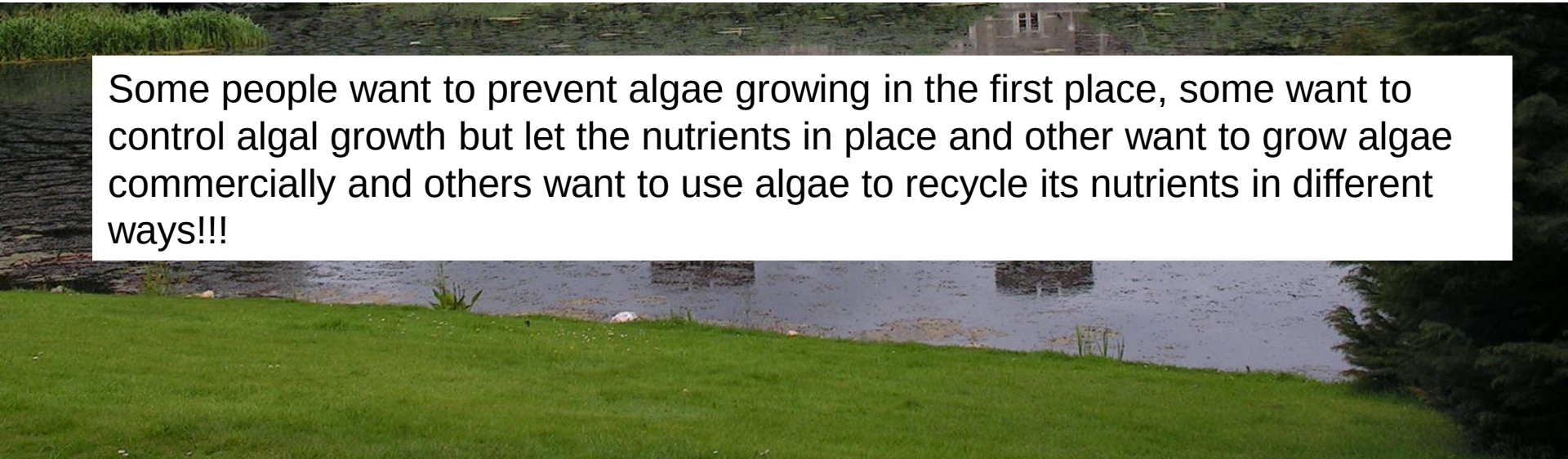


My side step into algal research….

J Appl Phycol
DOI 10.1007/s10811-009-9492-z

Barley (*Hordeum vulgare*)-induced growth inhibition of algae: a review

Daire Ó hUallacháin · Owen Fenton



Some people want to prevent algae growing in the first place, some want to control algal growth but let the nutrients in place and other want to grow algae commercially and others want to use algae to recycle its nutrients in different ways!!!

Fenton & OhUallacháin, 2012

Contents lists available at SciVerse ScienceDirect

Algal Research

journal homepage: www.elsevier.com/locate/algal

Review article

Agricultural nutrient surpluses as potential input sources to grow third generation biomass (microalgae): A review

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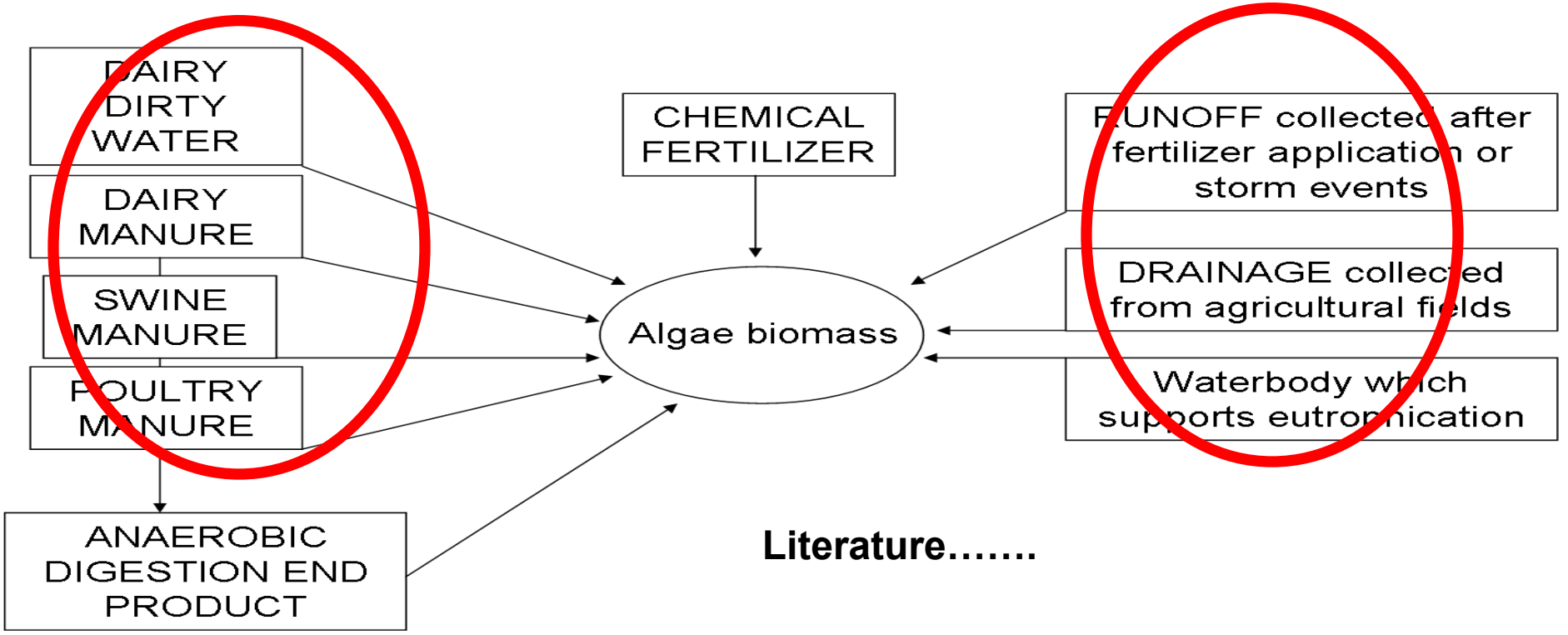
2012 Paper reviews:

1)Nutrient content of all of the sources in diagram below:

2)Documents all studies where organic fertilizers used in growing algae and gives some general useful information

3)Ireland Case Study – points to a possible way forward



Literature…….

In general...

Heterotrophic **&** ***mixothrophic*** **cultivation - increasing attention - most practical and promising way to increase the productivity**

Heterotrophic cultivation of microalgae is mainly focused on *Chlorella*. Cell densities as high as 104.9 g·L−1 (dry cell weight, *Chlorella pyrenoidosa*) have been reported. New research since review on *mixotrophy* with addition of molasses 3-10 times this figure.

Microalgae can adapt to different *organic* matters such as sucrose, glycerol, xylan, organic acids in slurry after acclimatisation.

Improving the *lipid content* in microalgae is a focus of commercial production of microalgae biomass. Current studies on high lipid content of microalgae are focused mainly on selection of *microalgae species, genetic modification of microalgae, nutrient management, metabolic pathways, cultivation conditions, and so on.*

Need carbon in the form of CO_2, light (for most but not all!!) and nutrients to undergo photosynthesis and biomass growth. Light source and intensity differs in open vs. Closed.

Review 1: No shortage of information out there on organic fertilizers… e.g. Here low nutrient content of dirty water

Table 2
Dairy dirty water nutrient (mg L^{-1}) results from various studies in U.K. and Ireland.

Study	Number of farms	Period of study		Kjeldahl N	BOD	K	NH_4	P	SUS	TN	TON	TP	Org N
Minogue et al., 2010 [57]	60	Monthly for 1 year	Mean		2246	568	212	37	5120	587	1	80	381
Ireland			Min		0	3	0	0	48	0	0	2	0
			Max		19085	7232	2933	1240	79400	6030	240	795	4251
			SD		2112	513	206	53	5865	536	10	68	413
Fenton et al., 2009a [101]	1	3 months (August, September, October)	Mean		–	–	–	14.0	–	170	30.4	20.1	–
Ireland			SD		–	–	–	9.2	–	33.2	9.2	6.9	–
Ryan et al., 2005 [128]			Min		–	–	–	–	–	43	88	–	–
Ireland			Max		–	–	–	–	–	126	225	–	–
Cumby et al., 1999 [55]	20	3 months (Feb, June, September)	Mean (Feb)		2.66	–	0.31	–	0.34	–	–	–	–
England and Wales			SD		1.8	–	0.32	–	0.34	–	–	–	–
			Mean (June)	0.95	9.67	1.50	0.58	0.49	0.83	–		–	–
			SD	0.76	9.67	1.05	0.48	0.34	0.66	–		–	–
			Mean (Sep)	0.70	7.45	0.85	0.48	0.34	0.52	–		–	–
			SD	0.60	6.55	0.40	0.41	0.22	0.37	–		–	–

Table 9 Nutrient availability in fertilisers

Article 15

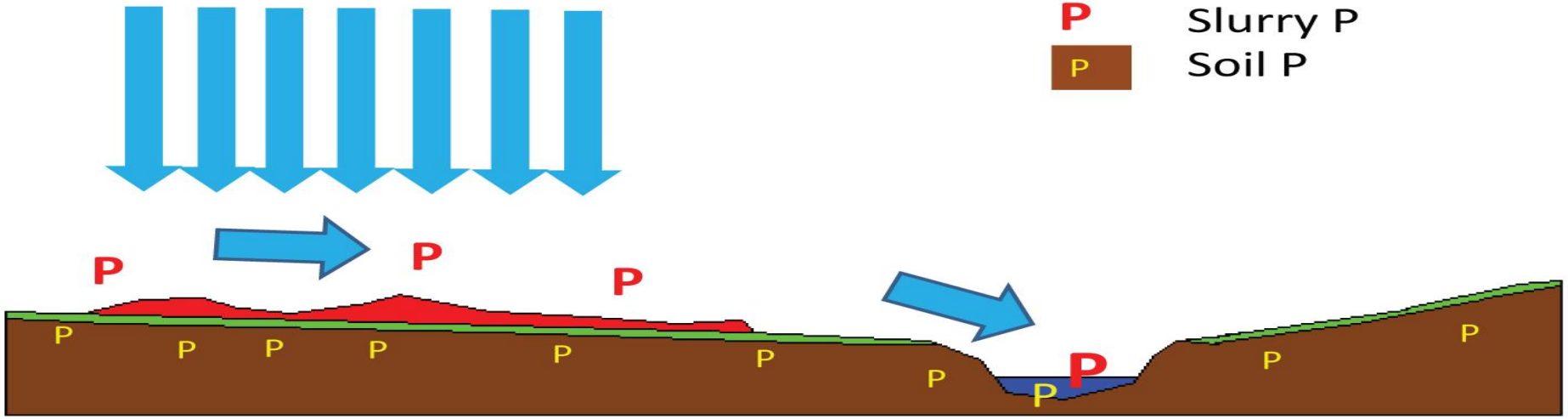
Fertiliser	Availability[1] (%)		
	Nitrogen		Phosphorus
	From January 1 2010	From January 1 2011	From January 1 20
Chemical	100	100	100
Pig and poultry manure	50	50	100
Farmyard manure	30	30	100
Spent mushroom compost	45	20	100
Cattle and other livestock manure (including that produced on the holding)	40	40	100

[1]Refers to year of application

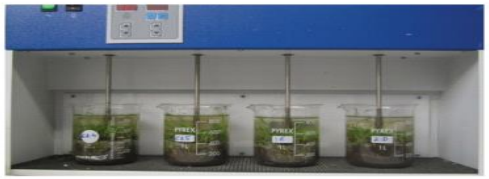
100%

Review 1: Examples of research on runoff (incidental and critical), drainage and groundwater nutrient losses…

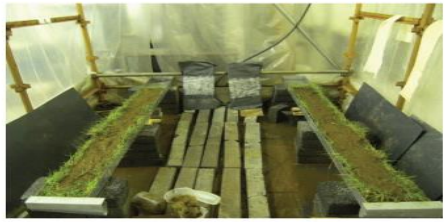
CHEMICAL AMENDMENT OF SLURRY AND DIRTY WATER – Still get mixed contaminant losses



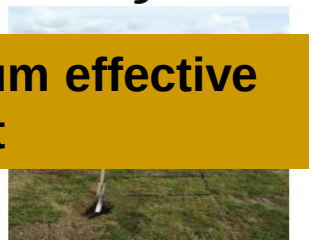
Batch-scale tests



Laboratory-scale tests



Plot and field-scale tests



Identification of amendments

Determine how much amendments to use per unit volume of wastewater

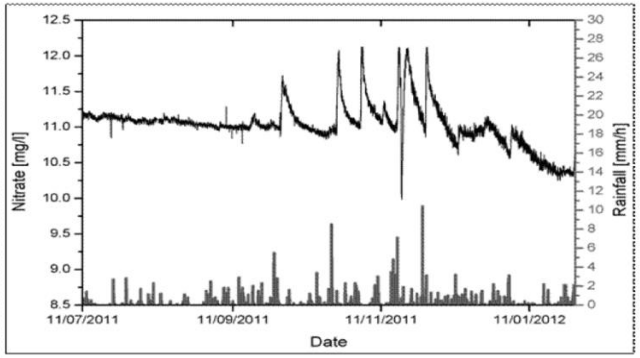
Efficacy of amendments at laborat[illegible]y-scale

Efficacy of am[illegible]

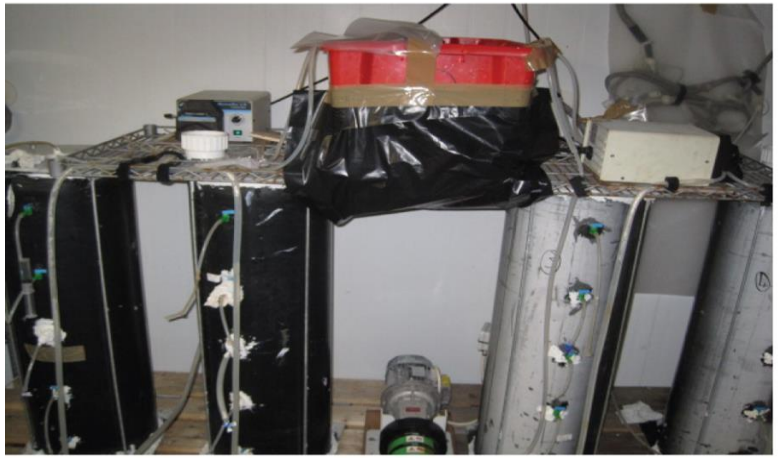
[illegible] scale

Poly Alumuminium Chloride and Alum effective after holistic assessment

Mixed contaminants - Permeable Reactive Interceptors



High resolution nitrate sensors

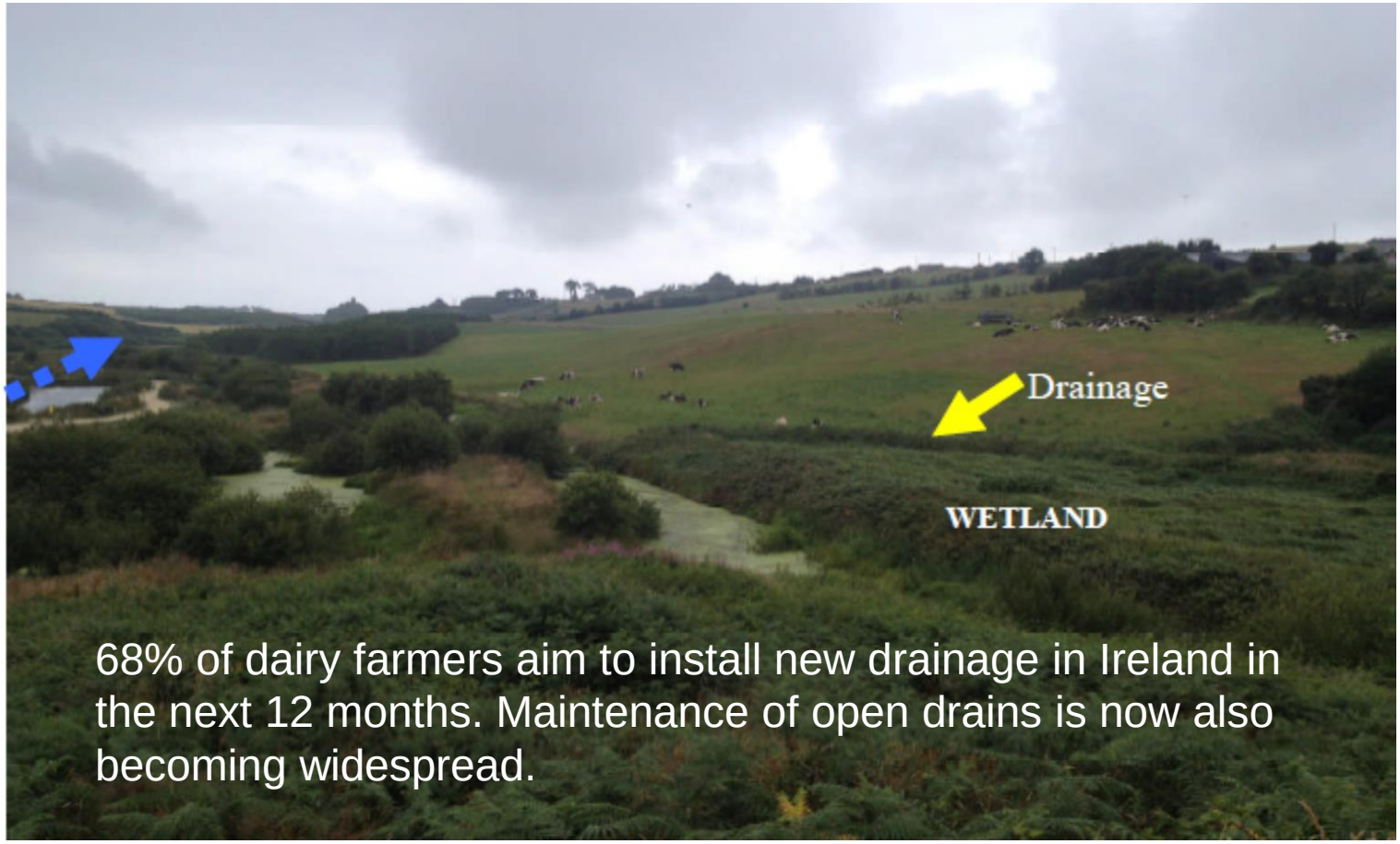


Zeolite, ochre etc…

Reactive materials can be recycled or used to grow algae???

Should we just let the nutrients escape?

Example of ICW at end of drainage system



68% of dairy farmers aim to install new drainage in Ireland in the next 12 months. Maintenance of open drains is now also becoming widespread.

REVIEW 2: Studies using organic manures - algae

Table 1
Selection of studies used to create algal biomass utilising nutrients from manures. (± standard deviation).

Study	Manure Type	Digested/ Undigested	Nh_4–N	Organic N	NO_3–N	TN	TP
			mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}
Mulbry and Wilkie, (2001) [46]	Dairy	Undigested	306	904	<1	1210	303
		Digested (Maryland, USA)	1620	751	<1	2371	240
		Digested (Florida, USA)	178	47	<1	225	24.7
Pizarro et al. (2002) [44]	Dairy	Digested	5 to 80	–	–	–	1 to 20
Sevrin-Reyssac, (1998) [65]	Swine		14000				2000–2300
Olguin et al. (2001) [66]	Swine	Digested	1700			2330	
Natarajan and Varghese, (1980) [68]	Poultry	Undigested (India)				3.5%	5.64%
Cheung and Wong, (1981) [69]	Poultry	Undigested (Hong Kong)				2.056 ± 0.08	261.3 ± 54.2
	Swine	Undigested (Hong Kong)				2.524 ± 0.04	344.2 ± 46.9
Wang et al. (2009) [124]	Dairy	Digested (Minnesota)	2232			3456	249.7
	Dairy	Undigested (Minnesota)	1782			3305	266
Kebede-Westhead, et al. (2004) [40]	Dairy	Digested manure effluent (Florida, USA)	233		<1	412	64.5

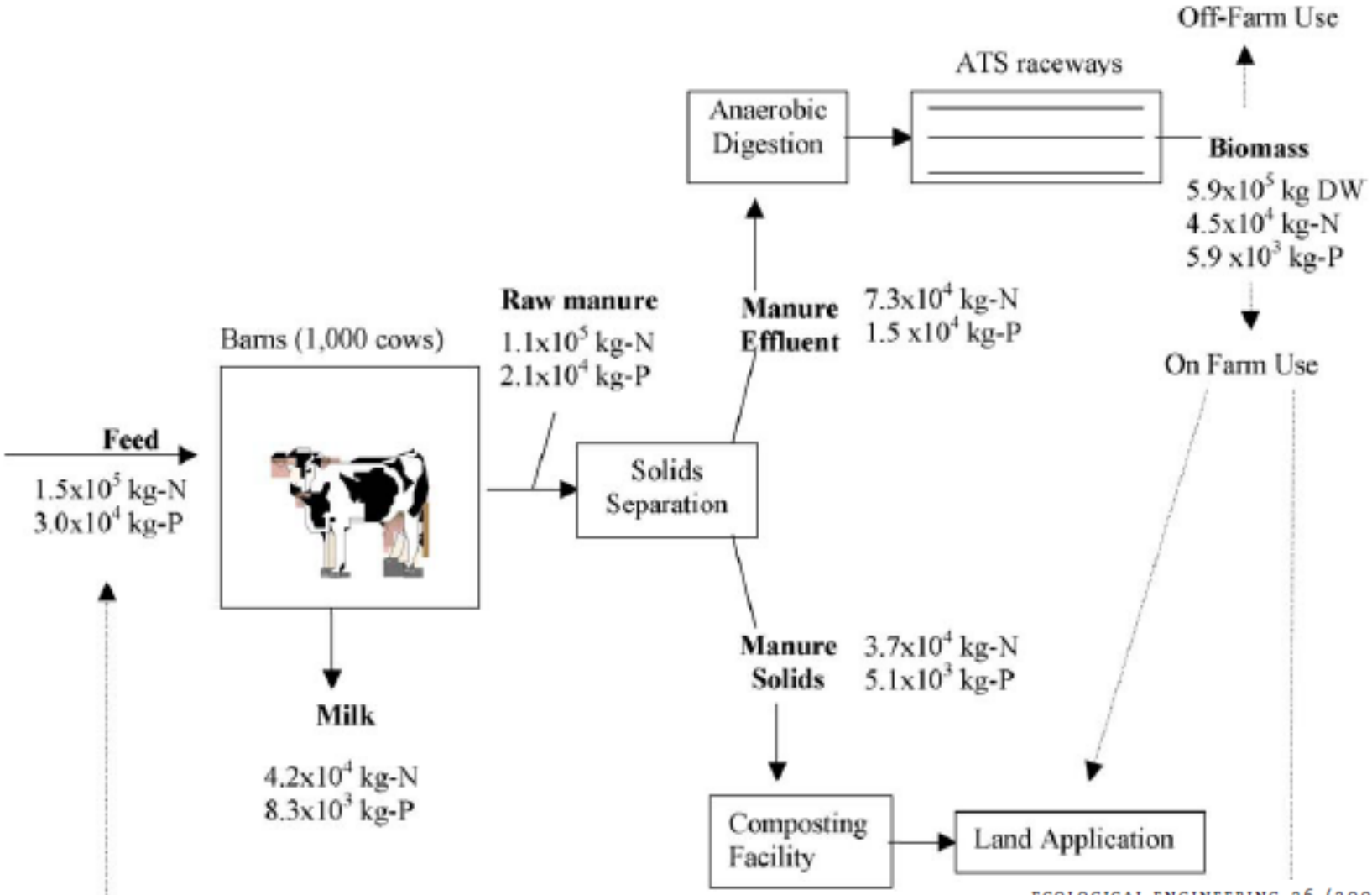
Identified some issues with undigested organic manures...

Some Problems with slurry/DW:

1) Nutrient variation within & across types
2) Loading rate determines fatty acid content and composition of algal biomass
3) Easy to dilute slurry in the lab but not in the field
4) P can precipitate during storage – overcome by agitation
5) N – volatilisation up to 30%
6) Ammonia emissions - storage 10-40 g N LU^{-1}
7) Transparency issues – dilution leads to greater storage needs
8) Pathogens etc....

Example:

Pizzaro et al. (2006) – On Farm Algal turf scrubber



ECOLOGICAL ENGINEERING 26 (2006) 321–327

Way forward....

•**Digested manures** as a nutrient supplement may have benefits with respect to maintenance of nutrients, sometimes becoming more concentrated, whilst being an easier product to handle afterwards.

•Methanogenic and psychrophilic anaerobic digestion is effective at **pathogen removal.**

•Interestingly bigger non-laboratory based studies have consistently used this product to grow algae.

•Selecting **high lipid content and fast growing microalgae** is an important step in the overall success of biodiesel production from microalgae. **High throughput techniques** to do this now e.g.lipophilic fluorescent dye staining (such as Nile Red) and fluorescence microscopy or flow cytometry, lipid content of algal cells is measured *in situ* without the need forextraction.
-lipid concentration within cells and the biomass produced by these cells is called **lipid productivity** – boosted by **genetic modification**

Things to note…..

Maintaining **pH** between 7 and 7.5 is important.

pH 8.5 results in **ammonia** volatilisation

Stress factors (limit N or P or CO_2, temp, pH etc)

Limiting nutrient availability such as N and P starvation during microalgae cultivation is a common method to induce lipid synthesis

Example:
When the nitrogen is exhausted and becomes the limiting factor, microalgae will continue to **absorb organic carbons**, which are to be converted to **lipids**. The nutrient limitation also results in a gradual change in lipid composition, *i.e.*, from free fatty acids to triacylglycerols which are more suitable for biodiesel production

Case Study in Ireland

FOOD HARVEST 2020 Proposes 50% expansion in dairy sector - huge movement in dairy industry and abolition of EU milk quota.

At present approx 40 Mt per annum of dairy slurry produced

Ireland has the ability to produce in excess 15.53 PJ of energy in 2020 by anaerobic digestion.

Other estimates predict 5% (each for cattle and pig) and 75% of poultry manure will also be diverted to AD.

But little or no adoption of AD in Ireland

Irish Case Study .....

Dirty water volumes are high & nutrient value is low

E.g. In SE Ireland (1000 mm Rainfall) 100 cow unit (milked twice daily) would have 9500 L daily.

Rotorainer irrigators and land application current management

So a managment change could be feasible

Transport costs for DW (50 km limit) and many other more dilute options redundant unless co-location occurs

Utilization of CO_2 from thermal power plants by large-scale microalgae production facilities can reduce a great deal of the greenhouse gas emissions. Co-location at these sites is feasible in pig and poultry areas of Ireland.

Pig & Poultry - nutrient contents are higher they can travel further.

Lots of activity.....

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Review

Current Status and Prospects of Biodiesel Production from Microalgae

Xiaodan Wu [1,2], Rongsheng Ruan [1,2,3], Zhenyi Du [3] and Yuhuan Liu [1,2,*]

1) biomass and lipid productivities were boosted by mixotrophic cultivation
2) addition of molasses increased again
3)documents lipid content of all known microalgae