A systematic review of policy approaches to dairy sector Greenhouse Gas (GHG) emission reduction

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A systematic review of policy approaches to dairy sector Greenhouse Gas (GHG) emission reduction.

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Abstract

The dairy sector is a significant source of anthropogenic greenhouse gas (GHG) emissions. The increasingly robust emission inventories allow researchers to consider mitigation. However, there is a gap in knowledge regarding the extent to which mitigation research has been implemented as policy. The authors undertook a systematic a review of national-level dairy policy of 23 countries broadly following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocols. The aim of the study was to identify international trends in dairy sector GHG emission reduction policy. Sampled countries included the 12 countries with the highest quantity of dairy sector enteric methane emission and 11 Annex I countries with the largest number of dairy cattle per capita. A total of 34 documents were collated containing 62 policies across five themes. Themes included: nutrition, manure, health, breeding and management. Thirty-one policies were identified for both the high emission nations and Annex I nations with the largest number of dairy cattle per capita. Nutrition based interventions account for 36% (n=11) of all policies identified for high emitting nations. Manure based interventions account for 48% (n=15) of all policies identified for Annex I nations with the largest number of dairy cattle per capita. Across the sample, policymakers favoured manure management strategies (n=24), particularly anaerobic digestion which accounted for 21% (n=13) of all identified policies. Nutrition based mitigation strategies were also preferred (n=17). Policies aimed at reducing sector size were largely ignored (n=4). The results indicate that significant mitigation is unlikely as manure emissions are only a small portion of total dairy sector emissions. The study concludes that policymakers are selecting the less politically sensitive mitigation strategies at the cost of emission reduction.

Keywords: systematic review, cow, mitigation, climate change, global warming

1. Introduction

Livestock's Long Shadow (FAO, 2006) introduced the livestock sector as a significant source of global Greenhouse Gas (GHG) emissions. Although the initial estimate of GHG emissions (18% of all anthropogenic GHG emission) (FAO, 2006) has been revised (see FAO, 2010) the publication gained traction within the scientific community, policymakers, and the general public. Since this time, the contribution livestock make to climate change (via GHG emissions) has received significant research interest. The dairy sector is the focal point of such research as it contributes an estimated 4% to total global anthropogenic GHG emissions (FAO, 2010).

Quantifications of emission from northern dairy systems (particularly intensive dairying) are considered increasingly robust. This has spurred emission mitigation research (e.g. Yan *et al.*, 2010; Doole, 2014; Dutreuil *et al.*, 2014). The less robust emission estimates from the global south have limited mitigation research. However, the need for mitigation remains as it is estimated that approximately 35% of the world's cattle are kept by smallholders in Sub-Saharan Africa and South-Asia alone (Oosting *et al.*, 2014). Thus, effective emission reduction policy must be developed for the north and south to ensure mitigation can occur at a global scale.

However, over ten years since publication of Livestock's Long Shadow (FAO, 2006), it is unclear what policies have been implemented to reduce the contribution of the dairy sector to global GHG emissions. It is broadly accepted to be government's role to initiate policies that will reduce emissions. Yet, the challenge posed by such a task should not be underestimated as mitigation policy must exist alongside policy tasked with safeguarding food security and climate change adaptation.

The research community increasingly notes that achieving emission reductions from the livestock sector will be difficult without an overall reduction in sector size. For example, Webb et al., (2014) found that achieving a 20% reduction in United Kingdom livestock sector GHG emissions was not possible without reducing output (or exporting emissions overseas). Similarly, reduced stocking rates were required to reduce emissions from the New Zealand dairy sector (Adler *et al.*, 2013; Doole, 2014). For tropical livestock systems a reduced stocking rate is recommended as it will also deliver additional benefits (such as; improved output, and lowering other environment impacts) (Oosting *et al.*, 2014). Yet, to implement policy tasked with reducing sector size will require significant political will. Thus, there is a gap in knowledge regarding the extent to which mitigation research has been implemented as policy.

The study explores this gap in knowledge by undertaking a systematic a review of national-level dairy policy of 23 countries. The aim of the study was to identify trends in dairy sector emission reduction policy. By examining trends across nations it becomes possible to identify which inventions are favoured by policymakers and the extent to which dairy sector emission reduction is likely at a global scale.

2. Methods

A systematic review of national-level dairy policy of 23 countries was undertaken broadly following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocols (Liberati *et al.*, 2009; Moher *et al.*, 2009). PRISMA protocols (Liberati *et al.*, 2009; Moher *et al.*, 2009) represent a more robust adjunct to documentary analysis techniques. However, as the investigation did not examine “studies” as the PRISMA statement (a 27 item checklist) (Moher *et al.*, 2009) was designed to investigate, not all components of the statement were relevant. Similarly, as the study did not examine clinical studies, meta-analysis techniques and the Cochrane approach were of limited use (Heffernan *et al.*, 2012).

2.1. Country selection

The 12 countries with the highest levels of dairy sector enteric methane emission and the 12 Annex I countries with the largest number of dairy cattle per capita were selected for inclusion. The sampling of 12 countries under each approach ensured the sample was representative of global dairy policymaking. The 12 highest emitting countries account for 55% of all enteric methane emissions from dairy cattle. The 12 Annex I countries represent 29% of all Annex I countries. However, five Annex I countries were included amongst the sample of highest enteric methane emitting countries. Therefore, a total of 17 Annex I countries (38% of all Annex I countries) were included in the study. The complete sample of 23 countries contribute 59% of the total global dairy sectors enteric methane emissions.

Enteric methane emission was used to indicate dairy sector emissions as the majority of dairy sector emissions are a result of enteric fermentation (FAO, 2006, 2010; Gerber *et al.*, 2011; Gerber *et al.*, 2013). A large number of dairy cattle per capita was assumed to indicate that the dairy sector contributes a disproportionally large amount to the country's total GHG emissions (Garnaut, 2008). Annex I countries were targeted as it was expected that these countries would be more aggressive in their attempts to reduce dairy sector GHG emissions. Under the United Nations Framework Convention on Climate Change (UNFCCC), Annex I countries have committed to reducing their GHG emissions to 1990 levels by the year 2000 (UNFCCC, 2014a).

The FAOSTAT database was used to identify those countries with large dairy sector enteric methane emissions (FAO, 2013a). Data from the year 2013 was used as this was the most recent data available. The countries with the highest emitting dairy sectors (via enteric fermentation) are shown in Table 1. Annex I countries were identified from the UNFCCC website (see UNFCCC, 2014b). The human and dairy cattle population size of each Annex I country was obtained from FAOSTAT (FAO, 2013b). The number of dairy cattle was divided by the human population in each Annex I country to determine the number of dairy cattle per capita (Table 1). The final sample was composed of a total of 23 countries as New Zealand appeared under both sampling strategies.

Table 1: The 12 countries with the highest enteric methane emitting dairy sectors and the 12 Annex I countries with the largest number of dairy cattle per capita in 2013 according to FAOSTAT (FAO, 2013a, b).

Countries with the highest enteric methane emitting dairy sectors	Quantity of enteric methane emitted by dairy cows (Tg of CH_4)[a]	Annex I countries with the largest number of dairy cattle per capita	The number of dairy cows per capita
India	2.60	New Zealand	1.07
Brazil	1.65	Ireland	0.25
USA[b]	1.18	Belarus	0.16
Sudan	0.83	Lithuania	0.11
China	0.83	Denmark	0.10
Russia[b]	0.77	Netherlands	0.10
Pakistan	0.66	Latvia	0.08
Ethiopia	0.50	Luxembourg	0.08
Germany[b]	0.50	Estonia	0.07
France[b]	0.43	Iceland	0.07
New Zealand[b]	0.43	Switzerland	0.07
Colombia	0.38	Australia	0.07

[a] Tg of CH_4 = Teragram of methane.
[b] Countries with the highest enteric methane emitting dairy sectors which are also Annex I Parties to the United Nations Framework Convention on Climate Change.

2.2. Policy collation

Government department websites relevant to the dairy sector for each country were examined. Only national level departments were searched. Websites were required to be in English to ensure a uniform approach to the collection of data. Available translation tools (specifically Google Translate™) did not have sufficient functionality to support a uniform approach. Although the requirement for English language websites may be a potential source of bias, a sampling strategy without uniformity also risks the creation of bias.

The focus on English language websites may also be a source of bias in countries where English is a second language (e.g. Brazil, Ethiopia, Pakistan, and Colombia). Such countries are unlikely to translate extensive policy documents into English. English language documents identified for these countries are likely a summarized version. This issue was managed via the inclusion of National Communications to the UNFCCC and the requirement for only an excerpt during data extraction (discussed below).

The departments searched within each country are shown in Table 2. As climate change and dairy production can be a cross-cutting issue, the websites of the various environmental departments were also included. The search was conducted over a period of one week (1 - 7 December 2014). Sudan and Russia were removed from the analysis as no English language departmental website could be identified.

Departmental websites had a search function of some form located on the homepage. However, there was no way to restrict searches to policy documents. Documents were located manually (electronically) via the policy (or legislative) archive. Within the archive, policy documents were primarily listed via hyperlink to a PDF file.

Document relevance was determined from the title of the document. The use of generalist terms was expected to generate a representative sample (Scott, 1990; Whittaker, 2009; Duffy, 2010). Titles were examined for an explicit mention of "climate change", "global warming", "mitigation", "adaptation", "dairy", and/or "livestock". The relevant documents were saved (as a PDF) and retained within the sample for content screening. For example, the documents of Pakistan were retrieved from the Ministry of Climate Change. On the Ministry's homepage, the link "policies" was followed. A total of ten documents were listed. Two document titles included the required keywords. These two documents were saved for content screening.

The most recent National Communication to the UNFCCC was also procured from the UNFCCC website (UNFCCC, 2014c, d) for each sampled country. This document was considered indicative of the countries stance on achieving GHG emission reduction from the dairy sector.

2.3. Content screening

Each document was reviewed as part of the content screening process. Within each document the text word search function (CTRL+F) was used. The same keywords used to initially identify documents (i.e. "climate change", "global warming", "mitigation", "adaptation", "dairy", and/or "livestock") were again used to determine relevance within the text of each document. However, the explicit mention of a key search term was insufficient to retain the document within the sample. Rather, the paragraph containing the search term was reviewed for a specific description of a dairy sector mitigation strategy or methodology.

2.4. Data extraction

Data were extracted from the final sample of documents in the form of a precise excerpt containing the mitigation strategy. The excerpt was copied from the document and placed into a Microsoft Word document. It was necessary to record precise excerpts to ensure all collated excerpts are reflective of the point in time in which the search was conducted.

Table 2: The government departments included in the search of dairy sector mitigation policy. The number of documents retrieved and excerpts collated from the documents is also provided.

Country	Website search locations	Policy documents collated	Excerpts collation
India	Government of India	3	6
	Department of Animal Husbandry Dairying & Fisheries		
	Department of Agriculture and Co-operation		
	Planning commission		
	National Dairy Development Board		
	Ministry of Environment and Forests		
	Second National communication to the UNFCCC		
Brazil	Government of Brazil	2	1
	Ministry of Agriculture, Livestock and Supply		
	Ministry of the environment		
	Second National communication to the UNFCCC		
USA	United States Environmental Protection Agency	3	3
	United States Department of Agriculture		
	The White House		
	Sixth National Communication to the UNFCCC		
China	The State Council for the People's Republic of China	1	7
	Ministry of Agriculture of the People's Republic of China		
	Second National communication to the UNFCCC		
Pakistan	Ministry of Climate change	2	5
	Ministry of national food security and research		
	Pakistan Agricultural Research Council		
	First National communication to the UNFCCC		
Ethiopia	Federal Democratic Republic of Ethiopia Ministry of Foreign Affairs	1	6
	Federal Democratic Republic of Ethiopia Ministry of Agriculture and Rural Development		
	First National communication to the UNFCCC		
Germany	Federal Ministry of Food and Agriculture	2	2
	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)		
	Sixth National Communication to the UNFCCC		
France	Ministry of Agriculture, Agrifood, and Forestry	1	1
	Ministry of Ecology, Sustainable Development and Energy		
	Sixth National Communication to the UNFCCC – abstract only		

New Zealand	Ministry for the Environment Ministry for Primary Industries Sixth National Communication to the UNFCCC	1	0
Colombia	Ministry of Agriculture and Rural Development Ministry of Environment and Sustainable Development Second National Communication to the UNFCCC – Executive summary	1	2
Ireland	Department of Agriculture, Food and the Marine Department of the Environment, Community and Local Government Sixth National Communication to the UNFCCC	3	3
Belarus	Ministry of Agriculture and Food of the Republic of Belarus Ministry of Natural Resources and Environmental Protection Department of Veterinary and Food Control President of the Republic of Belarus Fifth National Communication to the UNFCCC	1	1
Lithuania	Ministry of Agriculture of the Republic of Lithuania Ministry of Environment of the Republic of Lithuania State Food and Veterinary Service Sixth National Communication to the UNFCCC	2	4
Denmark	Ministry of Environment and Food The Danish AgriFish Agency Danish Agriculture and Food Council Ministry of Foreign Affairs Denmark The Danish Ministry of Climate and Energy Sixth National Communication to the UNFCCC	2	5
Netherlands	Ministry of Economic Affairs Ministry of Infrastructure and Environment Sixth National Communication to the UNFCCC	2	2
Latvia	Ministry of Agriculture Ministry of Environmental Protection and Regional Development Sixth National Communication to the UNFCCC	3	1
Luxembourg	Ministry of Agriculture, Viticulture and Consumer protection Ministry of Sustainable Development and Infrastructure Sixth National Communication to the UNFCCC	1	4
Estonia	Ministry of Agriculture Ministry of Environment Sixth National Communication to the UNFCCC	2	3
Iceland	Ministry of Fisheries and Agriculture Ministry for the Environment and Natural Resources Sixth National Communication to the UNFCCC	2	0

Switzerland	Federal Office of Agriculture The Federal Department of the Environment, Transport, Energy and Communications (DETEC) Sixth National Communication to the UNFCCC	1	2
Australia	Department of Agriculture and Water resources Department of the Environment Sixth National Communication to the UNFCCC	2	6

2.5. Categorized via theme

Following data extraction, the mitigation strategies were clustered together for further analysis. Grouping was determined by the emission reduction target (i.e. the component of the production system that the intervention targets to achieve a reduction in GHG emissions). The themes included nutrition, breeding, health, management, and manure. For example, Danish policy indicates that, "emissions could possibly be reduced by changing the feed given to cattle…." (pp. 45) (The Danish Government, 2013). This intervention was placed within the nutrition theme as it attempts to utilise nutritional pathways to reduce GHG emissions.

Any replicated (within country) policies were removed from the analysis at this stage. Additionally, if a legislative or policy statement contained a number of different interventions, each intervention was considered separately. For example, the Australian legislation, Regulation 3.28 identifies feed-based interventions that include five different feed additives (Commonwealth of Australia, 2014). Each additive was considered as a standalone intervention and placed into a theme accordingly. Ideally, the relationship between enteric and manure methane, and N_2O would be a consideration of reduction interventions (Knapp *et al.*, 2014). However, little evidence of this relationship was identified within the policy set. Similarly, there was no evidence of any potential additive effects of interventions. Thus, it was appropriate to consider interventions individually.

2.6. Categorized via topic

Due to the diversity of the interventions within each theme it was necessary to further categorize themes via topic. Interventions were sorted by their mode of action (i.e. how the intervention attempted to achieve a reduction in GHG). Those interventions which were seen to have a similar mode of action were grouped together. For example, Indian policy states, "conversion of high fibre fodder into silage and chaffing/chopping of such fodder would be encouraged" (pp. 21) (Government of India, 2013) whilst Dutch policy states, "…the better the digestibility, the lower the methane emissions." (pp. 72) (Ministry of Infrastructure and the Environment, 2013). Both statements suggest that improvements to the digestibility of feeds will be sought to reduce GHG emission. These two statements were grouped together under the topic of "improved digestibility". Figure 1 provides the schemata for the analysis.

INSERT FIGURE 1

Figure 1: The schemata outlining the various steps conducted to collate national dairy policy from 23 countries. Only 23 countries were included as New Zealand appeared under both country sampling strategies. Brackets indicate the number of variables at each stage of the analysis.

3. Results

A total of 62 policies were identified from the sampled countries (Table 3). India, China, Ethiopia and Australia had the most number of policies identified. A total of six policies were identified for each country. No mitigation policies could be identified for New Zealand and Iceland.

Thirty-one policies were identified for both the high emission nations and Annex I nations with the largest number of dairy cattle per capita. Nutrition based interventions account for 36% (n=11) of all policies identified for high emitting nations. Manure based interventions account for 48% (n=15) of all policies identified for Annex I nations with the largest number of dairy cattle per capita.

Table 4 indicates a difference in the number of policies identified from policy documents and the number of interventions reported in National Communications to the UNFCCC. Annex I countries with the largest number of dairy cattle per capita are under-reporting policy attempts to reduce dairy sector emissions whilst high emission countries are slightly over-reporting. However, there is variability between nations. For example, no policies to reduce dairy sector emissions could be identified from the National Communications of India and Australia. Yet, six policies were identified from national policy documents for both countries. Conversely, six policies were identified from the National Communications of China and Ethiopia. No policies were identified in national policy documents.

Table 5 compares the number of polices identified for sampled Annex I and non-Annex I countries. Annex I countries account for 65% (n=15) of the countries sampled and provide 58% (n=36) of the policies identified. The majority (n=18) of policies identified in Annex I countries are manure based interventions. Non-Annex I countries demonstrate a broader range of interventions compared Annex I countries. However, 42% (n=11) of the policies identified in non-Annex I countries are focused on nutrition based interventions.

Across the sampled nations, Table 6 indicates that a range of nutrition based interventions (total of 9 different interventions) are used by policymakers to mitigate dairy sector GHG emissions. Anaerobic digestion is the most common mitigation policy selected by policymakers. A total of 21% (n=13) of all sampled policies focus on anaerobic digester installation. Table 6 also indicates that anaerobic digestion is uniformly popular across nearly all nations. Breeding cows for higher genetic merit (n=7) and covering of liquid manure facilities (n=5) both garner significant policy support internationally.

Table 3: The distribution of dairy sector greenhouse gas mitigation policies offered by policymakers from 21 countries categorized via theme. Russia and Sudan are not presented as no English language websites could be located.

	Country	Number of policy interventions identified in each theme					Total number
		Nutrition	Breeding	Health	Management	Manure	
Countries with the highest enteric methane emitting dairy sectors	India	5				1	**6**
	Brazil					1	**1**
	USA[a]					2	**2**
	China	1	1	1	2	1	**6**
	Pakistan	2	2			1	**5**
	Ethiopia	2	1	1		2	**6**
	Germany[a]				2		**2**
	France[a]					1	**1**
	New Zealand[a]						**0**
	Colombia	1	1				**2**
	Sub-total	*11*	*5*	*2*	*4*	*9*	***31***
Annex I countries with the largest number of dairy cattle per capita	Ireland				1	2	**3**
	Belarus		1				**1**
	Lithuania				1	3	**4**
	Denmark	1	1			3	**5**
	Netherlands	1				1	**2**
	Latvia					1	**1**
	Luxembourg				2	2	**4**
	Estonia				1	2	**3**
	Iceland						**0**
	Switzerland		1		1		**2**
	Australia	4	1			1	**6**
	Sub-total	*6*	*4*	*0*	*6*	*15*	***31***
Total number		**17**	**9**	**2**	**10**	**24**	**62**

[a] Countries with the highest enteric methane emitting dairy sectors which are also Annex I Parties to the United Nations Framework Convention on Climate Change.

Table 4: A comparison of the number of policies tasked with reducing national dairy sector greenhouse gas emissions as stated by National Communications to the United Nations Framework Convention on Climate Change and other national level policy documents identified from 21 sampled countries**.** Russia and Sudan are not shown as no English language websites could be located.

	Country	Number of policies identified from policy documents	Number of policies identified from national communications	Total number of policies
Countries with the highest enteric methane emitting dairy sectors	India	6	0	**6**
	Brazil	1	0	**1**
	USA[a]	2	0	**2**
	China	0	6	**6**
	Pakistan	5	0	**5**
	Ethiopia	0	6	**6**
	Germany[a]	1	1	**2**
	France[a]	0	1	**1**
	New Zealand[a]	0	0	**0**
	Colombia	0	2	**2**
	Total	*15*	*16*	***31***
Annex I countries with the largest number of dairy cattle per capita	Ireland	2	1	**3**
	Belarus	0	1	**1**
	Lithuania	3	1	**4**
	Denmark	4	1	**5**
	Netherlands	0	2	**2**
	Latvia	1	0	**1**
	Luxembourg	0	4	**4**
	Estonia	3	0	**3**
	Iceland	0	0	**0**
	Switzerland	0	2	**2**
	Australia	6	0	**6**
	Total	*19*	*12*	***31***
Total number of policies		**34**	**28**	**62**

[a] Countries with the highest enteric methane emitting dairy sectors which are also Annex I Parties to the United Nations Framework Convention on Climate Change.

Table 5: A comparison of the number policies identified to reduce national dairy sector greenhouse gas emissions from sampled Annex I and non-Annex I countries. Russia and Sudan are not shown as no English language websites could be located.

	Country	Number of policy interventions identified in each theme					Total number
		Nutrition	Breeding	Health	Management	Manure	
Annex I countries	USA					2	**2**
	Germany				2		**2**
	France					1	**1**
	Belarus		1				**1**
	Lithuania				1	3	**4**
	Denmark	1	1			3	**5**
	Netherlands	1				1	**2**
	Latvia					1	**1**
	New Zealand						**0**
	Ireland				1	2	**3**
	Luxembourg				2	2	**4**
	Estonia				1	2	**3**
	Iceland						**0**
	Switzerland		1		1		**2**
	Australia	4	1			1	**6**
	Sub-total	*6*	*4*	*0*	*8*	*18*	36
Non-Annex I countries	India	5				1	**6**
	Brazil					1	**1**
	China	1	1	1	2	1	**6**
	Pakistan	2	2			1	**5**
	Ethiopia	2	1	1		2	**6**
	Colombia	1	1				**2**
	Sub-total	*11*	*5*	*2*	*2*	*6*	*26*
Total number		**17**	**9**	**2**	**10**	**24**	**62**

Table 6: The distribution of policies offered by policymakers from 19 countries as dairy sector GHG mitigation strategies. New Zealand and Iceland are not shown as no policies were identified. Russia and Sudan are not shown as no English language websites could be located.

Theme	Topic	Countries with the highest enteric methane emitting dairy sectors									*sub-total*	Annex I countries with the largest number of dairy cattle per capita										*sub-total*	**Total number**
		Ind	Bra	USA[a]	Chi	Pak	Eth	Ger[a]	Fra[a]	Col		Ire	Bel	Lit	Den	Net	Lat	Lux	Est	Swi	Aus		
Nutrition	Tannin feeding																				1	*1*	**1**
	Eremophila feeding																				1	*1*	**1**
	Fats/oils feeding																				1	*1*	**1**
	Nitrate supplements																				1	*1*	**1**
	Supplement feeding	1			1		1				*3*												**3**
	Improve digestibility	1					1			1	*3*					1						*1*	**4**
	Microbe manipulation	2				1					*3*				1							*1*	**4**
	Feed schedule	1									*1*												**1**
	Precision Feeding					1					*1*												**1**
Manure	Anaerobic digestion	1		1	1	1	1		1		*6*	1		1	1	1		1	1		1	*7*	**13**
	Covering liquid manure facilities			1							*1*			1	1		1		1			*4*	**5**
	Slurry Spreading											1		1				1				*3*	**3**
	Dry spreading		1				1				*2*												**2**
	Cooling slurry														1							*1*	**1**
Health	Veterinary Services				1		1				*2*												**2**
Breeding	High Genetic Merit				1	1	1			1	*4*		1							1	1	*3*	**7**
	Low emission cow					1					*1*				1							*1*	**2**
Management	Intensification				1						*1*	1										*1*	**2**
	Reduced stocking rate				1			1			*2*							1		1		*2*	**4**
	Organic production							1			*1*			1				1	1			*3*	**4**
Total number		**6**	**1**	**2**	**6**	**5**	**6**	**2**	**1**	**2**	***31***	**3**	**1**	**4**	**5**	**2**	**1**	**4**	**3**	**2**	**6**	***31***	**62**

[a] Countries with the highest enteric methane emitting dairy sectors which are also Annex I Parties to the United Nations Framework Convention on Climate Change.
Ind=India, Braz=Brazil, USA=United States of America, Chi=China, Pak=Pakistan, Eth=Ethiopia, Ger=Germany, Fra=France, Col=Colombia, Ire=Ireland, Bel=Belgium, Lit=Lithuania, Den=Denmark, Net=the Netherlands, Lat=Latvia, Lux=Luxembourg, Est=Estonia, Swi=Switzerland, Aus=Australia

4. Discussion

A diverse range of polices were collated from the sampled countries. Such diversity is not unexpected as dairy production takes many forms internationally. Interestingly, the number of policies identified under both sampling strategies was the same (Table 3). However, the preferred theme (Table 3) differed between the high emitting nations and the Annex I nations with the largest number of dairy cattle per capita. Differences in preference at the theme level, reflect the more intensive nature of dairy production in Annex I countries (Table 3). This is clearly illustrated by the comparison of Annex I and non-Annex I nations (Table 5). Annex I countries prefer manure based interventions whilst non-Annex I countries prefer nutrition based interventions.

Across the sampled nations, the clustering of interventions around particular themes reveals commonality. For example, manure management techniques are targeted for emission reduction across all nations sampled except Germany, Colombia, Belarus and Switzerland. Targeting manure management for mitigation is a particularly intriguing choice as it is well documented that the majority of dairy sector emissions are a result of enteric fermentation (FAO, 2006, 2010; Gerber *et al.*, 2011; Gerber *et al.*, 2013).

The importance of manure emissions as a contributor to dairy sector emissions differs depending on how the manure is managed. Yet, even if manure is managed in liquid form (common to intensive production systems such as; the United States) where the conditions are conducive to methane emission, the total quantity of GHG emitted from the manure is relatively small when compared to enteric emissions. For example, in the United States O'Brien *et al.* (2014) found that manure methane emissions in an intensive production system were a mere 33% of enteric methane emissions. The results suggest that policymakers view manure management as an easy target for reduction (compared with enteric sources). However, by not targeting enteric sources it is unlikely that a significant reduction in dairy sector emissions can ever be achieved.

Within manure management, policymakers are particularly focused on anaerobic digestion. Anaerobic digestion is likely favoured as it provides multiple benefits (York *et al.*, 2016). However, anaerobic digestion is far from applicable to all types of dairy production. For example, in pasture based systems (such as Australia, and Ireland) manure is excreted directly onto pasture. As a result, only a very small portion of total manure is available for digestion. Similarly, traditional manure management practices in India (making of dried dung cakes) are relatively climate change benign (IPCC, 2006; York *et al.*, 2017). Thus, although manure emissions may be viewed as mitigation "low-hanging fruit", the results illustrate a need for policymakers to be aware of the nuanced nature of the dairy sector in its various forms.

Nutrition based interventions are also favoured by policymakers, particularly microbe management. Such approaches target the enteric sources responsible for the majority of dairy sector emissions. However, the creation of a low-emission enteric environment is a particularly challenging task. For example, approaches that manipulate rumen microbes (via vaccination against methanogens, defaunation of protozoa, biological control of methanogens, and/or reductive acetogenesis) are far from being commercially available and applicable (Boadi *et al.*, 2004; Eckard *et al.*, 2010; Hristov *et al.*, 2013). Policies based around such technologies will have a significant lag-time between policy development/implementation and realised emission reduction.

Interestingly, attempts to reduce dairy sector size are largely ignored by policymakers. Such an omission illustrates the politicalized environment in which policies must exist. The research community is increasingly aware that a reduced sector size may be required for mitigation (see Adler *et al.*, 2013; Doole, 2014; Webb *et al.*, 2014). However, it appears there is little political will to support such a policy across the sampled nations. This is unsurprising in some nations such as India where cattle have a socio-cultural value with restrictions on slaughter. Yet, the broad trend to ignore strategies explicitly aimed at reducing sector size highlights the politically sensitive nature of dairy sector emission mitigation policy as policymakers are required to negotiate embedded societal values. Within India, policies which advocate the use of buffalo (which are generally not afforded the same socio-cultural value as cattle) are an example of the creativity that is required to address politicized policy issues.

It could be argued that policy tasked with ensuring intensification and breeding for improved genetic merit are euphemisms for a reduced sector size. Indeed, such terms are likely to receive support from lobby groups and other stakeholders. However, from an emissions perspective, unless productivity improvement is accompanied by a commensurate decrease in total population size it is unlikely sector emissions will be reduced.

The current investigation is not an exhaustive review of national dairy sector policy. Additionally, the study only considered English language documents obtained from internet based resources. This may have created bias as important dairying nations could not be included (e.g. Sudan and Russia). The sorting of policies into themes could also be critiqued for introducing bias due to the need for interpretation (Whittaker, 2009). However, the coupling of this interpretative process with the systematic approach taken toward the literature limits the likely introduction of bias from interpretation as the research can be replicated by others whom would likely arrive at the same conclusions (provided they follow the same protocol).

The study sampled only those nations with high levels of dairy sector enteric emissions and Annex I countries with the largest number of dairy cattle per capita. Although this attempted to target those countries which were heavily involved in dairying, important exceptions can be noted. This allowed the contrasting approaches of small and large dairying nations to be examined. For example, Luxembourg has a very small dairy sector. In 2013, Luxembourg had approximately 42 000 dairy cattle (FAO, 2013b). As such, policymakers are unlikely to experience pressure from lobby groups which distort the policy process as would be expected in countries with a large dairy sector (such as; United States). The absence of such political pressure appears to allow policymakers to be more progressive in their approach to mitigation as demonstrated by Luxembourg indicating the need for a reduced sector size. This is a stark contrast to New Zealand which is heavily involved in dairy, yet no mitigation policy could be identified. Thus, the role of political will in the development and implementation of mitigation policy within nations that have an economically important (and powerful) dairy sector should not be underestimated. This is concerning as such countries are responsible for a significant portion of the global dairy sector's GHG emissions. The results of this study clearly suggest that policymakers in these nations are unlikely to be proactive or progressive in their approach to reducing dairy sector emissions. As such, the international community may need to consider strategies to influence national dairy sector policy to drive change.

The inclusion of National Communications to the UNFCCC may have influenced the final sample of mitigation strategies. Indeed, there is discrepancy in the number of policies identified from policy documents and those reported in National Communications. The purpose of the UNFCCC reports is for each country to outline the steps taken towards emission reduction commitments. However, the results indicate some countries (e.g. India, Pakistan, and Australia) have not been reporting mitigation policies via the National

Communication. Conversely, some nations (e.g. China and Ethiopia) have been reporting the implementation of mitigation without the policies being identified from policy documents. Although the discrepancy may be due to limitations in the search methodology, it may also be an indicator of motivation to conform to international directives (i.e. being seen to be address GHG emissions). Alternatively, it may indicate that some countries are yet to integrate the reports into national policy processes and/or do not have the resources to report achievements via this method. Therefore, it may be necessary for the UNFCCC to reconsider current reporting practices to improve the utility of National Communications as a means of tracking mitigation progress.

Although a number of reviews of the available mitigation strategies have been undertaken internationally (e.g. Hristov *et al.*, 2013; Knapp *et al.*, 2014) this investigation is the first attempt at a systematic stocktake of dairy sector GHG emission reduction policy. By taking stock of the current policy environment, it becomes possible to identify the extent to which the burgeoning body of dairy sector emission research has been adopted by policymakers.

5. Conclusion

The study demonstrates manure management (primarily anaerobic digestion) and nutrition based mitigation strategies are favoured by policymakers. Explicit attempts to reduce emissions via manipulation of sector size remain ignored. The final form of the policy landscape cannot be determined from the results of this investigation. Rather, the results highlight the political sensitivity of mitigation policy. Indeed, there is no panacea that will ensure dairy sector emission reduction. However, the trade-offs that policymakers will be required to consider under the guise of climate change compatible development are likely to be significant. It is only by considering the various trade-offs can the long-term sustainability of the sector be secured.

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