Dairy and climate change interface in the Asia-Pacific region

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Background and Objectives

- Growing importance of dairy in both developed and developing countries in the region
- A major concern - Environmental sustainability
  - production and productivity improvement in the face of
    - scarcity of land, feed and water,
    - emerging diseases and public health risks
  - interface with climate change
    - Dairy impact on global warming through green house gas emissions
    - Short and long term impact of global warming on dairy
- But debate on climate change – livestock/dairy interface is based on inadequate and controversial evidence

Dairy climate change interface – Objectives of the study

- To review evidence on
  - contribution of dairy sector to GHG emissions in the Asia-Pacific region and relate that to the global situation.
  - adaptation and mitigation practices devised, tested and applied in the region
  - implications of dairy impact on climate change for nutrition, livelihoods/poverty reduction in the region

Presentation outline

- A view from above
  - Trend of global level emissions
  - Changes in sources by gases and sectors including dairy
  - Regional pattern
- A view from below
  - Estimates of livestock sector emissions including dairy
  - Estimates of dairy sector emissions
  - Experimental studies on dairy emissions
- Knowledge gaps and implications

Livestock impact on environment – Criticisms during late 1980s to early 2000s

- Criticisms from environmentalists and vegetarians
  - Water and environmental pollution through wastes
  - Desertification through overgrazing of rangeland
  - Global warming through deforestation for commercial livestock production and GHG emissions
- Responses from livestock stakeholders
  - Water and pollution a problem of industrial systems
  - Effects of drought and grazing on rangeland confused
  - Deforestation due to complex of poverty, population growth and policy supporting commercial livestock
  - Poor evidence on global GHG emission and from livestock

A view from above:
Trend in Global anthropogenic GHG emissions

Year	IPCC 2007 AR4	IPCC 2014 AR5*	% change AR4 to AR5
	$GtCO_2eq/yr$	$GtCO_2eq/yr$	
1970	28.7	27	-6
1990	39.4	38	-4
2000	44	40	-9.1
2004	49		
2005		45	
2010		49	

* Estimates are sensitive to assumption of GWP of different gases. This was based on GWP100 for Methane as 23 from AR2. Use of 25 or 34 found in AR4 and AR5 respectively would result in higher total emissions.

Changes in composition of global anthropogenic GHG, selected years

Gas	1970	1990	2010
Total emission, $GtCO_2eq/year$	**27**	**38**	**49**
% change	**100**	**141**	**182**
% share by type of gas			
Carbon dioxide from fossil fuel, industrial processes, transportation and buildings	55	59	65
Carbon dioxide from forestry and other land uses	17	16	11
Methane (Agricultural activities including livestock, waste management, energy use, and biomass burning	19	18	16
Nitrous oxide (Agricultural activities including manure management, fertilizer use, biomass burning)	7.9	7.4	6.2
Fluorinated gases (F-gases)	0.44	0.81	2
Total	100	100	100

Source: IPCC (2014)

Changes in sectoral sources of global anthropogenic GHG, selected years

	1970	1990	2010
Total emission, $GtCO_2eq$/year	**27**	**38**	**49**
% share by sector			
Electricity and heat production (burning of coal, natural gas, and oil for electricity and heat)		**26**	**25**
Industry (fossil fuels burned on site for energy)		**19**	**21**
Transportation		**13**	**14**
Buildings		**8**	**6**
Other energy		**3**	**10**
Agriculture, forestry, and other land use (crop, livestock, deforestation, biomass burning)	**37**	**31**	**24**

Source: IPCC (2014)

Changing regional shares of emissions from AFOLU sectors

	1970	1990	2010
Total global emissions, $GtCO_2eq/yr$	**27**	**38**	**49**
Total emissions from AFOLU, $GtCO_2eq/yr$	**10**	**13**	**12**
AFOLU share in global total (%)	**37**	**34.2**	**24.5**
Regional share in total AFOLU emissions (%)			
Asia	**26**	**31.5**	**39.2**
Middle East and Africa	**31**	**23.1**	**27.5**
Latin America	**18**	**16.9**	**15.8**
Economies in Transition	**12**	**11.5**	**5.2**
OECD-1990	**12**	**12.3**	**11.7**

Source: IPCC (2014)

Estimation of emissions from AFOLU sectors : IPCC methodological notes

- Estimation for AFOLU more difficult than for other sectors
  - Difficult to separate natural vs anthropogenic fluxes from land
  - Input data from country level or other sources may not be accurate
  - Range of methods to estimate GHG emissions, e.g. default IPCC guideline, terrestrial carbon cycle modelling, remote sensing
- Only agricultural non-CO_2 sources are reported as CO_2 emitted is considered neutral due to balancing by sequestration and oxidation through photosynthesis
- Non-CO_2 from forestry and land use change is minimal
- Livestock induced CO_2 mainly through feed production and processing, considered zero as covered under other sectors

Sources of emissions from agriculture

- IPCC guidelines reporting categories
  - rice cultivation,
  - enteric fermentation,
  - biomass burning,
  - 'agricultural soils'(synthetic fertilizer application, crop residues, manure management systems, manure deposited on pasture and manure applied to soils)
- But categories used by independent studies (FAO, EDGAR, USEPA) are :
  - rice cultivation
  - enteric fermentation,
  - manure management systems,
  - 'agricultural soils'.

Non-CO_2 GHG emissions from agriculture by sources in selected studies

	USEPA 2006	US EPA 2011	EDGAR 2013	FAOSTAT 2013
Total emissions , $GtCO_2eq/yr$	5.2 (4.8-7.0)	4.9 (4.5-6.5)	4.8 (4.2-6)	4.2 (3.9-5.5)
'Agricultural soils'	2.2 (1.8-4.0)	2 (1.5-3.5)	1.5 (1.3-2.9)	1.4 (1.2-2.8)
Enteric fermentation	1.9	1.8	2	1.9
Rice cultivation	0.6	0.7	0.8	0.5
Manure management systems	0.4	0.3	0.2	0.2

- Estimates are statistically consistent given the large uncertainties in IPCC default methodologies
- But questionable as large spread of 95% confidence intervals .
- IPCC : Livestock emissions in 2010 was 3.45 $GtCO_2eq$:
  enteric 2.1, manure management 0.99, manure on soil 0.36

A view from above - summary

- Contribution of livestock to global GHG emission got somewhat lost in the IPCC big picture
- Aggregation of manure related emissions with other categories did not permit a full account of livestock related emissions
- Specific contribution of dairy never mentioned

Yet livestock is often dubbed a villain in the global warming debate

A view from below: Livestock contribution to global GHG emissions per year, 2001-04

Gas and source	Global emission $GtCO_2eq/yr$	Sector emission $GtCO_2eq/yr$	Sector share %	Global share %
CO_2 (feed, land use change)	**24 (~31)**	**~0.16 (~2.7)**	**38.9**	**9.0**
CH_4 **(**enteric and manure management)	**5.9**	**2.2**	**30.2**	**37.3**
N_2O (manure and fertilizer)	**3.4**	**2.2**	**30.9**	**64.7**
Total	**33 (~40)**	**~4.6 (~7.1)**	**100**	**14~18**
Extensive systems		**3.2 (~5.0)**	**70**	**10 (~13)**
Intensive systems		**1.4(~2.1)**	**30**	**4(~5)**

Source : FAO (2006) Livestock's long shadow

Livestock contribution to global GHG emissions , 2005

Gas and source	Global emission $GtCO_2eq$ 2004	Sector emission $GtCO_2eq$ 2005	Sector share %	Global share of 2004 %
CO_2 (feed, land use change)	37.6	2.0	28.2	5.3
CH_4 (enteric and manure management)	7.0	3.1	43.6	44.3
N_2O (manure and fertilizer)	3.9	2.0	28.2	51.3
Total	49*	7.1	100	14.5

* IPCC AR5 total emission in 2005 45Gt, 49 Gt in 2010, so sector share in 2005 is 15.8%

Source : Gerber et al (2013) Tackling climate change through livestock, FAO

% Share of milk in total emissions by species and production systems, 2005

Species	Grazing	Mixed	All
Dairy cattle	69	74	73
Buffalo	64	67	67
Sheep	31	24	27
Goats	40	34	36
All dairy animals	58	67	66
All ruminants including specialized beef	21	41	36

Source: Gerber et (2013)

Emission intensities for milk and meat production by species and production systems , 2005

KgCO$_2$ eq/kg product

	Milk			Meat		
	Grazing	Mixed	All	Grazing	Mixed	All
Specialized beef				102	56	68
Dairy cattle	2.9	2.6	2.6	21.9	17.4	18.2
Buffalo	3.4	3.2	3.4	36.8	54.8	53.4
Sheep	9.8	7.5	8.4	23.8	23.2	23.4
Goats	6.1	4.9	5.2	24.2	23.1	23.3

Where emission intensity is high, share of methane in total emission is high

Source: Gerber et al (2013)

Emission intensity (KgCO_2 eq/unit of milk) by species and region, 2005

Region	Cattle	Buffalo	Small ruminants
South Asia	5.2	3.2	4.8
East and South East Asia	2.4	4.9	8.9
SSA	9.0		6.9
NENA	4.3	3.6	8.8
LAC	3.9		
Developed regions	<2		<5
World	2.6	3.3	6.5

Where emission intensity is high, share of methane in total emission is high

Source: Gerber et al (2013), FAO

Global dairy cattle milk and meat production and related GHG emissions, 2007

Product	Production Mil tonnes	GHG emission $GtCO_2eq$ *	Share in sector total, %*	Share in global total, %*	Emission intensity, kgCO2eq/kg milk*
Milk, FPCM	553	1.328	67	2.7	2.4
Meat from culled cows and bulls	10	0.151	8	0.3	15.6
Meat from fattened calves	24	0.490	25	1.0	20.2
Total		1.969	100	4	

* Estimates are subject to ±26% variation

Source: FAO (2010).

Dairy herd emission characteristics, 2007

- farm gate 93% , post farm 7%
- Higher farm gate ratios in developing countries
- Emission intensity : grazing system, 2.72, mixed system 1.78
- Intensities higher in tropical and arid zones
- Intensity by region – SSA 7.5, South Asia 4.6, NENA 3.7, developed 1.3
- Developed countries - share of CO_2 is higher,

  Developing countries - share of N_2O is higher.

  Methane more important in grazing system than mixed systems

Source: FAO (2010)

Livestock sector emissions from a synthesis of several studies, 1995-2005

Sources	Emission GtCO2eq/year
Feed N_2O	1.3–2.0
Feed CO_2 (LUC excluded)	0.92
Feed CO_2 (LUC)	0.23
Pasture expansion CO_2 LUC	0.43
Feed CH_4 rice	0.03
Enteric fermentation CH_4*	1.6–2.7
Manure CH_4*	0.2–0.4
Manure N_2O*	0.2–0.5
Direct energy CO_2	0.11
Embedded energy CO_2	0.02
Post-farm gate CO_2	0.023
Non-CO_2 emissions* (IPCC guidelines)	2.0–3.6
Total emissions (LCA approach)	5.6–7.5

Source: Herrero et al, 2016)

Emission intensity for milk production based on selected experimental studies

Source	Location	CO_2eq/ kg FPCM	CO_2eq/ kg meat
Foster et al., 2007	UK	1.14	
Verge et al., 2007	Canada	1.0	
Sevenster and DeJong, 2007	Annex 1 countries	0.75-1.65	
Blonk et al., 2008	Netherlands	1.2	8.9
Thomassen et al., 2008	Nether lands	1.5-1.6	
Basset-Mens et al., 2009	New Zealand	0.65- 0.75	
Cappaer et al., 2009	USA	1.35	
Cederberg et al., 2009	Sweden	1.0	19.8
Lesschen et al.,2011	EU-27	1.3	
Christie et al., 2011	Australia	1.4	
Browne et al. 2011	Australia	8.5 - 9.4??	
Hagemann et al. 2011	38 countries	0.8-3.1	

A view from below - Summary

- Few livestock sector estimates of emissions, fewer still for dairy, rare from developing countries .
- IPPC guidelines for livestock recommend only non-CO2 gases, but most sectoral studies used LCA to cover entire supply chain
- Some general findings
  - Developing countries share about 70% of ruminant emissions, mixed systems nearly 60%, dairy 45% of cattle emissions
  - CH4, N2O and CO2 share 40, 30 and 30% of sector emissions
  - Emission intensity higher in developing countries, in grazing systems and in arid and topical ecozones
  - CH_4 and N_2O more important where emission intensity is high
- Some national estimates show lower than IPCC estimate, e.g. Australia claims methane emission 30% less than IPCC estimate

A view from below – Summary 2

- **But varying degrees of uncertainty in estimates due to methodology and lack of appropriate data and emission factors**
  - overall livestock emission estimate 8-51% variation
  - methane from enteric fermentation CV= 18%,
  - methane from manure management CV =27 %
  - N_2O from manure management CV= 46%
  - **CO_2 share in developing countries is highly variable and controversial;**
  - Some national level estimates, mostly from developed countries, show even larger degrees of uncertainty

A view from below: Summary 3

- Application of LCA problematic for developing countries and dominant mixed systems due to
  - **diverse species and breeds of animals,**
  - **scales of production and processing, product types**
  - **production and feeding systems,**
  - **digestibility and productivity,**
  - **manure disposal and management systems, and**
  - **health and nutritional status of animals around the world**
- CH_4 and N_2O are real problems irrespective of share and variability, need main attention for mitigation
- Debatable if separate estimation of CO_2 from livestock or dairy useful or worthwhile
- Precision vs accuracy in estimation – is accuracy adequate? Is precision necessary and possible ?

Mitigation options for dairy

- **Experimental studies in developed countries mainly focus on CH_4 and N_2O**
- **Productivity and emission intensity inversely related , aim both productivity improvement and emission reduction**
- **Major options/strategies considered /evaluated**
  - **Feeds, nutrition and herd management interventions**
  - **microbial genomics and ecology/rumen microbiology**
  - **measurement techniques**
  - **Manure management , value of manure after reduced gas emission**
  - **mathematical /systems modelling to identify new strategy and technology**

Feeds, nutrition and herd management interventions

- **At animal level, most important is feed conversion efficiency**
  - **optimize rumen fermentation and improve productivity.**
  - **fat and other feed additives, feed digestibility, ration balance (nitrogen, carbohydrates), forage quality and feed efficiency**
- **At farm and herd level**
  - **Genetic selection and other aspects of herd management and feed resources management for efficiency**

Experiments dhow, with above options, 5-20% methane reduction possible

e.g. US cow for the future project (2005) planned to reduce CH_4 emission by 25% by 2020 : 10-12% with above options, remaining 13-15% with additional research

System modelling to assess outcomes of mitigation options for livestock sector

Mitigation options	Technical potential $GtCO_2eq/yr$
Improved feed digestibility	0.7
Feed additives	0.2-0.3
Manure management	<0.1
Genetics and herd management	0.1 – 0.25
CO_2 sequestration in grazing management	0.15-0.7
CO_2 sequestration in legume sowing	0.15
Rangeland rehabilitation	0.1-0.2
Reduced deforestation	0.25
Moderation of meat consumption	Large with high uncertainty

- **economic potential <10% of technical potential because of adoption constraints, costs and numerous trade-offs.**
- **Cost and emission reduction – complementary or competitive?**

Source: Herrero et al., 2016

Mitigation options for dairy in developing countries

- Studies rare. An example : Indian ration balancing study
  - **163 540 lactating cows and 163 550 buffaloes monitored over three years on existing vs balanced ration**
  - **Milk productivity improved by 52-90%**
  - **Emission intensity decreased by 31% for cattle, 35% for buffalo**

Cow 1.7 vs 1.2 Buffalo 2.4 vs 1.5 ??

But these are much lower than rates found by FAO for South Asia and world :

South Asia	**5.2/4.6**	**3.2**
World	**2.6/2.4**	**3.3**

- Explanation: Methodology, systems complexity and allocation techniques?
- Diversity of production systems and components may imply options and methods need to be diverse, more location specific.
- Genetic improvement a major focus in many countries. Emission intensity may be used as one of the criteria in genetic selection

Source: Garg et al., 2016 for the Indian study results

Impact of climate change on livestock production systems

- Increased frequency and magnitude of extreme weather events – **droughts, floods**
- Change in **water** availability
- Change in production and productivity and quality of crops and pastures
- Loss of animal productivity due to feed shortage and quality, water stress and other physiological reasons
- Increased incidence of emerging diseases
- Increased resource prices – water, feed, energy
- Several factors are at play so to precisely predict future climate scenarios may be difficult

Adaptation options – Principles

- Absence of precise future prediction of climate scenarios
- Best choice may to enhance macro level decision making capacity to take sound risk-based and informed decisions and increase the array of options available for adaptation to
  - increased heat and water stress,
  - vegetation change,
  - increased risk of soil degradation
  - changes in forage quantity, quality
  - altered pests and disease risk,

Long term monitoring, studies and modelling will be required

This is work in progress

Thanks for your attention