SINGLE-IMPACT FICHE
MANURE LAND APPLICATION TECHNIQUES

IMPACT: GHG EMISSIONS

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Note to the reader: This fiche summarises the effects of Manure land application techniques on GHG EMISSIONS. It is based on 6 synthesis papers[1], including from 21 to 142 primary studies.

1. WEIGHT OF THE EVIDENCE

CONSISTENCY OF THE IMPACT

Manure land application techniques have variable effects on greenhouse gas emissions, depending on the technique considered (**Table 1**).

The table below shows the number of synthesis papers with statistical tests reporting i) a significant difference between the Intervention and the Comparator, that is to say, a significant statistical effect, which can be positive or negative; or ii) a non-statistically significant difference between the Intervention and the Comparator. In addition, we include, if any, the number of synthesis papers reporting relevant results but without statistical test of the effects. Details on the quality assessment of the synthesis papers can be found in the methodology section of this WIKI.

- Land application with deep placement or immediate incorporation, compared to surface spreading/broadcasting: for CH_4 emission, results showed different effects, with 1 out of 2 synthesis papers reporting positive effect and 1 non-significant effect for deep placement or incorporation; for N_2O emission, results showed different effects, with 3 out of 7 synthesis paper reporting non-significant effect, 2 negative effect, 1 positive effect and 1 results without statistical test of the effects.
- Land application with banding, compared to surface spreading/broadcasting: for CH_4 emission, 1 synthesis paper reported negative effects; N_2O emission, 1 synthesis paper reported non-significant effect.
- No manure on paddy rice fields, compared to manure application on paddy rice fields: for both CH_4 and N_2O emission, only 1 synthesis paper was available and this paper reported positive effect.
- Land application with additives, compared to no substance addition: for N_2O emission, results showed different effects, as 1 out of 2 synthesis papers reported positive effect and 1 non-significant effect. Variability in the effects mainly depend on the type of either chemical or physical additive (e.g. biochar, Ca-superphosphate, nitrification inhibitors, lava meal) (see Table 2).

Out of the 6 selected synthesis papers, 5 included studies conducted in Europe (see **Table 2**).

Table 1: Summary of effects. Number of synthesis papers reporting positive, negative or non-statistically significant effects on environmental and climate impacts. The number of synthesis papers reporting relevant results but without statistical test of the effects are also provided. When not all the synthesis papers reporting an effect are of high quality, the number of synthesis papers with a quality score of at least 50% is indicated in parentheses. The reference numbers of the synthesis papers reporting each of the effects are provided in **Table 3**. Some synthesis papers may report effects for more than one impact or more than one effect for the same impact.

				Statistically tested			Non-statistically tested
Impact	Metric	Intervention	Comparator	Significantly positive	Significantly negative	Non-significant	
Decrease ghg emissions	CH_4	Land application with banding	Conventional management	0	1	0	0
		Land application with deep placement or immediate incorporation	Conventional management	1	0	1	0
		No manure on paddy rice fields	Conventional management	1	0	0	0
Decrease ghg emissions	N_2O	Land application with additives	Conventional management	1	0	1	0
		Land application with banding	Conventional management	0	0	1	0
		Land application with deep placement or immediate incorporation	Conventional management	1	2	3	1 (0)
		No manure on paddy rice fields	Conventional management	1	0	0	0

QUALITY OF THE SYNTHESIS PAPERS

The quality of each synthesis paper was assessed based on 16 criteria regarding three main aspects: 1) the literature search strategy and primary studies selection; 2) the statistical analysis conducted; and 3) the evaluation of potential bias. We assessed whether authors

[1] Synthesis research papers include either meta-analysis or systematic reviews with quantitative results. Details can be found in the methodology section of the WIKI.

addressed and reported these criteria. Then, a quality score was calculated as the percentage of these 16 criteria properly addressed and reported in each synthesis paper. Details on quality criteria can be found in the methodology section of this WIKI.

2. IMPACTS

The main characteristics and results of the 6 synthesis papers are reported in **Table 2** with the terminology used in those papers, while **Table 3** shows the reference numbers of the synthesis papers reporting for each of the results shown in **Table 1**. Comprehensive information about the results reported in each synthesis paper, in particular about the modulation of effects by factors related to soil, climate and management practices, are provided in the **summaries of the synthesis papers** available in this WIKI.

Table 2: Main characteristics of the synthesis papers reporting effects on ghg emissions. The references are ordered chronologically with the most recent publication date first.

Reference number	Population	Scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Ref1	European agricultural systems with slurry fertilisation	Europe	38	Injection, Incorporation, or Band application	No slurry treatment, no storage cover, or band spread application	1) CH_4 emissions; 2) N_2O emissions	Different field application techniques (injection, incorporation, band application) were effective to varying degrees for the abatement of ammonia emission, but also resulted in the increased emission of at least one other greenhouse gas.	50%
Ref5	Pig and cattle manure	Not reported	89	Manure shallow injection	No abatement options	N_2O emissions	Manure injection led to major increases in N_2O emissions. However, these results are considered as uncertain, as based on descriptive statistics, and not on a model taking into account between-studies variability.	44%
Ref6	Cattle manure	Global	104	Manure incorporation; Manure additives (biochar, nitrification inhibitor)	No mitigation strategy	N_2O emissions	This study shows that manure incorporation significantly reduced N_2O emissions, compared to land application, while adding additives to manure had no significant effect.	69%
Ref7	Arable crops	Global	21	Deep placement	Shallow placement	Area-scaled N_2O emissions	This meta-analysis was unable to detect a significant pattern in N_2O emissions resulting from fertiliser (both organic and inorganic) placement techniques.	69%
Ref8	Swine manure	Global	142	Slurry injection; Slurry incorporation; Solid incorporation; Digested slurry; Land application with nitrification inhibitor; Avoiding manure application to rice paddy fields	No mitigation strategy	1) CH_4 emissions; 2) N_2O emissions	This study shows that avoiding to spread swine manure in rice paddies and adding nitrification inhibitors in the manure before spreading in upland were effective in mitigating CH_4 and N_2O emissions, while slurry injection increased N_2O emissions. Land application of digestate, Slurry and solid incorporation showed non-statistically significant effects on N_2O emissions.	69%
Ref10	Liquid manure of dairy cows and swine stables	Global	126	Manure land application techniques (Band spreading, incorporation, injection), Anaerobic digested slurry	Conventional storage technique, surface spreading with broadcast, Raw slurry	N_2O emissions	Injection or direct incorporation of manure into soil significantly decreased ammonia emissions, but significantly increased N_2O emissions.	88%

Table 3: Reference numbers of the synthesis papers reporting for each of the results shown in **Table 1**.

				Statistically tested			Non-statistically tested
Impact	Metric	Intervention	Comparator	Significantly positive	Significantly negative	Non-significant	
Decrease ghg emissions	CH_4	Land application with banding	Conventional management		Ref1		
		Land application with deep placement or immediate incorporation	Conventional management	Ref1		Ref1	
		No manure on paddy rice fields	Conventional management	Ref8			
Decrease ghg emissions	N_2O	Land application with additives	Conventional management	Ref8		Ref6	
		Land application with banding	Conventional management			Ref1	
		Land application with deep placement or immediate incorporation	Conventional management	Ref6	Ref8 and Ref10	Ref1, Ref7 and Ref8	Ref5
		No manure on paddy rice fields	Conventional management	Ref8			

3. FACTORS INFLUENCING THE EFFECTS ON GHG EMISSIONS

No factors were found.

4. KNOWLEDGE GAPS

Table 5: Knowledge gap(s) reported by the authors of the synthesis papers included in this review.

Ref Num	Gap
Ref6	There are only 2 papers that studied the impact of compost additives on gas emissions from beef cattle manure, with one study specified for CH_4 and N_2O and the other for ammonia; No research is available for the effect of biofilter on compost CH_4 and N_2O emissions specifically for beef cattle manure;
Ref10	The results collected did not allow comparing management options across animal species (e.g. pigs vs. cattle). Data from both field-and laboratory-scale studies were included in our database as data solely from field-scale studies were insufficient.

5. SYNTHESIS PAPERS INCLUDED IN THE REVIEW

Table 6: List of synthesis papers included in this review. More details can be found in the summaries of the meta-analyses.

Ref Num	Author(s)	Year	Title	Journal	DOI
Ref1	Emmerling, C; Krein, A; Junk, J	2020	Meta-Analysis of Strategies to Reduce NH_3 Emissions from Slurries in European Agriculture and Consequences for Greenhouse Gas Emissions	Agronomy 10, 1633	10.3390/agronomy10111633
Ref5	Sajeev, EPM; Winiwarter, W; Amon, B	2018	Greenhouse Gas and Ammonia Emissions from Different Stages of Liquid Manure Management Chains: Abatement Options and Emission Interactions	Journal of environmental quality	10.2134/jeq2017.05.0199
Ref6	Wang, Y; Li, XR; Yang, JF; Tian, Z; Sun, QP; Xue, WT; Dong, HM	2018	Mitigating Greenhouse Gas and Ammonia Emissions from Beef Cattle Feedlot Production: A System Meta-Analysis	Environmental Science & Technology	10.1021/acs.est.8b02475
Ref7	Han, Z; Walter, MT; Drinkwater, LE	2017	N_2O emissions from grain cropping systems: a meta-analysis of the impacts of fertilizer-based and ecologically-based nutrient management strategies	NUTRIENT CYCLING IN AGROECOSYSTEMS, 107, 335-355.	10.1007/s10705-017-9836-z
Ref8	Wang, Y; Dong, HM; Zhu, ZP; Gerber, PJ; Xin, HW; Smith, P; Opio, C; Steinfeld, H; Chadwick, D	2017	Mitigating Greenhouse Gas and Ammonia Emissions from Swine Manure Management: A System Analysis	ENVIRONMENTAL SCIENCE & TECHNOLOGY	10.1021/acs.est.6b06430
Ref10	Hou, Y; Velthof, GL; Oenema, O	2015	Mitigation of ammonia, nitrous oxide and methane emissions from manure management chains: a meta-analysis and integrated assessment	Glob. Chang. Biol. 21, 1293–1312	10.1111/gcb.12767