ESTIMATING AMMONIA EMISSION FLOW BY THE IMPLEMENTATION OF REVERSE MODELLING

E. Angelino, G. Malvestiti, A. Marongiu, M. Moretti, P. Edoardo

ARPA Lombardia, U.O. Modellistica della Qualità dell'Aria e Inventari

Via I. Rosellini 17, 20124, Milano, Italy

Objective

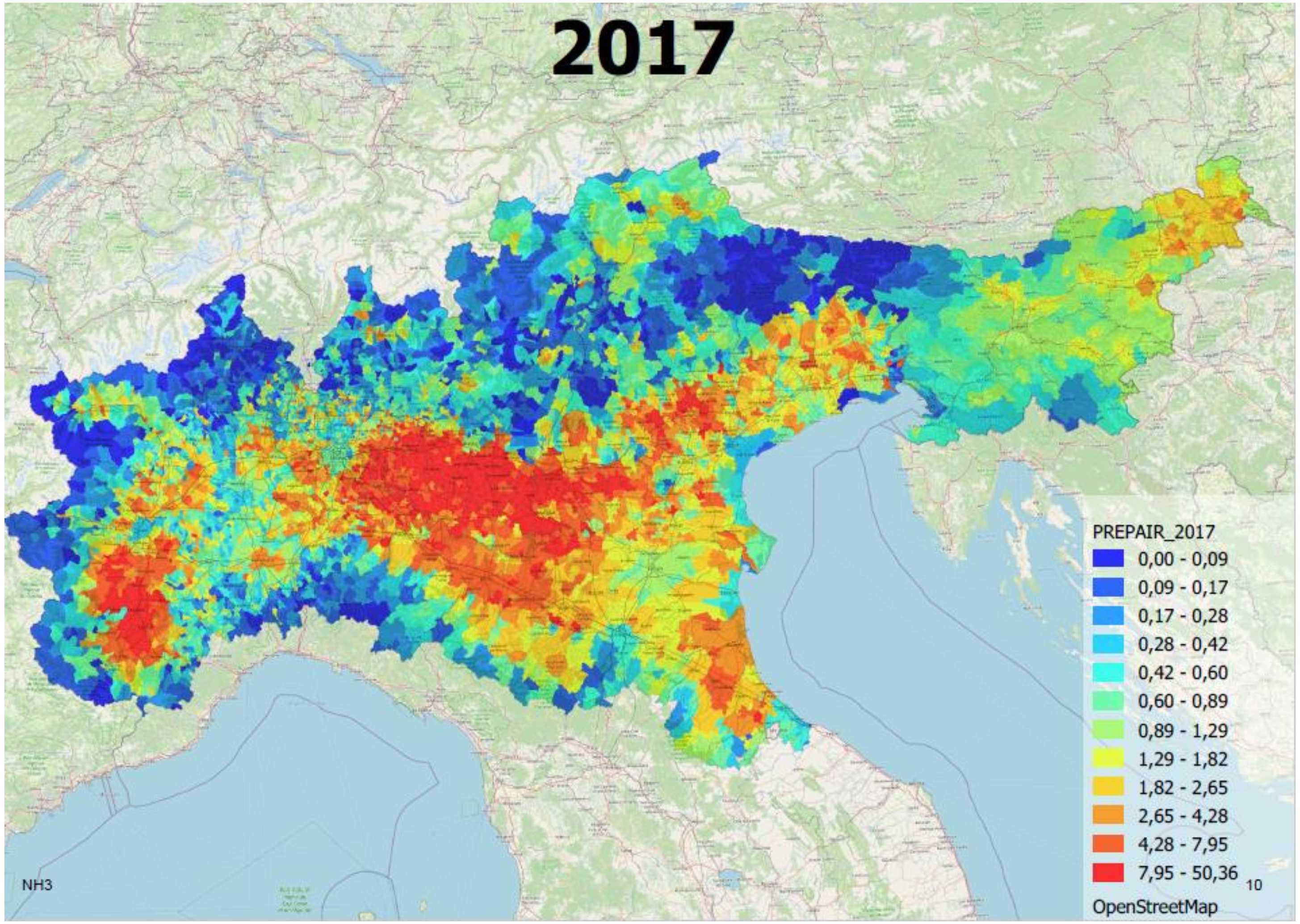
Illustrate the application of ***reverse modelling*** technique to estimate ammonia emission flows in atmosphere from agricultural activities, in particular manure management, starting from experimental data.

Agricultural sector has relevant effects on air quality and on ammonia emissions in atmosphere. The Regione Lombardia emission inventory, INEMAR, updated to 2017 estimates that the 97% of regional ammonia emissions are due to fertilization and manure management. In particular, manure management accounts for the 86% of total emissions in 2017. Moreover, NH_3, with NO_x, plays an important role in the formation of secondary fine particulate matter.

Main variables that influence ammonia emissions from agricultural sources refer to the amount of excreted nitrogen, housing, storage, spreading and treatment technologies, type and quantity of manure and meteorological conditions.

This work, part of a project required to ARPA Lombardia by Regione Lombardia, focuses on the effects of spreading techniques on ammonia emissions and concentrations in atmosphere.

Ammonia emissions in Po Valley



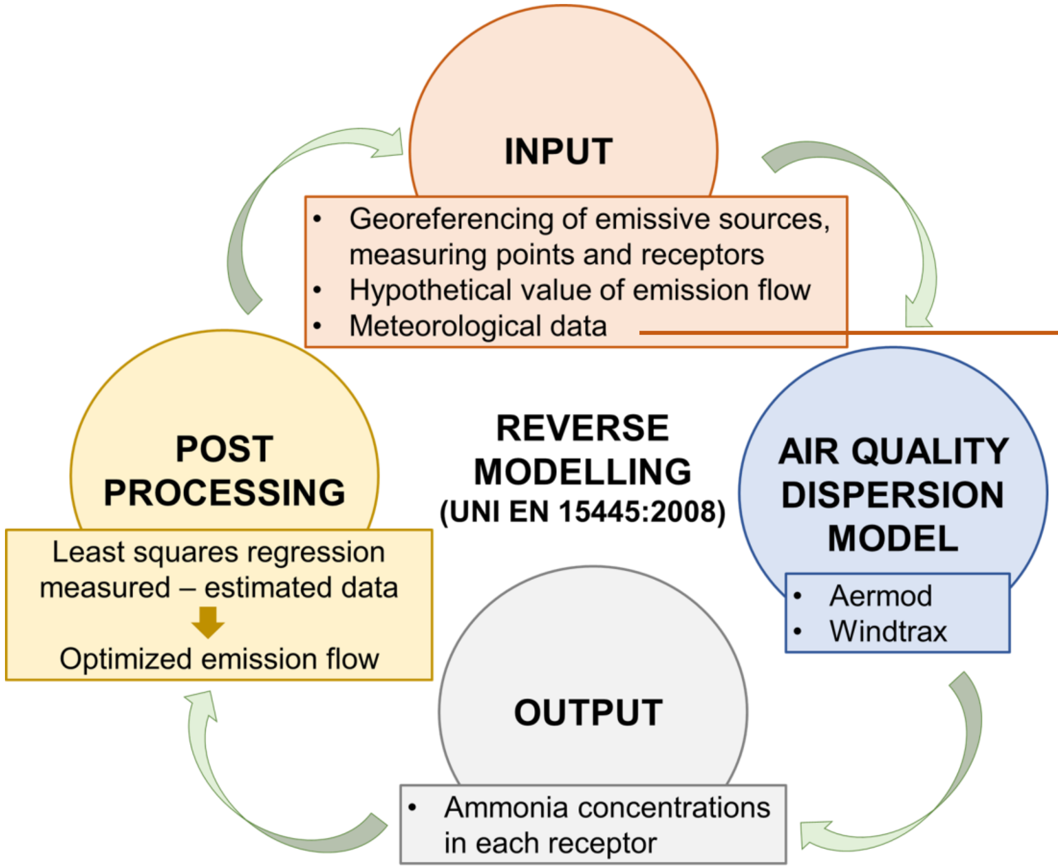
Source: https://www.lifeprepair.eu/

The map, provided by the European LIFE PREPAIR ACTION D.2 project, illustrates the distribution of ammonia annual emissions (in tNH_3/km^2) in atmosphere in 2017 over the territory of North of Italy and Slovenia.

In the map, we can observe that the highest values of ammonia emissions are detected over the area characterised by agricultural vocation, such as the Po valley. This spatial distribution confirms the evaluation of Regione Lombardia emission inventory, INEMAR, which estimates that the 97% of regional ammonia emissions are due to fertilization and manure management.

Method (1)

Reverse modelling is a procedure widely applied in scientific literature which consists in the use of a local dispersion model to calibrate the value of emissions produced by specific sources or to determine the value of emission factors.
The procedure, defined by a European regulation, involves several steps.



METEOROLOGIAL DATA

Air quality diagnostic modelling system used in ARPA Lombardia characterised by a domain set on Regione Lombardia and covered by a grid of 1 km step and 13 vertical levels between 10 and 6000 m.

Method (2) – Air quality dispersion models

Two air quality dispersion models are used and compared:

AERMOD

- A steady-state plume air quality dispersion model approved by US Environmental Protection Agency.
- The model incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concept including treatment of both surface and elevated sources and both simple and complex terrain.
- The model gives in output hourly ammonia concentration in each receptor.

https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod

WINDTRAX

- An air quality dispersion model that simulates the transport of pollutants in the atmosphere surface layer and calculates emission rates or pollutants concentrations near to emissive sources.
- The model can be applied if surface around the sources and the sensors is flat and free of obstructions and if the maximum distance between them is one kilometer
- The model is not time dependent (a meteorological field including parameters representing all simulation period cannot be provided as input); therefore, as many simulations as the hours in simulation period must be carried out, obtaining an emission flow for each hour of simulation.

http://www.thunderbeachscientific.com/

Case of study

Two farms located in Po Valley, North of Italy, where ARPA Lombardia (D'Angelo et al., 2020) carried out monitoring campaigns to measure ammonia concentration during slurry application. Two different spreading techniques are analysed: band spreading and injection.

	Main emissive sources	Scenarios analysed
Cattle farm	• Spreading area	During band spreading: • May 2018 (scenario 2) • September 2018 (scenario 4) During injection: • May 2018 (scenario 1) • September 2018 (scenario 3)
Swine farm	• housing (cattle and swine) • storage • spreading area • linear traffic sources	During injection: • May 2019 (scenario 5)

Results (1): ammonia emission flows

NH_3 emission flows obtained by reverse modelling using Aermod in five scenarios analysed

Scenario	Farm	Emissive source	Emission flow ($\mu g\ m^{-2}\ s^{-1}$)	R2
1	Cattle	Field	40.20	0.63
2	Cattle	Field	232.00	0.73
3	Cattle	Field	62.90	0.98
4	Cattle	Field	110.00	0.65
5	Swine	Cattle housing (B1)	80.64	0.81
5	Swine	Cattle housing (B2)	186.4	0.81
5	Swine	Swine housing (P1)	74.44	0.81
5	Swine	Storage (S1)	75.38	0.81
5	Swine	Storage (S2)	26.24	0.81
5	Swine	Storage (S3)	37.64	0.81
5	Swine	Field (D1)	3.57	0.81
5	Swine	Road (L1-1)	16.67	0.81
5	Swine	Road (L1-2)	0.00	0.81
5	Swine	Road (L1-3)	898.12	0.81
5	Swine	Highway (L2-1)	32.22	0.81
5	Swine	Highway (L2-2)	63.44	0.81
5	Swine	Highway (L2-3)	0.00	0.81

NH_3 emission flows obtained by reverse modelling using Windtrax in scenarios 1-4

Scenario	Farm	Emissive source	Emission flow ($\mu g\ m^{-2}\ s^{-1}$)	R2
1	Cattle	Field	11.90	0.38-0.58
2	Cattle	Field	105.00	0.72-0.98
3	Cattle	Field	27.53	0.27-0.41
4	Cattle	Field	67.80	0.60-0.84

- By analysing emission flows obtained using AERMOD, the correlation coefficient (R2), whose values are more than 0.6, proves the accuracy of the procedure implemented. These results are comparable to values estimated by using Windtrax. Nevertheless, Windtrax appears less accurate than Aermod: R2 assumes some values less than 0.6, since it varies from a minimum of 0.27 to a maximum of 0.98.

Results (2): emission flows from slurry application

NH_3 emission flows obtained by reverse modelling using Aermod scenarios 1-4

Scenario	Farm	Emissive source	Emission flow ($\mu g\ m^{-2}\ s^{-1}$)	R2
1	Cattle	Field – injection	40.20	0.63
2	Cattle	Field – band spreading	232.00	0.73
3	Cattle	Field – injection	62.90	0.98
4	Cattle	Field – band spreading	110.00	0.65

NH_3 emission flows obtained by reverse modelling using Windtrax in scenarios 1-4

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3	Cattle	Field – injection	27.53	0.27-0.41
4	Cattle	Field – band spreading	67.80	0.60-0.84

- Lower values are detected when slurry is applied by injection.

UN-ECE (2014) calculates a reduction of more than 60% in case on injection.

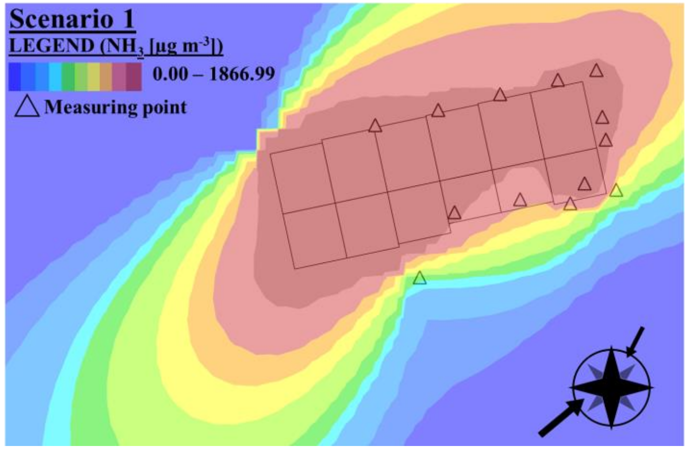
- Emission flows related to slurry application are comparable to values reported in scientific literature.

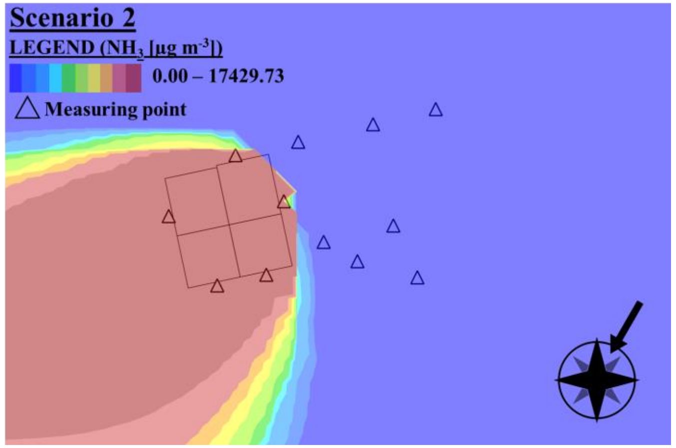
Carozzi et al. (2012) estimate an ammonia emission flow equal to 163 $\mu g\ m^{-2}\ s^{-1}$ by using Windtrax in case of slurry band spreading on soil surface.

Results (3): concentration maps

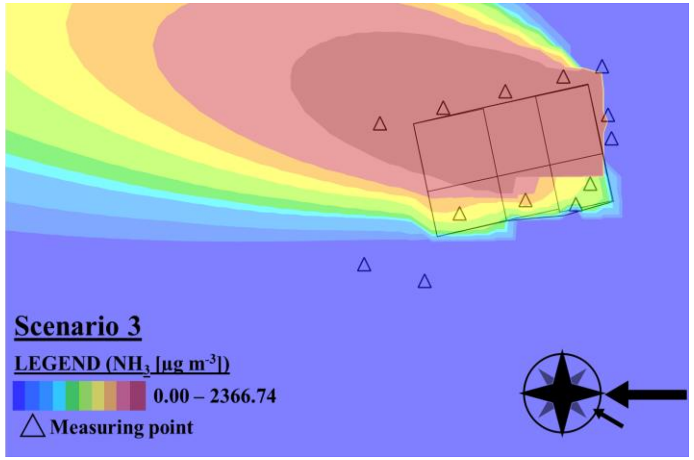
Maps illustrate, for different scenarios analysed, ammonia mean concentration on simulation period estimated by Aermod, when optimised emissions flows are given in input to the model.

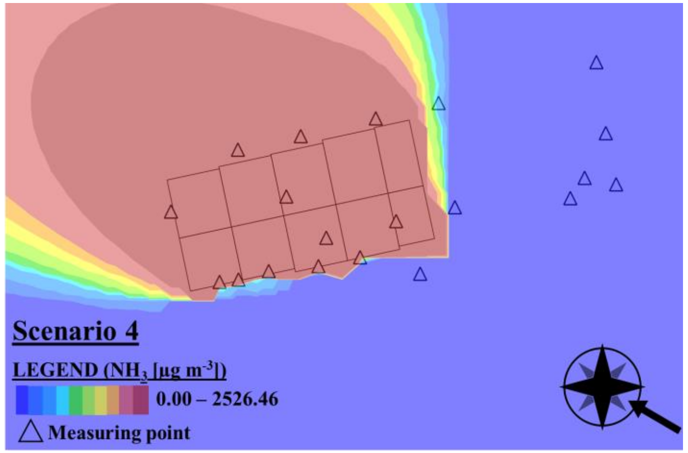
- Higher values are detected in the areas above the identified emission sources
- The plume follows the prevailing direction in which wind blows.

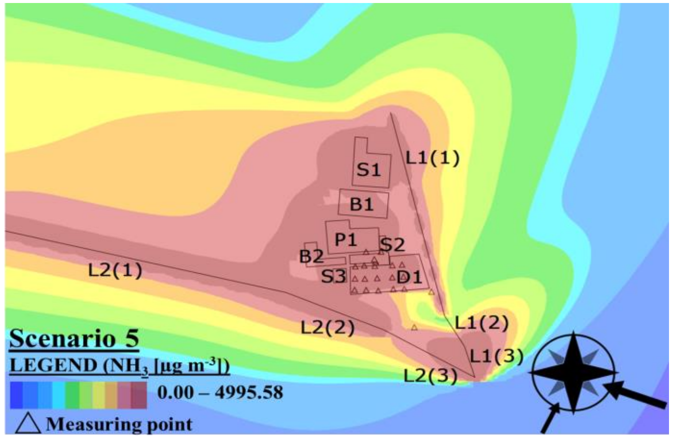




- The maps confirm the trend detected by emission flows: greater concentrations arise from band spreading on soil surface than injection.







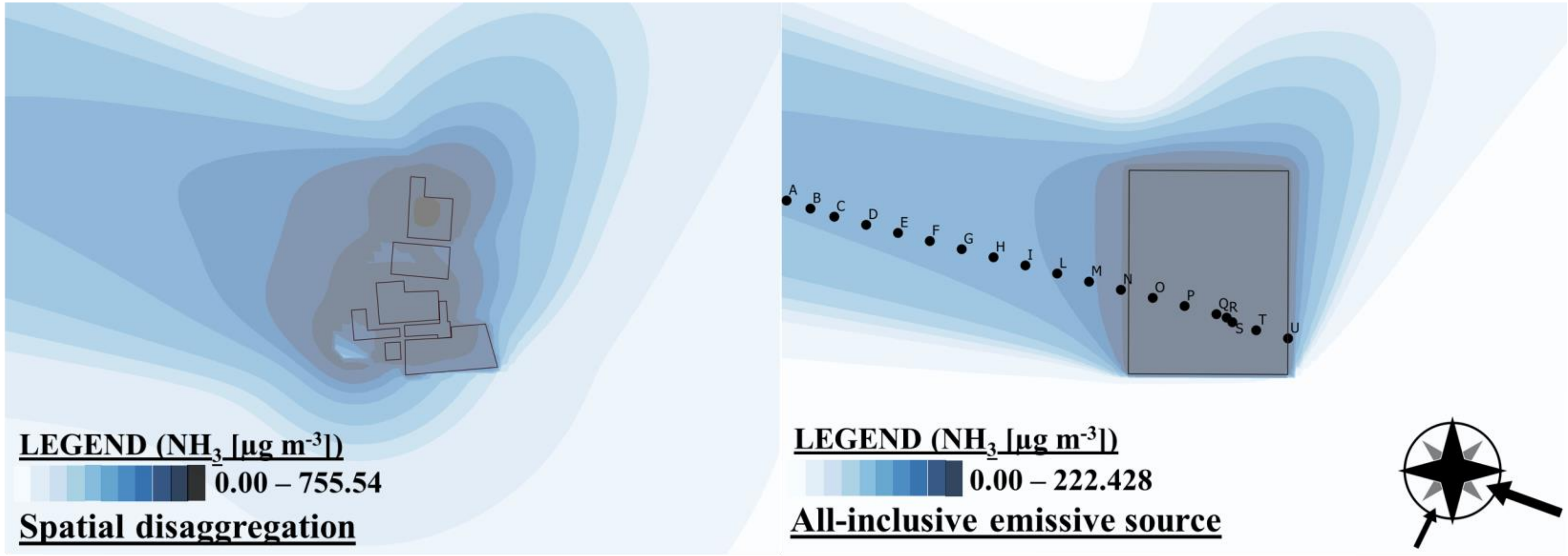
Average ammonia concentration on simulation period (the black outlined areas represent emission sources)

Results (4): spatial disaggregation

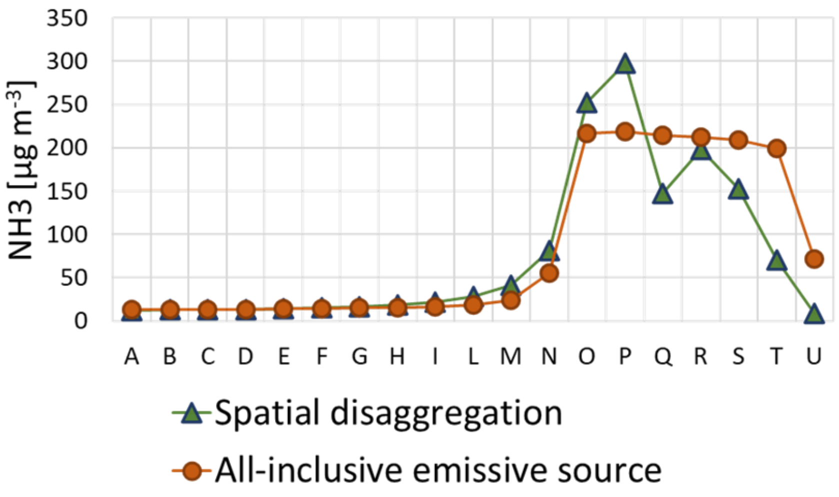
Results calculated by the implementation of reverse modelling are affected by spatial disaggregation of emissive sources.

- In the map on the left different emissive sources related to housing, storage and distribution areas are identified
- In the map on the right only one emissive source including all housing, storage and distribution areas, is considered

➢ The comparison of two maps illustrates that ammonia concentration are spread more uniformly throughout the territory when only one source is identified; while, when emissive sources are disaggregated, NH_3 is more concentrated over the located areas and reaches higher values.



NH_3 concentration maps for different spatial disaggregation of emissive source areas.



Ammonia concentrations estimated in two scenarios along the direction in which wind blows

Conclusion

- Reverse modelling is a procedure that quantify and allocate emissions to their own sources, starting from measured concentration data, but the results obtained refer to specific case of study and specific meteorological conditions of simulation period.

- The main uncertainty in the implementation of reverse modelling occurs when a plurality of emission sources is identified, since this multiplicity involves an excessive number of parameters with respect to the number of observation (overfitting). In this case, air quality dispersion model can have difficulty in allocating emissions to specific sources.

- Results of this study demonstrate efficiency of injection spreading technique in terms of ammonia emission. Nevertheless, in order to reduce ammonia emissions arising from agricultural sector, integrated interventions including all manure management phases must be considered because emission reduction in one phase can cause an increase in following steps. This phenomenon is demonstrated by the simulation of two different scenarios, referring to a swine farm, by using software BAT-Tool (CRPA, 2019), a model developed by LIFE PREPAIR project (Project PREPAIR – LIFE15 IPE IT013, https://www.life prepair.eu/) to calculate ammonia emissions from intensive pig and poultry livestock. The two scenario differ only in storage technique: without and with covering. BAT-Tool model estimates a reduction of 90% in ammonia emission arising from storage and a consequent increase of 12% in NH3 level from slurry application when storage is covered.

Thank you…