International Institute for Applied Systems Analysis (IIASA)

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Current and Future Emissions of Ammonia in China

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Why ammonia?

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- Plays a role in acidification and eutrophication of ecosystems but ‘forgotten’ a bit so far;
- Importance of NH_3 is growing since efforts are under way to reduce emissions of other pollutants;
- Several atmospheric modeling studies initiated recently in East Asia;
- The models need spatially and temporally disaggregated data but currently available inventories lack the necessary detail.

Inventory resolution

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Spatial resolution

- *Chinese provinces, including Hong Kong*
- 1^o x 1^o degree grid system (longitude/latitude)

Temporal resolution

- Annual estimates for 1990, 1995, 2000, 2010, 2020, and 2030

Sectoral resolution

- *Anthropogenic sources only:*
  eight livestock categories, fertilizer production and application, other activities

Emission sources included

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Livestock farming

- cattle (dairy and other), pigs, poultry, sheep, goats, horses, camels

Mineral fertilizer application

- Urea, ammonium bicarbonate, other N-fertilizers

Nitrogen fertilizer production

Other sources

Methodology

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$$E(NH_3)_{i,l} = \sum_j L_{j,l} \sum_k \sum_{s=1}^{4} [ef_{i,j,l,s}(1-\eta_{i,k,s})X_{i,j,k,l}] + \sum_m [nf_{i,m}(17/14)FC_{i,m,l} + ef_{i,m}FP_{i,m,l}] + OS$$

where:

i,j,k,l,m	- province, animal type, abatement, year, fertilizer type;
s	- four stages, i.e. animal house, storage, application, grazing;
L	- animal population [thousands head];
FC	- fertilizer consumption [Gg N/year];
FP	- fertilizer production [Gg N/year];
ef	- emission factor [kg NH_3/animal; kg NH_3/Mg N-fert.produced);
nf	- nitrogen loss per fertilizer [% of N content/100];
η	- removal efficiency;
X	- implementation rate of the abatement technique.

RAINS - *Ammonia module*

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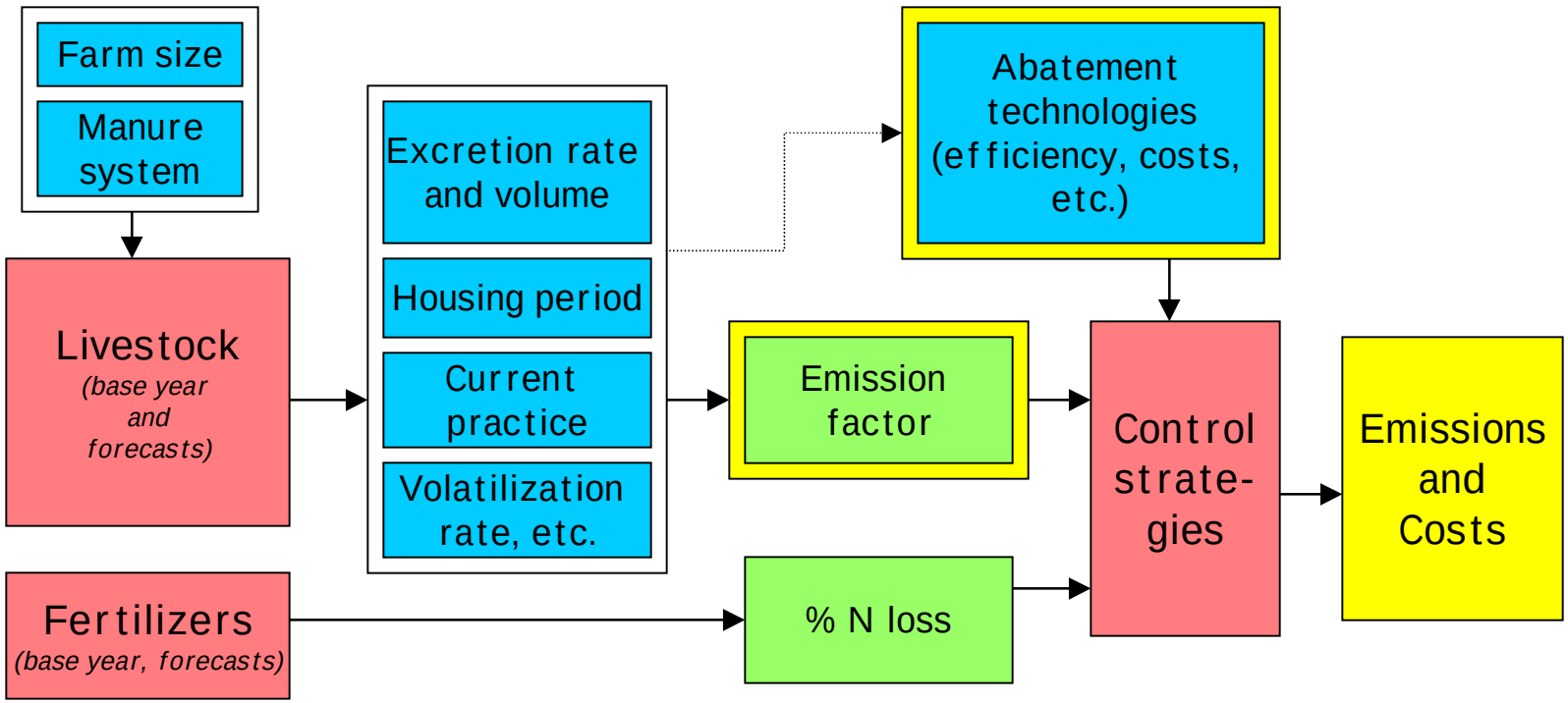

Legend:

- Data asked for
- Data assumed in the model but available for review
- Data available from guidebooks
- Result of calculation

The model: RAINS

developed by IIASA (http://www.iiasa.ac.at/~rains)

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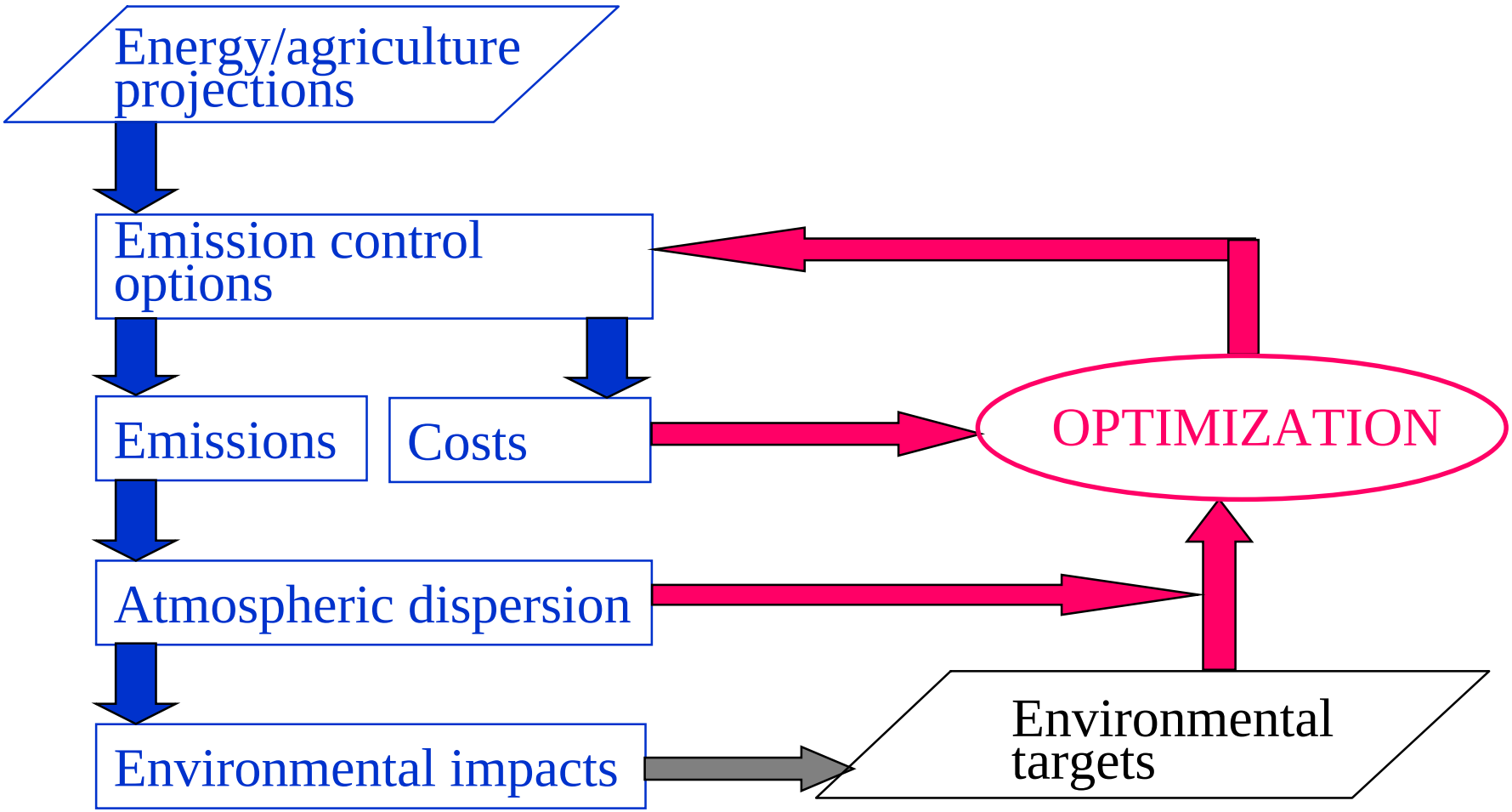

Activity data: *Sources*

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- Statistical data for 1990-95 from national yearbooks, FAO, IFA, OECD *(difficulties in spatial allocation)*
- Projections for 2000, 2010 and 2030 derived from agroeconomic studies (*OECD, 1995-99; Alexandratos, 1995; Simpson, 1997*) and other work (*Li, 1997; Wang, 1997; Bouwman and Hoek, 1997; Lin et al., 1996; IFA, 1997*)
- Spatial distribution derived from LUC project at IIASA, Li, Isherwood, Wang (1997)

Forecast of activity levels

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The principal elements of the forecast include:

- Future per capita consumption of milk, beef, pork, poultry, other meat and rates of fertilizer application;
- The change in efficiency of production;
- The import-export balance of dairy products, meat, etc.
- Possible impact of the change of efficiency of production on emission rates.

Assumed change in livestock numbers and fertilizer use in China

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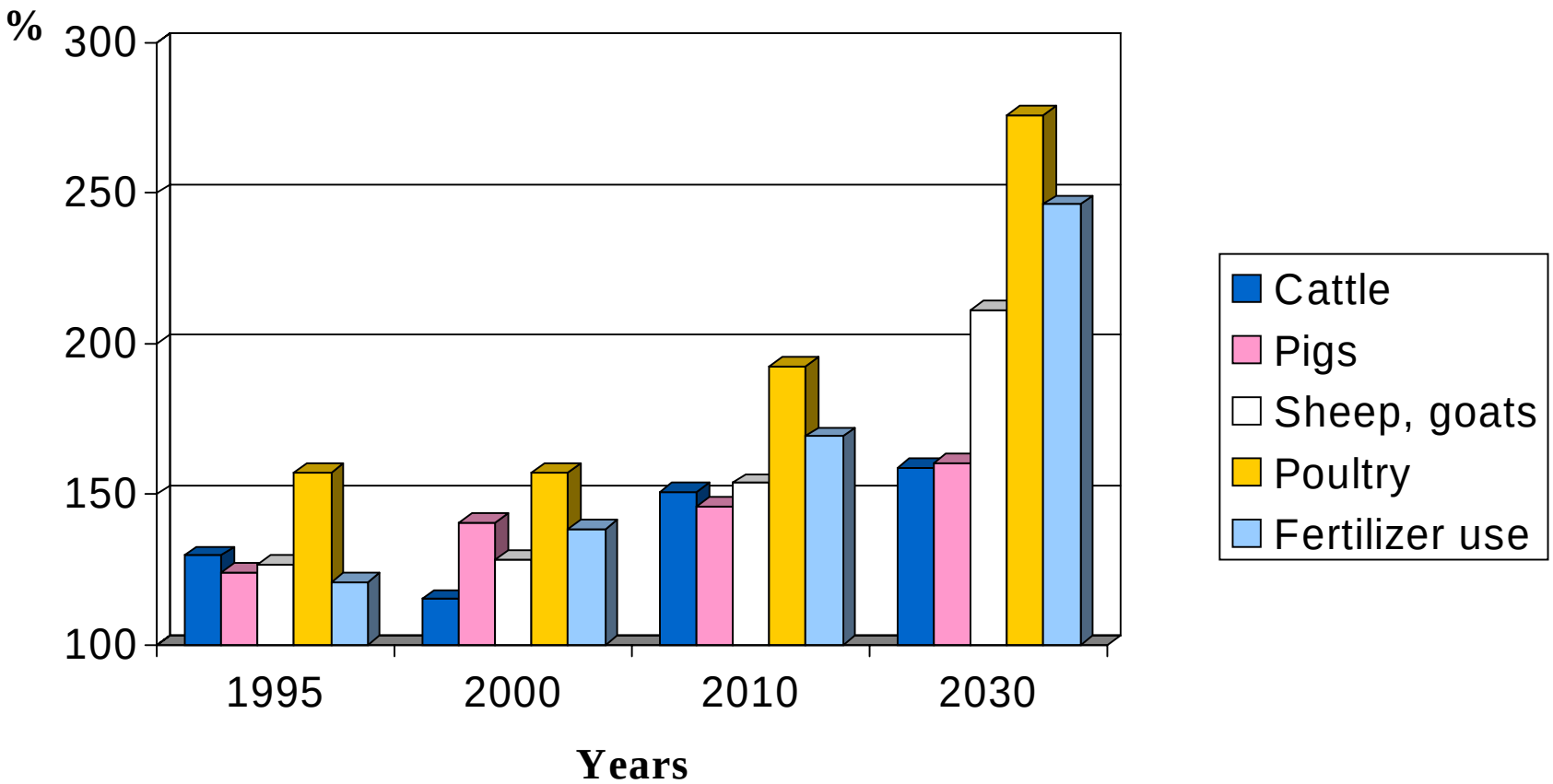

Emission factors *and more*

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- Originate from national and international sources as well as expert judgement;
- Country, region and sector specific parameters taken into account *(including climate conditions where appropriate)*;
- Autonomous improvement as well as changes in production efficiency considered.

Comparison of emission coefficients

(kg NH_3/animal; %N loss for fertilizers)

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Category	IIASA, Rains-Europe	EEA, 1996	Asman, 1990	Bouwman *et.al.*, 1997	This study
Dairy cows	22 - 40	28.5	25.1	17.4	19.4 - 24.8
Other cattle	10 - 18	14.3	25.1	10.0	9.5 - 9.9
Pigs	3 - 7	4.8	4.8	4.8	4.8
Laying hens	0.16 - 0.42	0.37	0.32	0.24	0.32
Broilers	0.14 - 0.23	0.28	0.32	0.24	0.18
Sheep [a]	1 - 3	1.34	1.9	1.2	1.2
Horses [b]	12.5	8	12.5	10.6	10.6
Camels	-	-	-	12.9	12.9
Urea application	15 - 20	15	15	15/25 [c]	15/20 [c]
ABC application	-	-	-	20/30 [c]	20/30 [c]

[a] - includes goats

[b] - includes mules and asses

[c] - loss assumed for temperate and tropical zones, respectively

Control techniques

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- Low nitrogen feed;
- Biofiltration (air purification);
- Animal housing adaptation;
- Covered storage of manure;
- Low ammonia application techniques;
- Substitution of urea and ABC;
- End-of-pipe options for fertilizer plants.

Emissions of NH_3 by sector in China,

(Gg NH_3)

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Sector	*1990*	*1995*	*2030 (Base)*	*2030 (BAT)*
Cattle	1040	1341	1716	1300
Pigs	1744	2124	2749	1900
Sheep and goats	250	330	549	500
Poultry	536	843	1479	1100
Horses, asses, mules	283	273	204	204
Camels	6	5	3	3
N-fertilizer application	5073	6049	12174	2300
N-fertilizer production	29	37	90	45
Other	696	736	901	901
Total	**9658**	**11738**	**19866**	**8253**

Ammonia emissions in China

(Tg NH_3)

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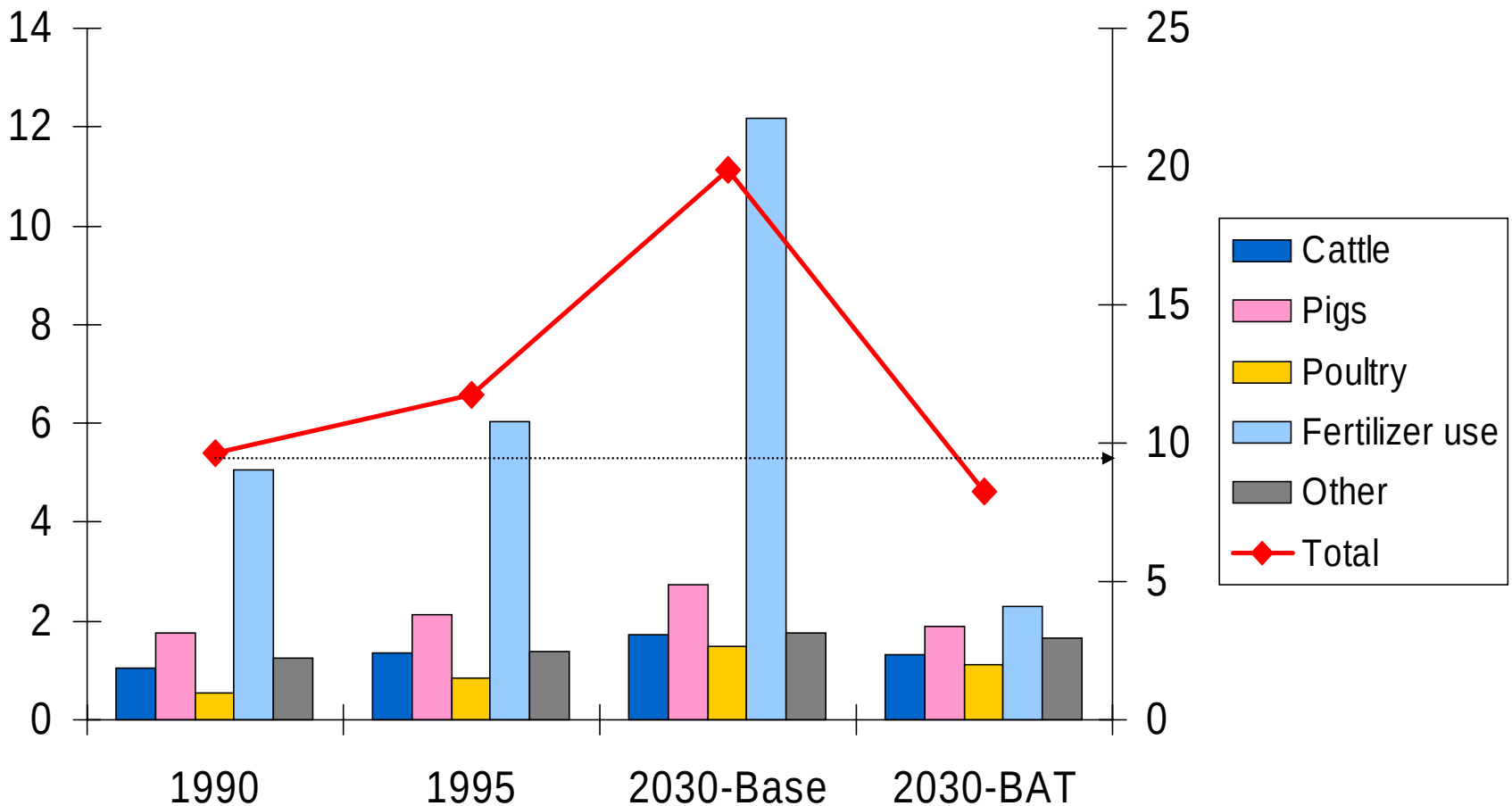

NH_3 emission structure in China and other regions in 1990

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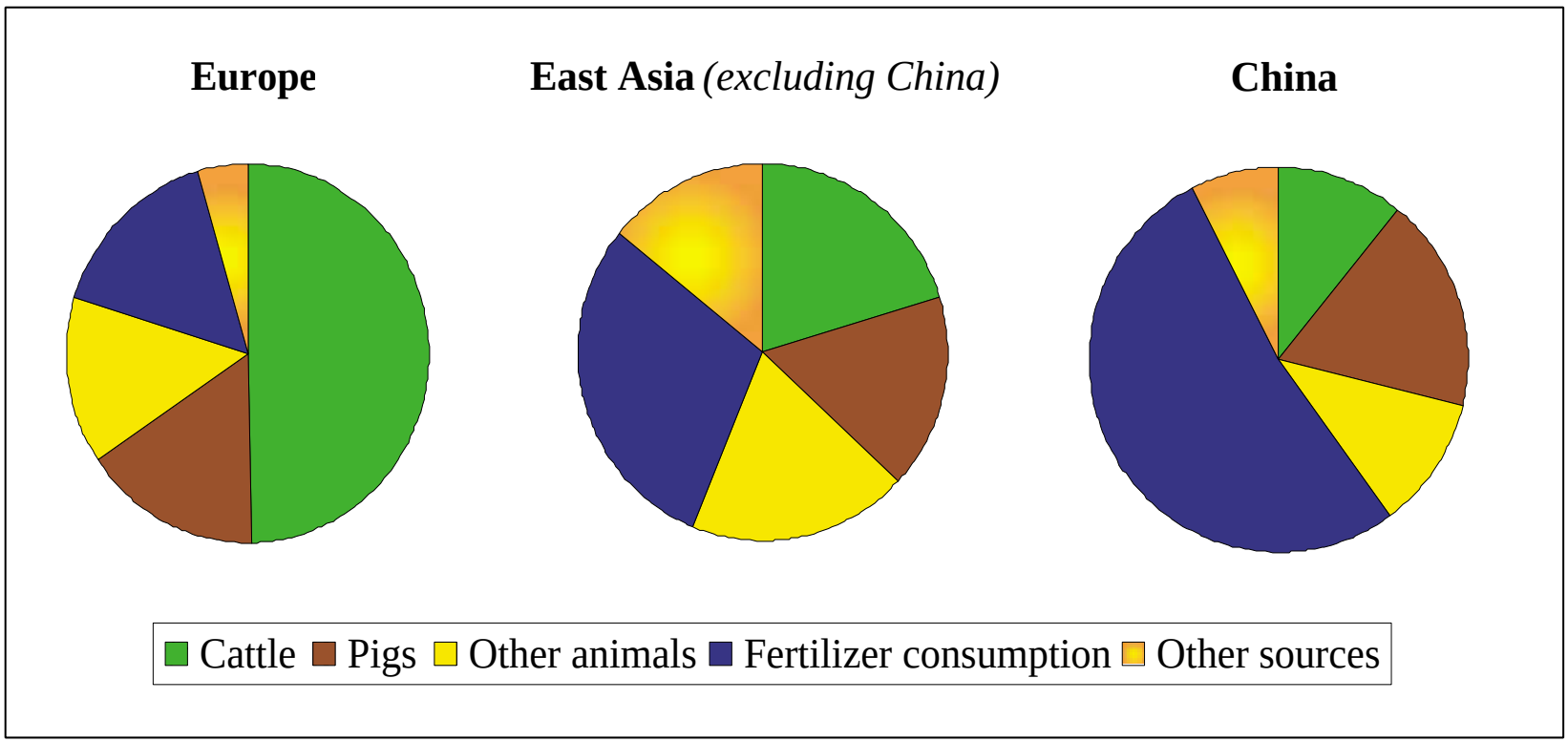

Population density

(10^6 capita/grid, data for 1990-95)

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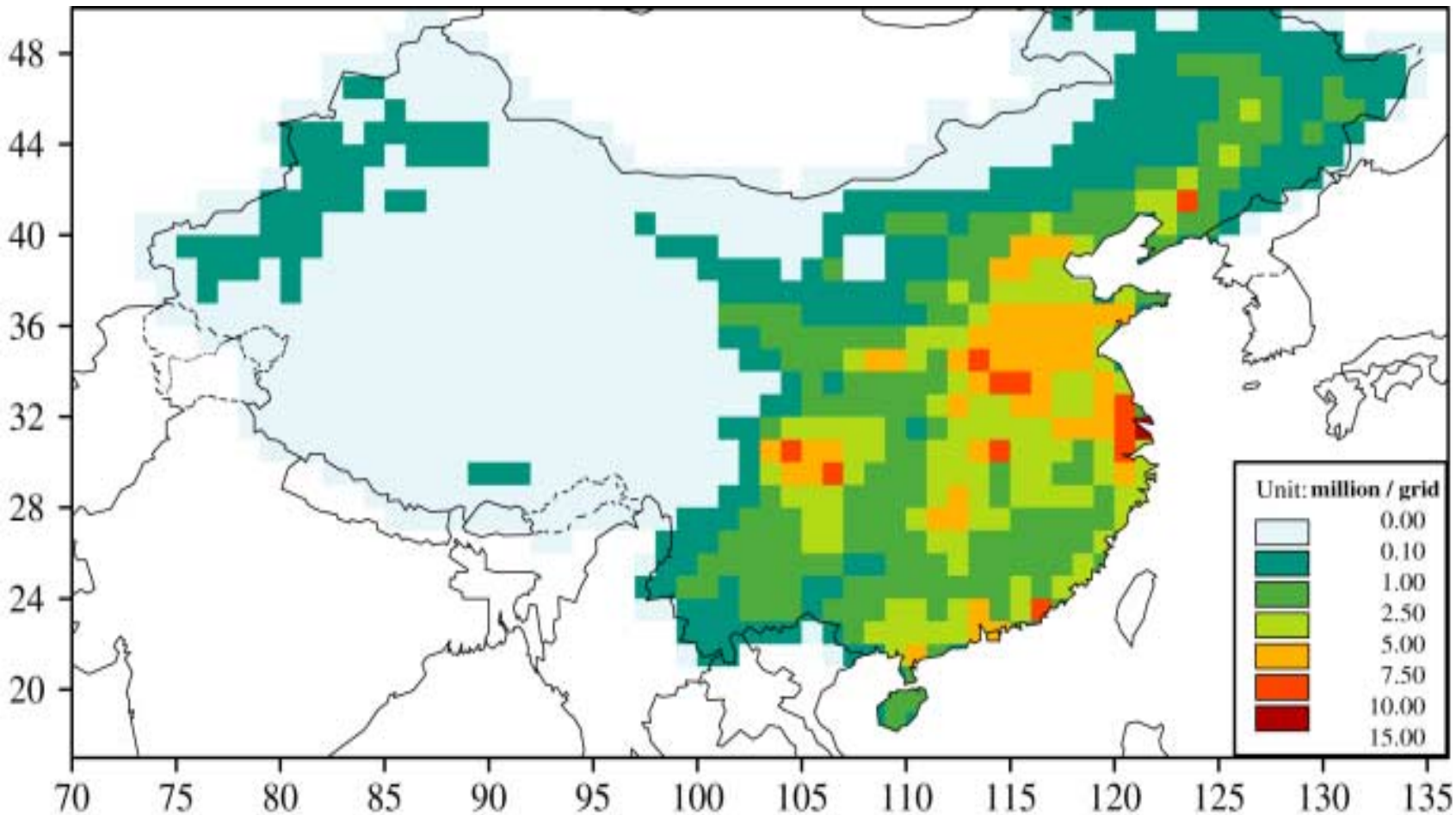

Spatial distribution of livestock in East Asia

(10^3 head /grid; data for 1990-1993)

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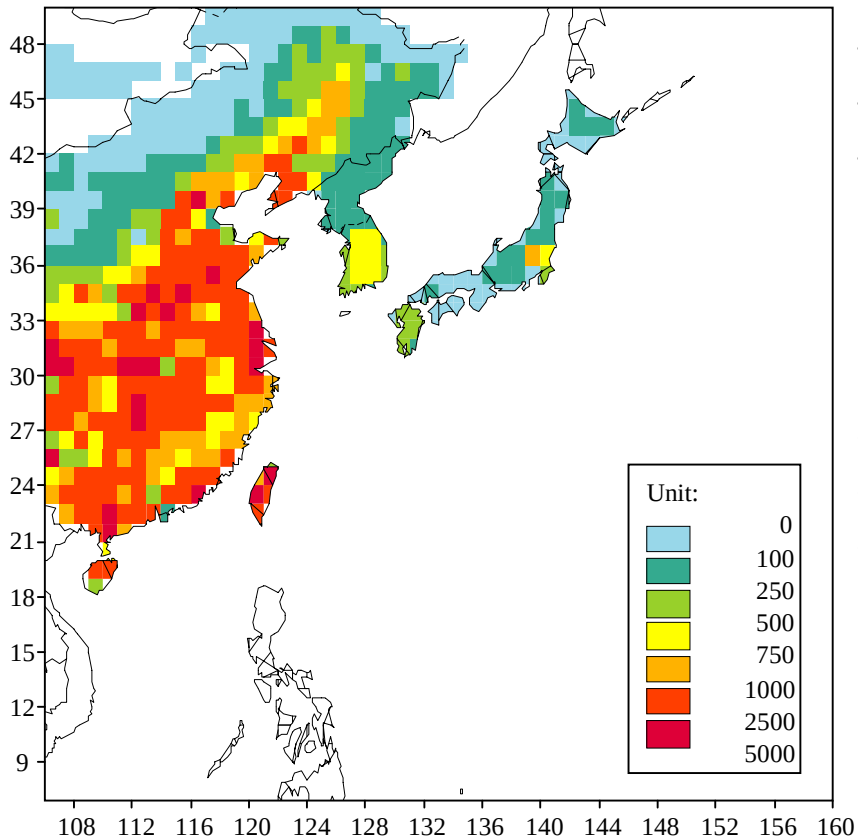
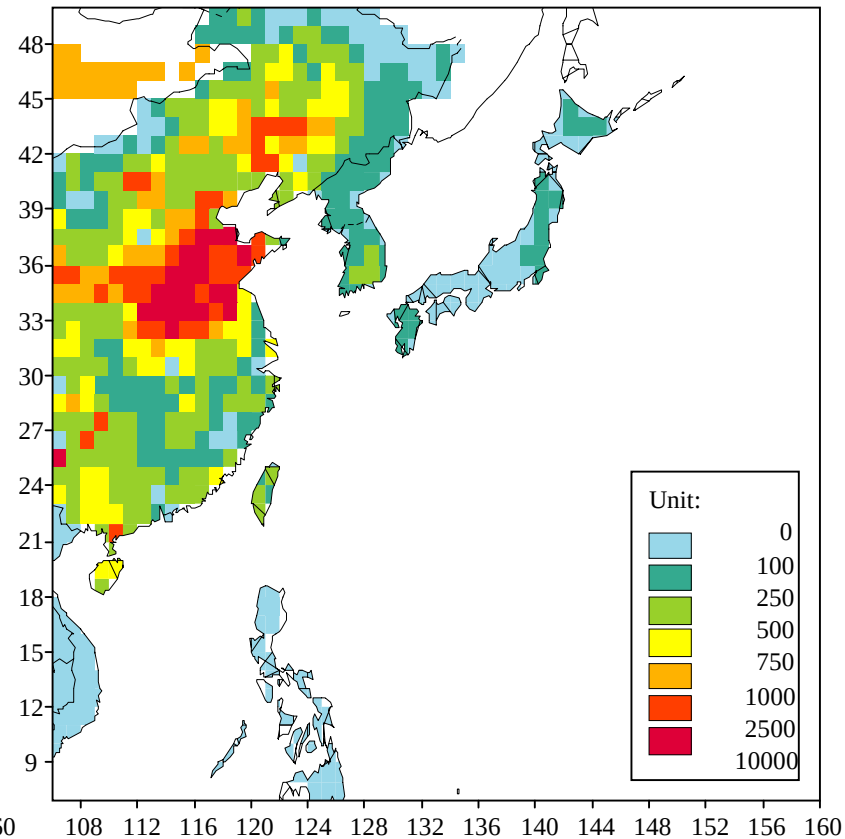
Pigs



Large animals



Spatial distribution of NH_3 emissions in 1995

(Gg NH_3 / grid)

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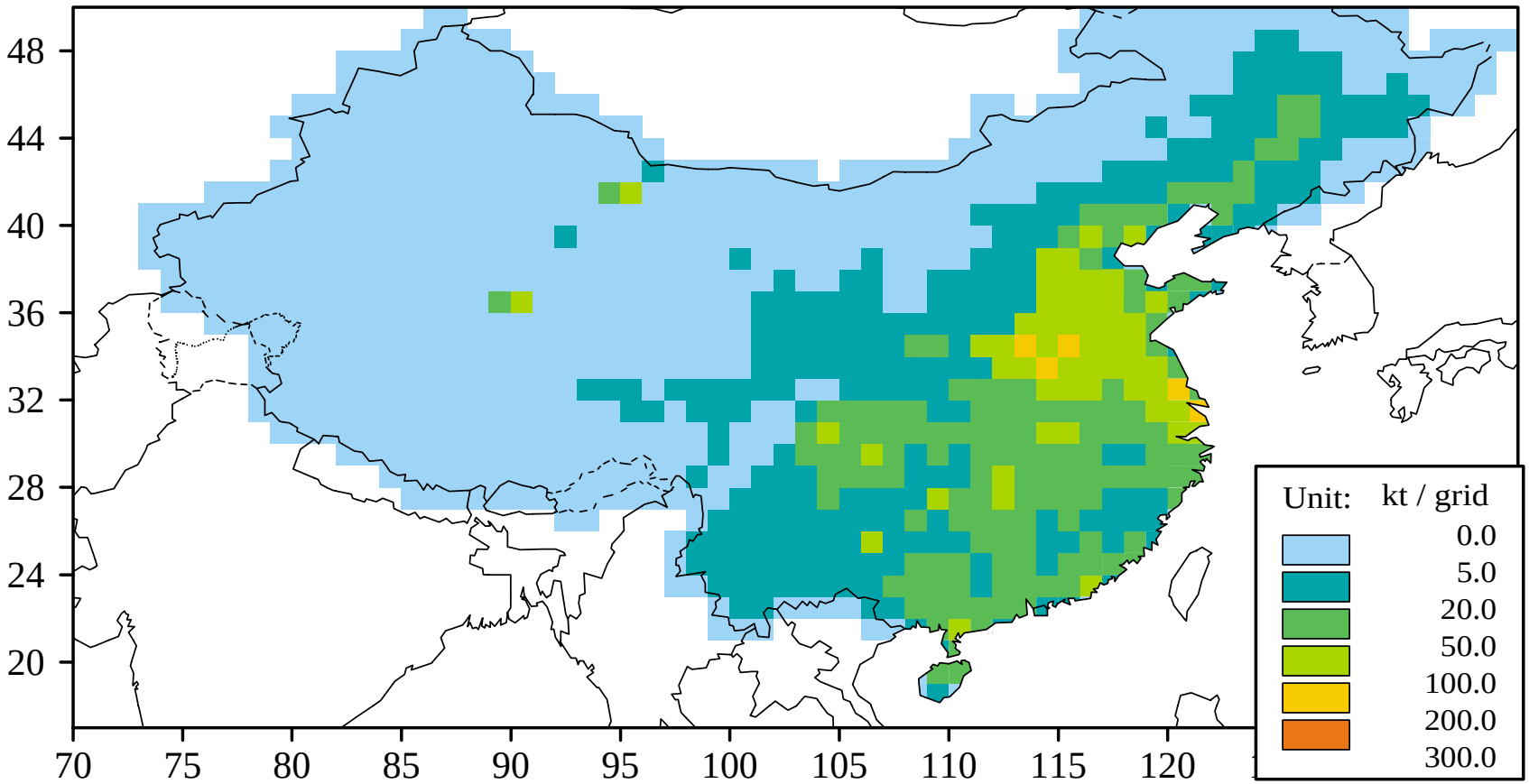

Spatial distribution of NH_3 emissions in 2030

(Gg NH_3 / grid)

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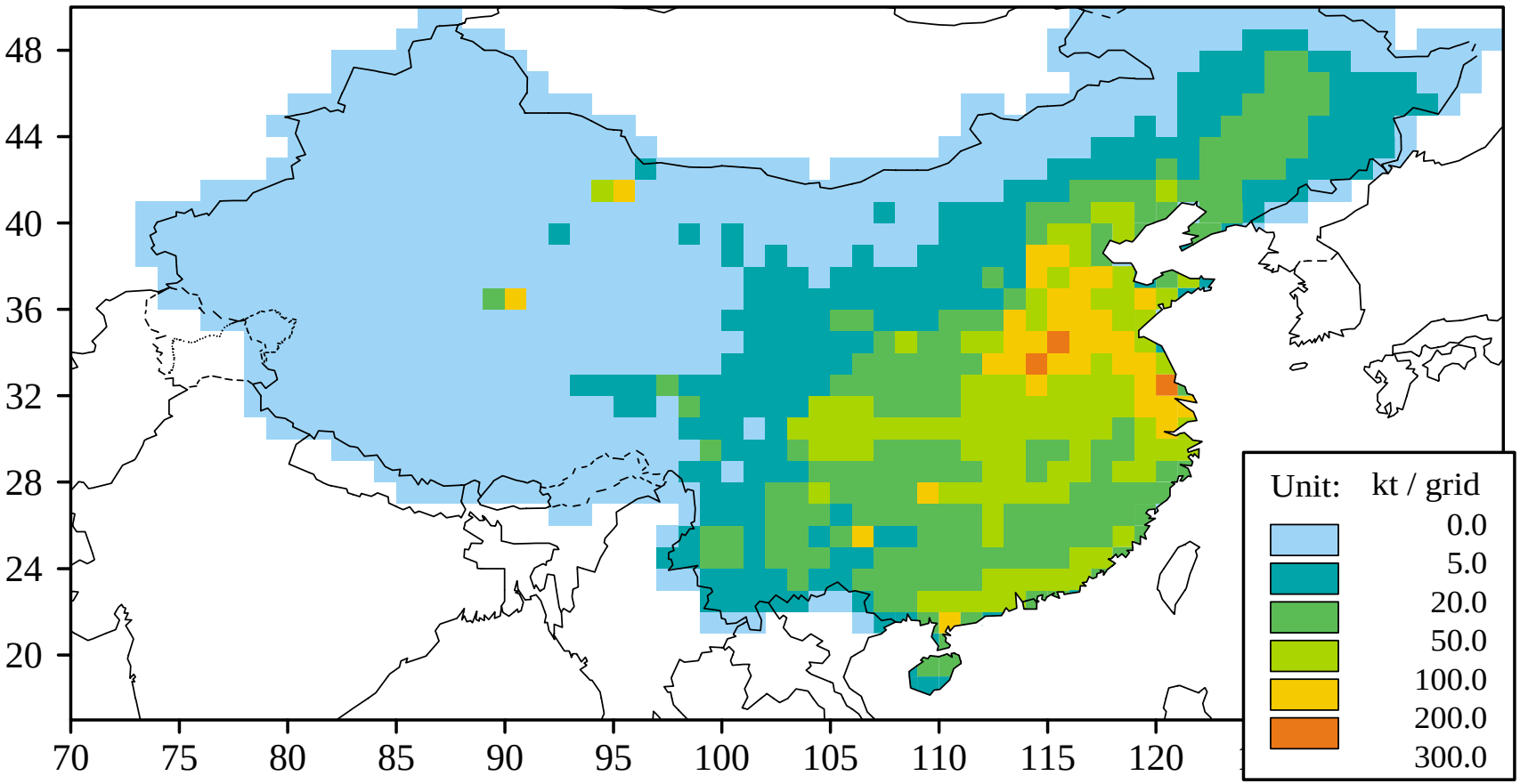

Comparison of NH_3 estimates for China for 1990, *(Tg NH_3)*

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Source	***1990***
Zhao and Wang, 1994	13.6
Bouwman *et al.*, 1997	13.0 [a]
This study	**9.7**

[a] This estimate is for the whole of East Asia

Conclusions

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- Current structure of NH_3 emissions in China differs from that of Europe and also from other East Asian countries;
- The main contribution to ammonia emissions comes from urea and ammonium bicarbonate application;
- Emissions of NH_3 are expected to double by 2030 in spite of assumed improvement in production efficiency;
- More work needs to be done to improve our understanding of the local factors, including distribution of activities;

Necessary improvements

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- Filling in gaps in historical data;
- Locally validated emission factors;
- Spatial (provincial and lower level) distribution of activities in the past and analysis of the possible future developments;
- Incorporation of the land use data in order to better estimate the patterns of fertilizer application.

Acknowledgment

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