Annex 1: ***Application of the ecological footprint (ecological paw print) analysis***

The Ecological paw print (EPP) has been derived from the Ecological footprint (EF), which calculates the area of productive land needed to support the consumption of resources, and to dispose the waste that is generated, for a given population (Shanahan and Carlsson Kanyama 2005, Wackernagel and Rees 1998a). EF is often used to measure humanity's overall impact on nature, by quantifying and analysing six main categories of ecologically productive areas including arable land, grazing land, forest land, fishing land, built-up land and energy land (Fu et al. 2015, Wackernagel and Rees 1998a). Companion animals' dietary EPP was calculated based on per capita data of dog's and cat's consumption of commercial dry food. We presumed that the proteins and fats in this food were from Chicken, while the carbohydrates were from cereal (maize, wheat and rice). Therefore, only the arable and grazing land-types were considered in the present study.

The equation of per capita dietary EPP is as shown below (Du et al. 2006, Liu et al. 2017):

$$EPP_{dietary} = \sum_{i=1}^{n} r_i \times C_i / Y_i$$

Where,

$i =$ the number of consumption items; r_i is equivalence factor; $C_i =$ per capita consumption of item i (kg); $Y_i =$ the annual average productivity in the world of item i (kg/ha).

To align the measurement units, the two land types should be converted using an equivalence factor (Table S1) (Liu et al. 2017, Wackernagel et al. 1999).

Table S1 The annual average productivity and equivalence factor of different land types

Items	Annual average productivity	Equivalence factor	Land type
Poultry	33	0.5	Grazing land
Cereal	2744	2.8	Arable land

We used the raw chicken and cereal in the calculation process, and the equations of the raw chicken and cereal are as shown below:

$$Chicken_{raw}\ (kg) = \frac{(protein_{commercial\ food} + fat_{commercial\ food})\% \times food\ consumption\ (kg)}{(protein_{raw\ chicken} + fat_{raw\ chicken})\%}$$

$$Cereal_{raw}(kg) = \frac{carbonhydrate_{commercial\ food}\% \times food\ consumption(kg)}{carbohydrate_{raw\ cereal}\%}$$

The average percentages of protein (17.33%) and fat (17.98%) in raw whole chicken and the percentage of carbohydrate (73.3%) in raw cereal were calculated according to the data from the Department of Agriculture, United States (USDA). We assume that the weights of protein and fat in raw chicken and the carbohydrates in raw cereal do not change during the process of industrial production (the conversion rate is one to one), which means that one unit of each item in raw chicken or cereal equate to one unit of commercial food.

Greenhouse gas (GHG) emissions

The greenhouse gas (GHG) emission is an indicator directly related to global warming and climate change (Francke and Castro 2013). In the present study, we mainly focused on companion dogs and cats' indirect GHG emissions from food consumption.

The per capita GHG emissions of companion animals are calculated as follows (Xu and Lan 2017):

$$\mathrm{GHG} = \sum I_i \times EF_i$$

Where,

i is the number of items of food inputs, I_i is the food inputs of item i (kg), EF_i is the GHG emission factor (kg CO_2/kg) (Table S2).

Table S2 Greenhouse gas emissions for the food commodities (Gerber et al. 2013, Nemecek et al. 2012)

Food category	GHG emissions (kgCO2e/kg)
Poultry Meat	5.40
Cereal	1.15
Maize	0.49
Wheat	0.58
Rice	2.38

Note: the GHG emission of cereal was the average score of maize, wheat and rice.

Box: Three cases: China, Japan and the Netherlands

Basic information about the nutrients and calorie content of companion animals' commercial dry food in China, Japan and the Netherlands is presented in Table 1.

Table 1 Percentage of nutrients and calorie contents in commercial dry dog and cat food

	Dog			Cat		
	China	Japan	The Netherlands	China	Japan	The Netherlands
Protein (%)	25.21	25.67	24.70	29.15	26.00	33.18
Fat (%)	13.80	14.67	8.33	13.17	7.50	12.76
Ash (%)	9.23	8.00	6.25	8.39	8.00	7.70
Fiber (%)	3.72	3.83	2.33	4.66	6.25	3.58
Moisture (%)	10.44	10.00	13.44	8.75	10.00	10.12
Carbohydrate (%)	37.60	37.83	44.95	35.88	42.25	32.66
Calorie (kcal/kg)	3371.35	3533.3	3145.80	3395.50	3445.0	3389.00

According to the data we collected from these three countries, we quantified individual and total companion dog and cat food consumption (Table 2).

Table 2 Companion animal numbers and their commercial dry food consumptions in three countries

	dog			cat		
	China	Japan	The Netherlands	China	Japan	The Netherlands
Per capita food consumption (kg/year)	48-243	19-123	61-247	20-34	18-31	20-33
Total numbers (million)	27.4	10.35	1.8	58.1	9.96	3.2
Total food consumption (million kg/year)	1308-6656	194-1271	109-445	1168-1954	178-311	64-106

The environmental impacts of companion dogs and cats in the Netherlands, Japan and China

We quantified companion dogs and cats' dietary EPP, GHG emissions and energy consumption according to their food consumption of commercial dry food in these three countries (i.e., the Netherlands, Japan and China). The dietary EPP of an average-sized dog in China was 0.82 to 4.19 ha. year^{-1}, while for a cat was 0.36 to 0.63 ha. year^{-1}. Given that China has a large companion dog and cat population; their total environmental impacts are undoubtedly significant. Specifically, if we assume that all companion dogs and cats eat commercial dry food in China, their dietary EPP is calculated to be between 43.4 and 151.4 million ha. year^{-1}, which is equivalent to the dietary EF of 72.3 to 252.3 million Chinese people in a year. GHG emissions from this dry-food consumption are between 16.7 and 57.4 million tons per year. The dietary EPP of an average-sized dog in Japan was 0.33 to 2.19 ha. year^{-1}, while for a cat was 0.32 to 0.56 ha. year^{-1}. The dietary EPP of all companion dogs and cats in Japan lies between 6.6 and 28.3 million ha. year $^{-1}$, equivalent to the dietary EF of 4.62 to 19.79 million Japanese people. The GHG emissions from Japanese dog and cat food consumption were 2.52 to 10.70 million tons, which is equivalent to the GHG emissions resulting from the food consumption of between 1.17 and 4.95 million Japanese people. With regard to companion dogs and cats in the Netherlands, our results showed that the dietary EPP of an average-sized dog was 0.90 to 3.66 ha. year^{-1}, while for a cat, between 0.40 and 0.67 ha. year^{-1}. The dietary EPP of all companion dogs and cats in the Netherlands was 2.9 to

8.7 million ha. year $^{-1}$, which was equivalent to the whole EF of 0.50 to 1.51 million Dutch people. The GHG emissions from Dutch dog and cat food consumption was in the range of 1.09 to 3.28 million tons, which is equivalent to between 94 and 284 thousand Dutch peoples' GHG emissions regarding their total resource consumption (Table 3, Table 4).

Our results show that the dietary EPP of one companion dog relying on commercial dry food in the Netherlands or in China was around two times that of a dog relying on commercial dry food in Japan. Consequently, their GHG emissions and energy consumption were higher than their Japanese equivalents. China has the largest number of companion dogs among the three countries and the Netherlands has the least. Therefore, the dietary EPP, carbon emissions and energy consumption of all companion dogs in China were the largest, while these values in the Netherlands were the smallest (Table 3). With regard to cats, our results show that dietary EPP, GHG emissions and energy consumption per capita for companion cats are similar across the three countries. However, although per capita environmental impacts were similar, their total environmental impacts were quite different. The total companion cats in China, due to their greater numbers, consumed more resources and, to a large extent, contributed to greater environmental impact than companion cats in the Netherlands and Japan (Table 4).

Additionally, we also found that many companion dogs in the Netherlands and China consumed more energy than their actual needs, while in all three countries the calorie intake of companion cats was sufficient to offset their energy requirements.

Table 3 The dietary ecological paw print (EPP) and greenhouse gas (GHG) emissions of companion dogs in the Netherlands, Japan and China.

		EPP (ha)	GHG emission (ton)
Per capita average-sized dog	The Netherlands	0.90-3.66	0.349-1.424
	Japan	0.33-2.19	0.127-0.831
	China	0.82-4.19	0.313-1.592
Lifetime of one dog	The Netherlands	10.77-43.93	4.188-17.087
	Japan	4.01-26.28	1.522-9.972
	China	9.89-50.32	3.756-19.104
		(million ha)	(million ton)
Total dogs	The Netherlands	1.62-6.59	0.608-2.480
	Japan	3.40-22.70	1.312-8.596
	China	22.5-114.8	8.576-43.621

Note: An average-sized dog weights 10-20kg.

Table 4 The dietary ecological paw print (EPP) and greenhouse gas (GHG) emissions of companion cats in the Netherlands, Japan and China.

		EPP (ha)	GHG emission (ton)
Per capita average-sized cat	The Netherlands	0.40-0.67	0.150-0.251
	Japan	0.32-0.56	0.121-0.211
	China	0.36-0.63	0.141-0.237
Lifetime of one cat	The Netherlands	5.62-9.39	2.102-3.511
	Japan	4.46-7.80	1.693-2.959
	China	5.04-8.82	1.974-3.318
		(million ha)	(million ton)
Total cats	The Netherlands	1.28-2.14	0.480-0.803
	Japan	3.20-5.60	1.204-2.105
	China	20.90-36.60	8.192-13.770

Note: An average-sized cat weights 2-6kg.

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