The Water and Land Footprint of Pets

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Summary

Nowadays, dogs and cats are considered as a family member, and they demand food from their owners. Since pets consume food, they might contribute to the water and land footprint of humanity by the share of freshwater and land demand of pet food production and consumption.

This study shows that the global water and land footprint of pets are 193×10^{6} m^3 and 280×10^{6} m^2 in 2016. They contribute 2×10^{-21} % and 2×10^{-35} % to the total global annual average of water and land footprint of humanity with $9{,}087\times10^{27}$ m^3 and $9{,}903\times10^{10}$ m^2. In a global average, the large dog breeds are the most significant contributor with 39% and 35% respectively of the global water and land footprint of pets. The average of a large dog breed has much higher water and land footprint (703 m^3/year and 1,147 m^2/year) than a medium dog breed (416 m^3/year and 683 m^2/year), a small dog breed (231 m^3/year and 376 m^2/year) and a cat (85 m^3/year and 86 m^2/year). These results confirm that the body weight which regarding the annual food intake is important in determining the global water and land footprint of pets.

Although in this study dog foods have lower animal content (58%) than the cat food products (67%), the water and land footprint of dog food products in average (5 m^3/kg and 8 m^2/kg) are larger than cat food products (2 m^3/kg and 3 m^2/kg). These are due to dog products contain higher meat meal, or dried meat ingredients (23%) compare to the cat food products (17%). Also, the dog foods use lower by-products with 8% of the whole animal content within the whole ingredients, while cat foods use higher animal by-products contents with 11% in the products.

The water footprint of pets can be understood from two factors namely the total water footprint of the ingredients used in the pet food products and the water footprint of the drinking water, whereas the land footprint of pets only considers the total land footprint of the ingredients used in the pet food products. The pet's consumption rate and composition in the pet food products influence the value of water and land footprint of a pet. First, the more food is consumed by a pet, the more water and land are required to produce the pet food. Second, the more animal content in the pet food products, the higher water and land footprint of the products. Further, a pet food containing more meat meal and animal primary products tends to have higher water and land footprints rather than a product with fresh meat and animal by-products content.

Overall, the consumption rate and ingredient selection are the major components in determining the water and land footprint of pets. Nevertheless, unlike a human who can control their diets and pick the ingredients which have low footprints, pets cannot adjust their consumption rate and choose what to eat in the pet food as the ingredients are already blended by the manufacturers. Thus, the decision in reducing water and land footprint of pets is from the pet owners to give the proper amount of pet food and choose the best ingredients both for pets and environments.

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1. Introduction

1.1. Background

The relationship between humans and pets, specifically dogs and cats, has existed for over 14,000 years (J. A. Serpell, 2006). Many studies have shown that owning pets offers physical, psychological and social benefits to humans (Allen et al., 1991; Friedmann et al., 1995; Headey, 1999; Headey et al., 2002; McCardle et al., 2011; J. Serpell, 1991). Due to the ample roles that pets have in human's life, it is important to understand the potential environmental impacts such as water and land footprint associated with pet ownership.

Dogs and cats are counted as a commodity that humans have at home, and for most people, they are considered as a family member (Mantle, 2014). As the result of the domestication, dogs and cats have adjusted their natural behavior from hunting prey for the survival to be demanding food from their care takers (Driscoll et al., 2009). Nowadays, most dogs and cats are fed by commercial pet food containing animal and crop products that take water and land to produce it.

Pet food manufacturers depend on natural resources used to grow and process the ingredients in the pet food products. These ingredients can compete either directly or indirectly to the human's food which can affect the footprint of humanity (Swanson et al., 2013). Further, growing feed from the agricultural production has led to the drying up of freshwater resources, groundwater depletion, soil loss and land degradation globally (Bosire, 2016; Campbell et al., 2005; Meyer et al., 1994; Naylor et al., 2005). It is estimated that the total water withdrawals for the agricultural sector will increase from 3,100 billion m^3 today to 4,500 billion m^3 by 2030 (Addams et al., 2009). Simultaneously, the agriculture land is expected to expand from 5.1 billion ha to 5.4 billion ha in 2030 (Wirsenius et al., 2010).

The water footprint of agricultural production contributes to around 92% from the total global average water footprint which consists of agricultural production, industrial production and domestic water supply (Hoekstra et al., 2012). Moreover, almost one third is directly and indirectly used for animal products (Gerbens-Leenes et al., 2013; Hoekstra et al., 2012). The water footprint of humanity indicates that the total water use of both production and consumption perspective is associated with various components of human life (Hoekstra et al., 2012) and only 4% of the water footprint of humanity relates to the water footprint of households (Mekonnen et al., 2011). In other words, the largest fraction of the water footprint of humanity is related to the food consumption where the largest proportion dominated by the animal products (Hoekstra, 2012).

The land footprint is defined as the real amount of land that is needed to produce a product or service (Giljum et al., 2013). The land footprint of food products points out the total domestic and foreign of land

both directly and indirectly required to meet the demand of domestic food supply (Giljum et al., 2013). Approximately 38% of the land on earth is used for agriculture (FAO, 2011) and almost 80% of the total agricultural land is used for livestock (Elferink et al., 2007). Animal based products have larger land footprint than plant-based products due to the vast land required to grow crops for feeding livestock (für Vegetarismus, 2009). As meat is the largest fraction in human's diet, it plays an important role of the land footprint of humanity (Steinfeld et al., 2006).

The global annual average of the water and land footprint of humanity is estimated around $9{,}087\times10^{27}$ m^3 (Hoekstra et al., 2012) and $9{,}903\times10^{10}$ m^2 (Lambin et al., 2011). However, within the water and land footprint of humanity, the consumptive water use of pets held in households is not incorporated. As pets are a component in the households, it is expected that they might contribute to the water and land footprint of households (Aivazidou et al., 2017; Vale et al., 2009). Since pets consume food, they are likely contributing to the water and land footprint of households by the share of freshwater use and land demand of pet food production and consumption (Rushforth et al., 2013).

Understanding the potential environmental consequences of keeping pets are important to develop well-informed impacts to the humanity. Rushforth et al. (2013) studied on the land requirements, water withdrawal, and global warming potential caused by dog food production in the US resulting that grain farming consumes most of the land and water for pet food production as the pet food ingredient and livestock's food. A study about the nutritional sustainability of pet foods using carbon and water footprint as the indicators has been conducted based on the selection of pet food ingredients, nutrient composition, digestibility and consumption rates of a diet (Swanson et al., 2013). This study concluded that pet food production gives a contribution to the security of human food supply. However, a detailed calculation of carbon and water footprints were missing in that study. A book written by Vale et al. (2009) discussed the environmental impacts of pet ownership based on their dietary intake, specifically on the ingredient selection and nutrient composition. Vale et al. (2009) stated that keeping a medium sized dog, such as a Labrador retriever, has a higher land footprint with 0.84 ha/yr than having an SUV car with 0.41 ha/year.

Although keeping pets influences the freshwater and land demand through their diets (Aivazidou et al., 2017; Rushforth et al., 2013; Swanson et al., 2013; Vale et al., 2009), the water and land footprint of pets have not been quantified yet. To understand their contribution to the water and land footprint of humanity, the objective of this study is to estimate the global water and land footprint of dogs and cats through their diets.

In this report, I present my thesis report to estimate the water and land footprint of pets of nations in 2016. After the introduction in chapter 1, some information about how pet food has its footprints will be explained in chapter 2. The method on how to calculate the water and land footprint of pet food will be explained in

chapter 3. In chapter 4, the results of the calculation are presented which visualize the water and land footprint of pets of nations in 2016 in charts and maps. In chapter 5, a discussion about the accuracy of the results and recommendations is done. Finally, the conclusions of this report can be found in chapter 6.

1.2. Research objective and questions

The objective of this research is to estimate the contribution of the water and land footprint of pets of nations in 2016 to the water and land footprint of humanity, particularly through the impact of different feed composition. The research objective will be achieved by answering the following research question:

To what extent do the water and land footprint of pets of nations in 2016 contribute to the water and land footprint of humanity?

This question will be answered by the following sub-questions:

1. How can the water and land footprint of pets be quantified?
2. What are the water and land footprint of pets of nations in 2016?
3. How do pets affect the water and land footprint of humanity?

2. The footprint of pet foods

In this chapter, factors that may influence water and land footprint from the pet food products are described. First, an explanation on how commercial pet food might link to the human consumption is introduced. Then, an explanation about how the nutrient content and ingredient selection matter in determining the water and land footprint of a pet food product is presented.

The linked of pet and human food

Commercial pet food demand has increased constantly due to the growing popularity of owning pets (Daumas et al., 2014). Some surveys conducted in the US, Australia, and France have indicated that the majority of pet owners feed their dogs and cats with commercial pet foods (Colliard et al., 2006; Laflamme et al., 2008; Remillard, 2008). Feeding commercially pet foods are an easy and economical way to meet the nutrient requirements in dogs and cats. However, most owners do not know the required nutrients for their pets (Swanson et al., 2013). Instead, they trust commercial pet food manufacturers to formulate the ingredients in order to meet the nutrient requirements in dogs and cats (Remillard, 2008).

Many pet owners expect that they feed their dogs and cats with the natural ingredients like what human consume (Nielsen, 2016). To satisfy the consumers' demand, pet food manufacturers often use ingredients that compete with human foods where pet owners believe to be high quality with unnatural preservatives or modified ingredients (Nielsen, 2016; Swanson et al., 2013). Therefore, many manufacturers produce pet foods with high meat content and other natural ingredients instead of using waste products (Cheuk et al., 2002). The pet food system is connected with many aspects including human food (see Figure 1). Pet food manufacturers might increase the demand for animal and crop products if they use ingredients which are directly competed with human foods (Swanson et al., 2013).

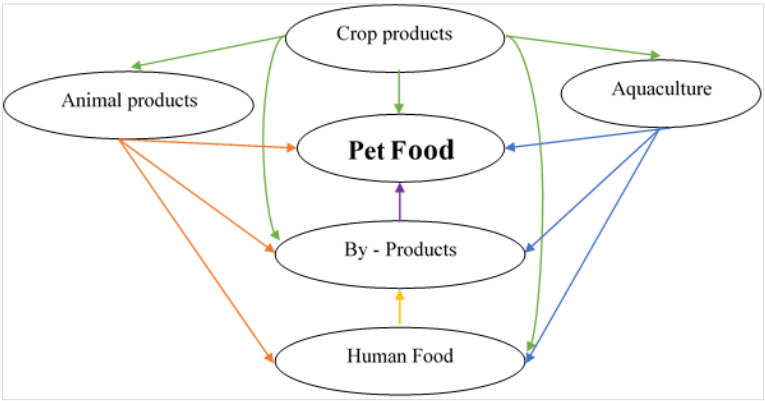

Figure 1. The pet food system. Source: Swanson et al. (2013)

The nutrient composition

Whether the pet owners feed their dogs and cats with a dry, wet or semi-moist pet food (Crane et al., 2010), it is important to understand nutrients needed for dogs and cats. Six primary nutrients essentially use in dogs and cats for survival namely: protein, carbohydrate, fat, water mineral and vitamin (Gross et al., 2010). The first three nutrients determine the produced energy content as the basic requirement of life. Water and mineral are essential for enhancing chemical reactions, transporting substances throughout the body and maintaining the body temperature. Vitamins are used with metabolic functions (Gross et al., 2010). From the sustainability point of view, protein becomes the main concern because they mainly based on the animal protein source which has a higher environmental impact compared to the plant protein source in the pet food products (Ifip Wg 5.7 Working Conference on Advances in Production Management Systems State College et al., 2013). Also, protein content has a high proportion of the pet food content, while for other nutrients sources are mainly based on the plant products and have a lower share of the pet food products (Hill et al., 2009).

Dogs and cats belong to the order Carnivora animals where many people believe that they require high protein content from animal flesh in their diets (Swanson et al., 2013). However, some study has proved that cats need more protein than dogs (Hewson-Hughes et al., 2011; Knight et al., 2016; Tôrres et al., 2003). AAFCO (Association of American Feed Control Officials) recommends 18% for dogs and 26% for cats of protein in their diets. Hill et al. (2009) analysed 1,156 wet and 750 dry dog and cat foods. They have found that wet and dry pet food contains more than 30% of the protein in average and most of the protein is taken from the animal products where they have higher water and land footprint than the crop products (Gerbens-Leenes et al., 2002; Hoekstra, 2013a)

Pet Food Ingredients

A wide variety of ingredients can be used to meet the target requirements of dogs and cats. Table 1 shows the common ingredients used as the source of the certain nutrients in the pet food.

Table 1. Nutrients and common ingredient sources in the pet food. Source: Wills et al. (1994)

Nutrient	Common Ingredient Sources
Protein	Beef, chicken, fish, offals, rice, soy
Fats	Animal fats, linseed, flax seed, cereals, roots and tubers
Carbohydrate	Rice, maize, wheat, potato
Vitamins	Liver, fish, eggs (vitamin A); tuna, sardines (vitamin D); grains, cereals (vitamin E)
Minerals	Vegetables, fish, eggs

Many commercial pet foods are formulated to provide complete nutrients to the pets which use different combinations of ingredients to reach certain nutrients target. In the pet food products, the ingredient list can be found on the pet food label. Roudebush et al. (2010) stated that the ingredients should be listed in descending order by weight which is used in the product. However, the ingredient list on the pet food label often uses unfamiliar terms for the pet owners thus pet owners can be confused by terms such as meat, meat meal and meat by-products (Box 1).

Ingredients that perform as the animal protein sources need more water and land to be produced compared to the plant protein sources (Reijnders et al., 2003). Pimentel et al. (2003) estimated that 1 kg of animal protein needs 100 times more water than 1 kg of grain protein. Also, plant based proteins are 6-17 times more efficient regarding the land use compare to the animal proteins (Pimentel et al., 2003). Beside of that, the inefficient conversion of the plant into animal protein is also a factor that makes animal protein sources has higher water and land footprint rather than crop protein sources. This conversion can be illustrated by 1.75 kg of feed (~ 350 gram protein) can produce 1 kg of chicken (~ 190 gram protein) (Beynen, 2015).

Box 1. Definition of meat, meat by-products, and meat meal. Adapted from: AAFCO (2017)

- Meat is the clean flesh derived from slaughtered mammals and is limited to that part of the striate muscle which is skeletal or that part which is found in the tongue, in the diaphragm, in the heart or in the esophagus; with or without the accompanying and overlying fat and portions of the skin, sinew, nerve, and blood vessels which normally accompany the flesh
- Meat meal is the dry rendered product from mammal tissues, exclusive of any added blood, hair, hoof, horn, hide trimmings, manure, stomach and rumen contents except in such amounts as may occur unavoidably in good processing practices
- Meat by-products are the most of the parts of the animal other than the muscle tissue, including the internal organs and bones. It also includes some parts that humans eat such as livers, kidneys, and tripe.

3. Method and data collection

3.1. Method

Scope

This study will only focus on dogs and cats, specifically the indoor ones, hence other pets such as birds, small mammals, or fish are excluded in this research because to the reason that dogs and cats have the biggest pet ownership percentage with 33% and 23% respectively around the world (Global GFK Survey, 2016). In addition, dogs and cats are expected to have the most significant contribution to the water and land footprint of humanity because meat is the biggest fraction in the pet food which requires water and land to produce it (Rushforth et al., 2013; Swanson et al., 2013; Vale et al., 2009). The vast majority of pet food consumption is in commercial dry food product with 32% of the whole pet foods, which is what this study will limit the calculation of water and land footprint to, excluding so-called table scraps, home cooked, mixed, scavenge and wet which only comprise 18.5, 11.5, 6 and 2% respectively of global trends pets diets (World Society for the Protection Animal, 2008). Only "complete and balanced" formulated pet food will be chosen. Countries with dogs and cats ownership at most in 2016 will be taken into account for the estimation of global water and land footprint of pets due to the reason that the most updated survey of pets population around the world was held in 2016 by Euromonitor (2017).

Calculation method

To calculate the water and land footprint of pets, the method of the water footprint of a live animal (Mekonnen et al., 2010) was used. The water of a live animal has three components: the indirect water footprint of the feed, the direct water footprint of the drinking water and service water consumed (Chapagain et al., 2003, 2004; Mekonnen et al., 2012). In the case of the water footprint of a pet calculation, the service water consumed by a pet was considered negligible. While for the land footprint of a pet, the only considered component was the land footprint to grow feed both for a crop which is directly used in the pet food or to feed the animal to produce meat.

The water and land footprint of a pet are expressed as follow

$$WF[a,w] = WF_{feed\ ing}[a,w] + WF_{drink}[a,w] \quad (1)$$

$$LF[a,w] = LF_{feed\ ing}[a,w] \quad (2)$$

where $WF_{feed\ ing}[a,w]$ and $LF_{feed\ ing}[a,w]$ represent the average of water and land footprint of ingredients consumption from different pet food products related to the pet animal breed a weighing w.

$WF_{drink}[a, w]$ represents the required drinking water consumption for the pet breed a weighing w. The water and land footprint of feed ingredient can be determined as

$$WF_{feed\ ing}[a, w] = \sum_{p=1}^{n} f\ [p, a, w] \times\ Feed\ [a, w] \times WF_{ing}[p] \quad (3)$$

$$LF_{feed\ ing}\ [a, w] = \sum_{p=1}^{n} f\ [p, a, w] \times Feed\ [a, w] \times LF_{ing}[p] \quad (4)$$

where $f\ [p, a, w]$ is the fraction of an ingredient p in the commercial pet food applies to the pet breed a with a certain weight w, n is the number of ingredients in the commercial pet food, $Feed\ [a, w]$ is the total amount of commercial pet food consumed by pet breed a weighing w kilogram over a year, $WF_{ing}[p]$ and $LF_{ing}[p]$ are the water footprint (blue, green and grey) and land footprint of ingredient p. The water and land footprint of pets in a particular nation was estimated by multiplying the water and land footprint of a certain pet breed with the total population in a nation. Then, the global water and land footprint of pets was calculated by summing all the water and land footprint of pets of nations.

Composition and fraction of pet food

The composition and share of ingredients in the pet food vary depending on the formula of pet food products. Some of the pet food company did not give their full fraction data per ingredient. Therefore, an assumption had to be made to complete the animal (by-) and crop (by-) products ingredient. First, ingredients which are listed on the pet food labels should be ordered in descending order by their weight in the product (Beynen, 2014; Roudebush et al., 2010). Second, in order to assess the water and land footprint of meat meal (section 2), this ingredient must be converted into fresh meat.

Volume of feed

In this thesis, the total amount of pet food consumed by dogs and cats is based on the daily intake guideline provided by every pet food products. The daily intake guideline states the feed (weight/unit of product) per body weight of dog or cat. Dogs have more various body weight compared to cats. Depending on the breed, the body weight of adult dogs varies from Chihuahua with 1 kg to St. Bernard with 115 kg (Burger, 1994), while for adult cats, the body weight each breed is almost similar around 4 - 6 kg (Kienzle et al., 2011). A distinction was made depending on the breed and body weights of pets. There are 189 dog breeds and 43 cat breeds with different body weight which were used in this study.

Water footprint of ingredient

The green, blue and grey water footprint for crops (by-) and animals (by-) products were taken from Mekonnen et al. (2010, 2011). The water footprint of ingredients used in this thesis was the global average with the reason that the pet food company kept secretly the origin of their ingredients. The commonly used ingredient for pet food are listed in Table 2.

Table 2. The water footprint of typical pet food ingredients. Source: Mekonnen et al. (2010, 2011)

Ingredient	Water Footprint (m^3/ton)
Linseed	9,416
Lamb	8,561
Red lentils	5,873
Chicken	4,300
Turkey	4,325
Eggs	3,265
Rice	1,674
Chicken liver	1,213
Potato	287
Cranberries	276

Land footprint of ingredient

Similarly to the water footprint of the ingredients, the land footprint of the ingredients is divided into crop and animal products. The land footprint of the ingredients in this study was assessed in a world average taken from FAOSTAT (2017). The land footprint of crop products (LF_c) can be calculated by

$$LF_c = \frac{A_c}{P_c} \tag{5}$$

where LF_c is the land footprint of crop product c with the unit of ha/ton. A_c is the total area harvested of crop c in the world (ha) and P_c is the total production of crop c in the world (ton).

The land footprint of animal products, on the other hand, was taken from Nijdam et al. (2012). The data shown from Nijdam et al. (2012) presents ranges and units represent how much land used to grow crops for animal feed during a year to produce a kilogram of animal products (see Table 3). To simplify the calculation, an average of the land footprint of every animal products was conducted.

Table 3. The land footprint of animal products. Source: Nijdam et al. (2012)

Ingredient	Land Footprint (m^2/kg)
Beef	7 - 420
Industrial systems	15 - 29
Meadows	33 - 158
Extensive pastoral systems	286 - 420
Culled dairy cows	7
Pork	8 - 15
Poultry	5 - 8
Eggs	4 - 7
Mutton and lamb	20 - 33

Water footprint of drinking water

To calculate the water footprint of drinking water of pets, an approach from Harrison et al. (1960); Haskins (1984) was used. The general water requirement of dogs and cats (ml/day) is approximately equivalent to the daily energy requirement (DER) (kcal/day) (Gross et al., 2010) where DER represents the average daily energy expenditure of any animal depending on life stage and activity. The water footprint of drinking water of pets can be expressed as

$$WF_{drink}[a, w] = k \times RER \tag{6}$$

where k is the factor to estimate daily energy for pets (k_{dogs} = 1.6; k_{cats} = 1.2) and RER (Resting Energy Requirements) represents the required energy for a normal but fed animal at rest in a thermoneutral environment. The RER can be calculated by raising the body weight (BW) of the animal to the power of 0.75 and the average RER for mammals is approximately 70 kcal/day/kg metabolic body size (Gross, Yamka, Khoo, Friesen, Jewell, Schoenherr, & Zicker, 2010). RER can be expressed as

$$RER = 70(BW)^{0.75} \tag{7}$$

RER is expressed in kcal/day and BW is expressed in kg

Pet population

The pet population of nations in 2016 was based on the most recent survey from Euromonitor (2017). This data combines the market industry knowledge and in-country research resulting 54 countries dog and cat population in 2016. To add up the pet population in the missing countries from Euromonitor (2017), another data from World Society for the Protection Animal (2008) was included in the pet population data. However, this data was based on dog population in 93 countries and cat population in 81 countries in 2008. So that, a modification from World Society for the Protection Animal (2008) data was conducted to estimate the pet population in 2016. The estimation was based on the trend population of pets from the past ten years (2006 – 2016) from Euromonitor (2017) (see Figure 2), then the trend population was applied to the countries that do not exist in Euromonitor (2017) but available in World Society for the Protection Animal (2008). Additionally, a distinction was made for dog's category due to the wide range of their body weight namely: small breed (1 – 9 kg), medium breed (9 – 23 kg) and large breed (more than 23 kg).

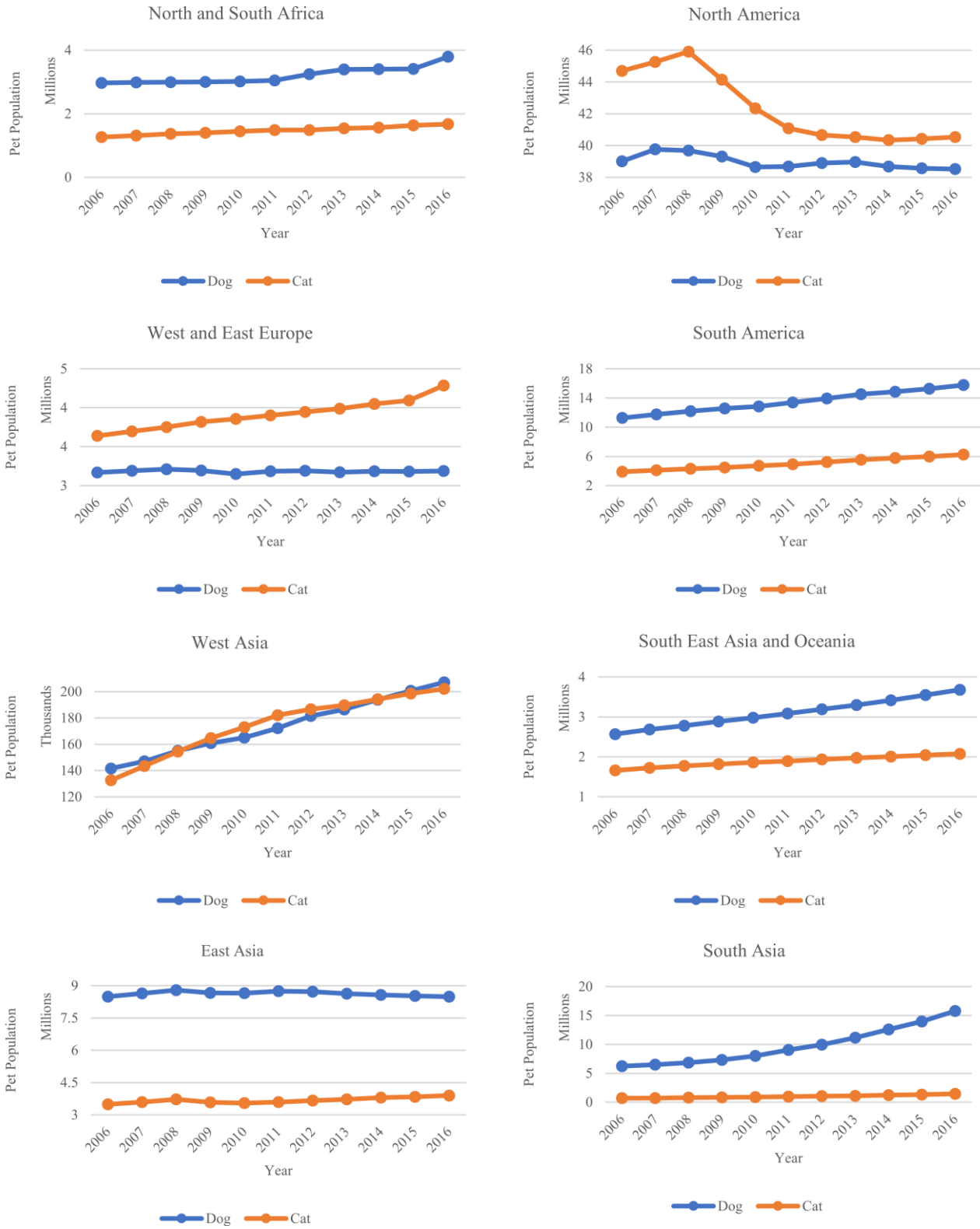

Figure 2. World pet population trends during the period from 2006 to 2016. Source: Euromonitor (2017)

3.2. Data collection

The input data has been collected from different resources. The data source of the composition and ingredient's fraction in the pet food was gathered from the interview with the pet food companies. Qualitative semi-structured interviews were conducted with five pet food companies located in the Netherlands, Canada, and the United States. Seven dry dog food and six dry cat food products were assessed in this study. However, the product brands and manufacturers' name would be kept strictly confidential and used only for the analysis of this thesis. Therefore, to represent the dog and cat food products in this study, the name of the brands were disguised in the alphabet letters. For dog food products were shown with the alphabet A-G, while for cat food products were presented with the alphabet P-U. Table 4 and Table 5 provide the information about the first five ingredients listed on every pet food products. Appendix I and II provide complete data composition of the pet foods. Table 6 summarises the specific data resources for this study.

Table 4. The composition of dog foods. Source: Interview with the pet food companies

A		B		C		D		E		F		G	
Ing*	%	Ing*	%	Ing*	%	Ing*	%	Ing*	%	Ing*	%	Ing*	%
fresh chicken	11%	fresh chicken	26%	chicken meal	25%	lamb meal	20%	chicken meal	12%	fresh chicken	21%	fresh chicken	44%
turkey meat	7%	dried chicken	19%	oat	23%	brown rice	19%	fresh chicken	10%	chicken meal	21%	sweet potato	23%
eggs	6%	potato	15%	fresh chicken	5%	rice	19%	brown rice	19%	potato	14%	dried chicken	16%
dried chicken	4%	sweet potato	10%	fresh chicken by-products	5%	chicken fat	10%	dried potato	18.6%	turkey meal	10%	fresh turkey	6%
dried turkey	4%	beet pulp	6%	red lentils	4%	salmon	6%	Peas	10%	dried eggs	4%	dried turkey	3%

*Ing = Ingredients

Table 5. The composition of cat foods. Source: Interview with the pet food companies

P		Q		R		S		T		U	
Ing*	%	Ing*	%	Ing*	%	Ing*	%	Ing*	%	Ing*	%
fresh chicken	18%	fresh chicken	35%	fresh turkey	36%	fresh chicken	22%	fresh chicken	9%	salmon	20%
fresh turkey	7%	dried chicken	22%	dried chicken	18%	sweet potato	21%	fresh turkey	9%	salmon meal	20%
eggs	5%	sweet potato	15%	sweet potato	15%	dried chicken	17%	fresh chicken liver	9%	peas	20%
fresh chicken liver	5%	potato	10%	potato	10%	dried turkey	12%	chicken meal	8%	dried potato	20%
fresh flounder	4%	flax seed	5%	chicken fat	6%	fresh turkey	5%	turkey meal	8%	chicken fat	8%

*Ing = Ingredients

Table 6. Overview of data sources

Data	**Sources**
Composition and fraction of the ingredient in the pet food	Interview with the pet food companies
Water content of meat	United States Department of Agriculture (2011); Williams (2007); Wong et al. (1993)
Water content of fruits and vegetables	DeLong (2006)
Total amount of pet food consumed	Feeding guideline from the pet food label
Dog breeds and their body weight	American Kennel Club (2017)
Cat breeds and their body weight	Kienzle et al. (2011); The International Cat Association (2016)
Water footprint of ingredients	Mekonnen et al. (2010, 2011)
Total area harvested of crop	FAOSTAT (2017)
Total production of crop	FAOSTAT (2017)
Land footprint of animal products	Nijdam et al. (2012)
Pet population	Euromonitor (2017); World Society for the Protection Animal (2008)

4. Results

In this chapter, the results of the methods are presented. First, the result of the water and land footprint of the pet food products is shown followed by the global pet population and water and land footprint of pets in 2016.

The water and land footprint of pet food products

Figure 3 and Figure **4** show the water and land footprint of dog and cat food products. The average water and land footprint of dog foods are higher than cat food products with 5 m^3/kg and 8 m^2/kg for dog food products while for cat food products are 2 m^3/kg and 3 m^2/kg. Additionally, from all the pet food products assessed in this study, all of them put meat in the first order of their ingredient lists meaning that meat has the biggest fraction in both dog and cat food products. For the dog food products, ingredients based on the animal products account for the largest share out of this total with 58%, and ingredients from the crop products account for the remaining 42%. The cat foods, on the other hand, contain higher animal products with 67% and crop products with 33%. Furthermore, dog food products use more meat meal or dried meat ingredients with 23% from the whole animal content in the product in average, while cat food products only use 17%.

The value of water and land footprint every pet food products vary depending on the composition of ingredients and nutrient contents. Dog food product F and G have similar ingredients of meat. Dog food product F uses 21% of fresh chicken meat and 21% of the chicken meal, while dog food product G uses more fresh chicken with 44% and 16% of dried chicken. Although dog food product F uses less fresh chicken, it has around 20% higher water and land footprint than dog food product G. The reason is that to produce 1 kg of dried chicken or chicken meal, it requires 2.5 kg of fresh chicken. Thus, it increases the amount of fresh chicken which also linearly increases the product's footprints. It implies that more dried ingredients in the pet food, it requires more water and land to produce it.

On the other hand, from the nutritional perspective, dog food product A and F have almost similar protein and fat content also they are based on the poultry meat (see Figure 5). However, dog food product A uses 20% more animal by-products rather than dog food product F. This resulted that dog food product A has 50% lower water and footprint of a product than dog food product F per kilogram.

Even though dog food product B has higher meat content (60%) than dog food product D (46%), the water and land footprint of dog food product B are lower than dog food product D. It is because of the different type of meat used in each product. Dog food product B uses poultry meat which has lower water and land footprint value than dog food product D which is based on the lamb meat. On the similar case, cat food product R and U have similar protein and fat content (see Figure 6). However, cat food product U has very

low water and land footprint compare to cat food product R. This is due to cat food product R is based on the poultry meat, while cat food product U is based on the wild-fish meat which has zero water and land footprint.

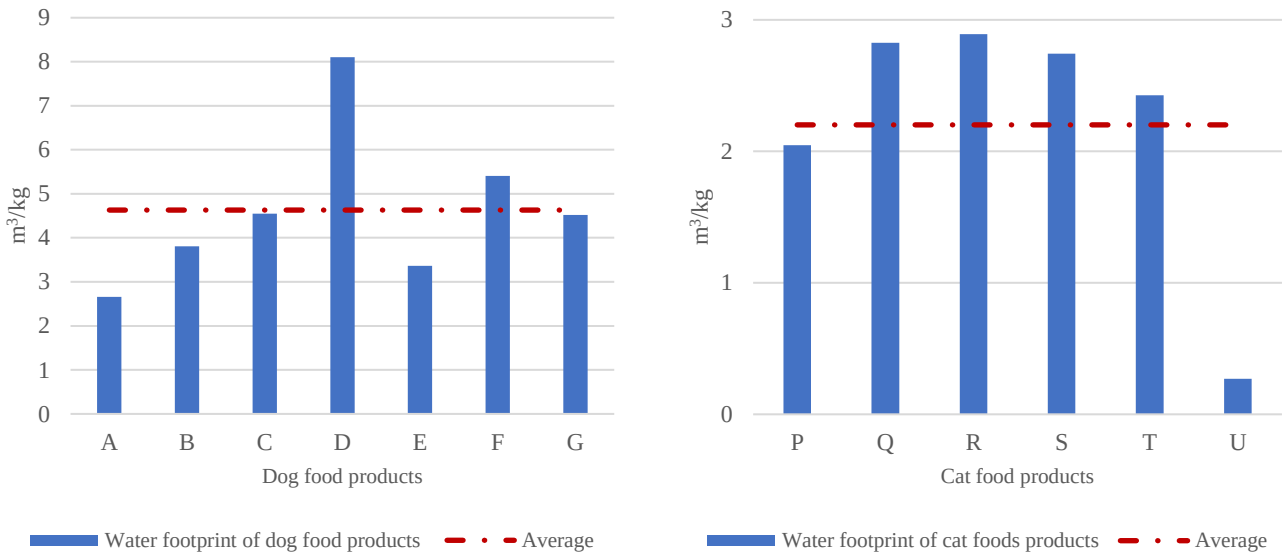

Figure 3. The water footprint of dog and cat food products (m^3/kg)

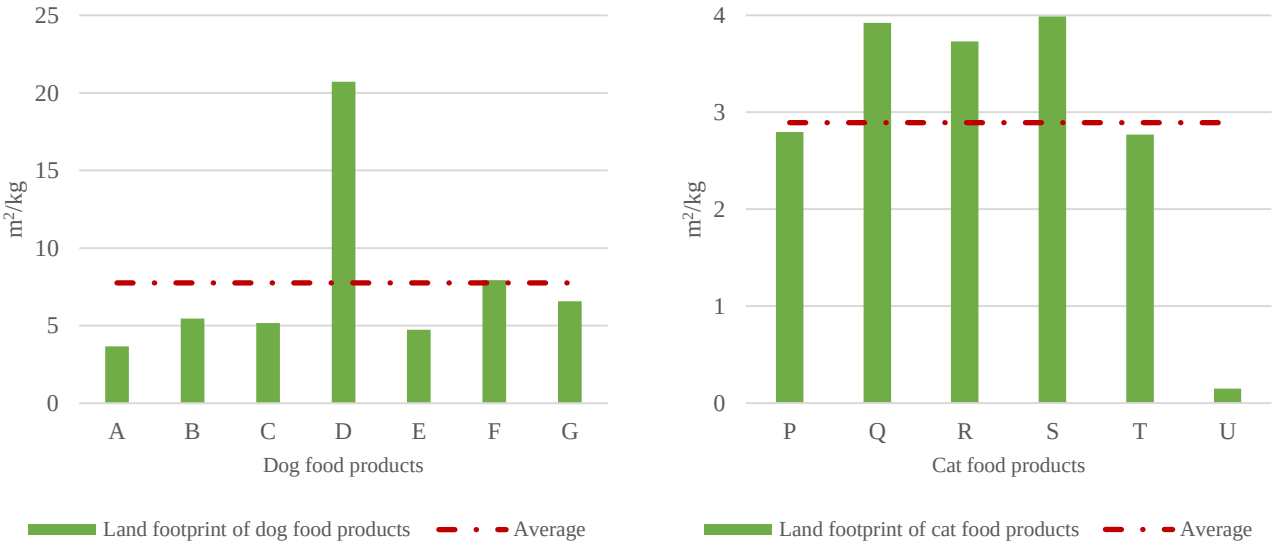

Figure 4. The land footprint of dog and cat food products (m^2/kg)

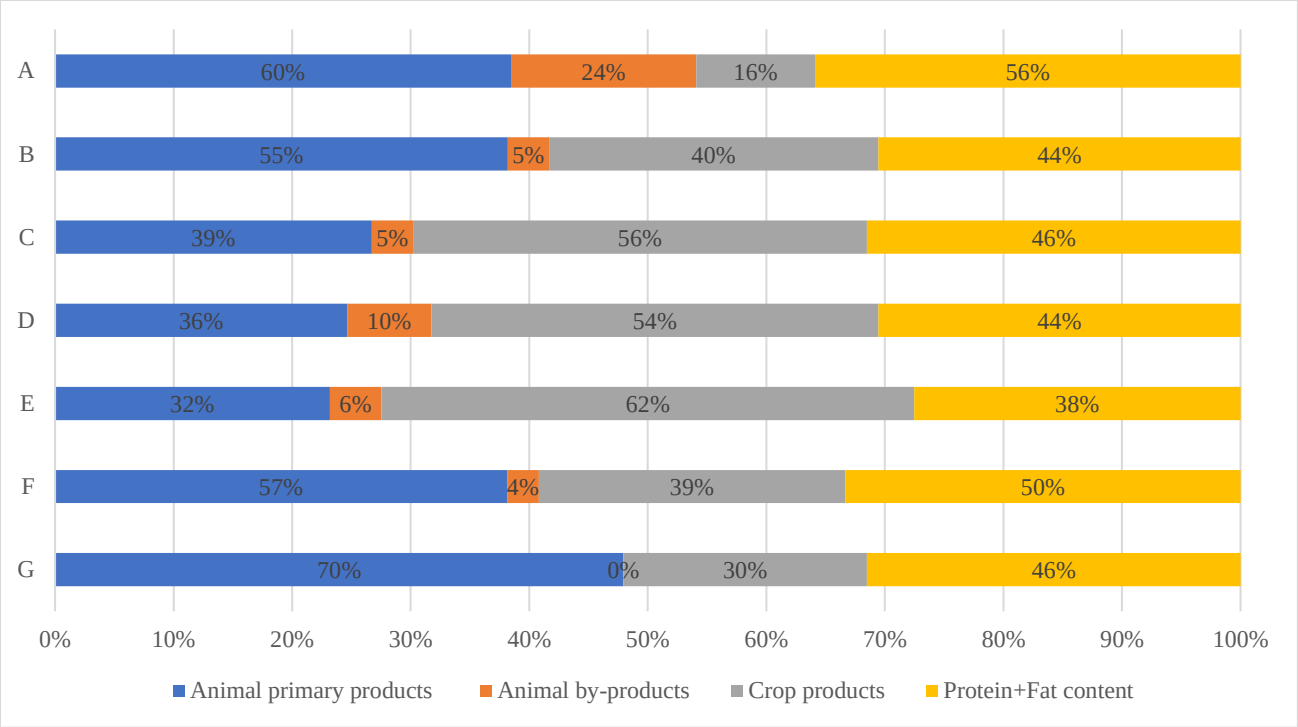

Figure 5. Comparison of the ingredients and nutrients in the dog foods. Source: Interview with the pet food companies

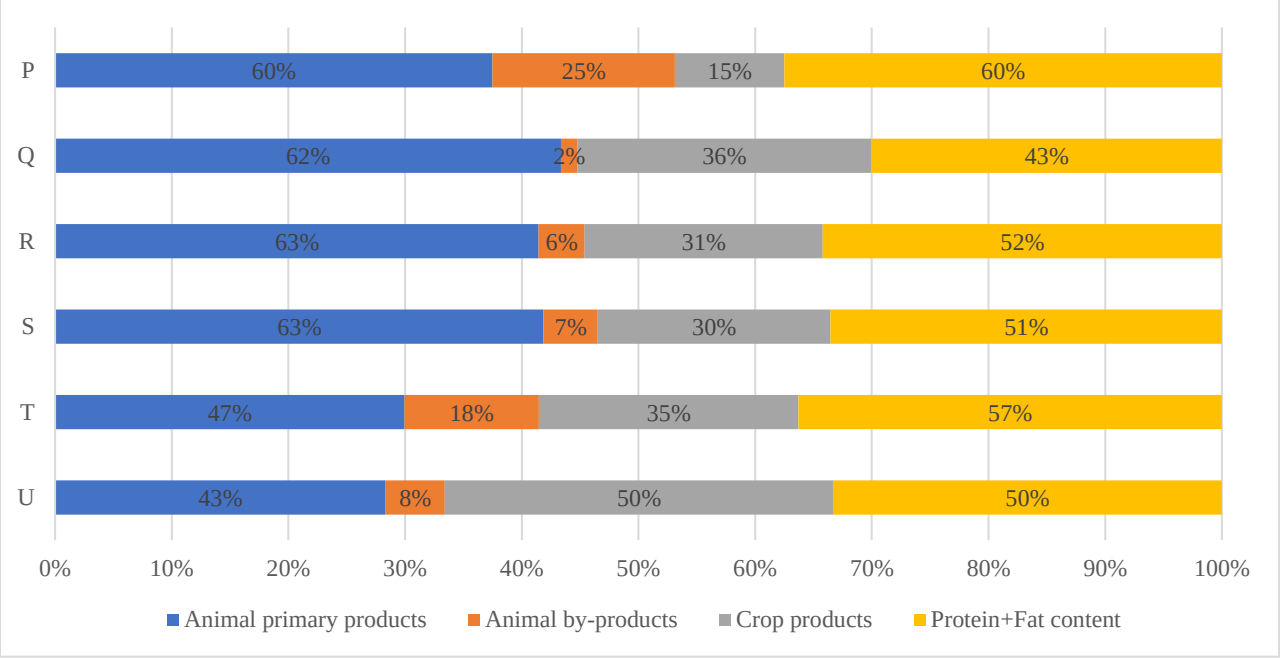

Figure 6. Comparison of the ingredients and nutrient contents in the cat foods. Source: Interview with the pet food companies

Pet population

The total global pet population was estimated for 735,888,192 in 2016. The United States had the highest pets population with 143,284,000 followed by Brazil, China, and Russia with 80,059,700; 39,949,000 and 39,603,000 respectively. Global pet population in 2016 is presented in Appendix III. Globally, the population of dogs outnumbered cats in 2016 with the proportion 58% and 42%. However, if it is looked closely based on the range of body weight, the number of cats exceed the population of other three dog's breeds category (see Figure 7). The least population was the large dog breeds with 111,745,030 followed by the medium and small dog breeds category with 128,669,240 and 188,177,428, while the global cats population was 308,296,500 (see Appendix III).

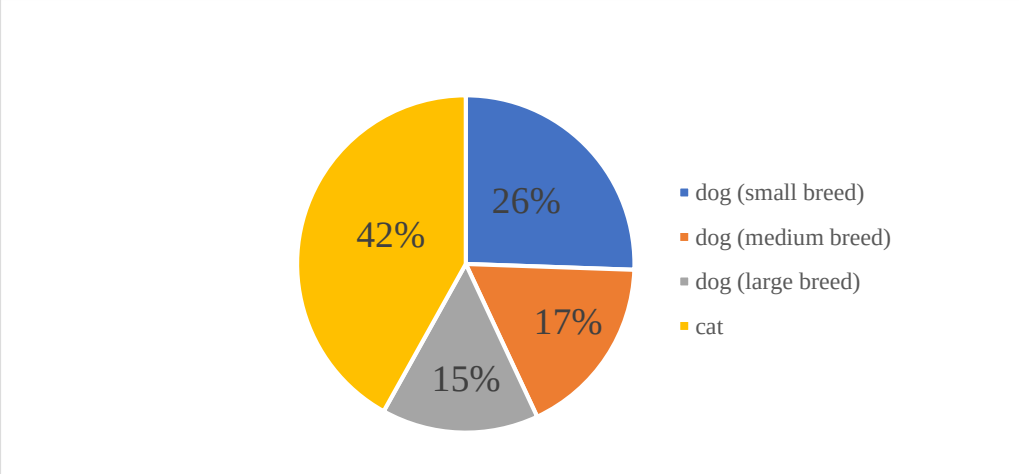

Figure 7. The proportion of global pet population in 2016. Adapted from: Euromonitor (2017)

Water and land footprint of pets 2016

In 2016, the total global water and land footprint of pets were estimated to be 193×10^6 m^3 and 280×10^6 m^2. Appendix VI and VII provide the complete data of water and land footprint of pets of nations in 2016. The largest fractions of the water and land footprint pets lied in the USA with 18% and 14% respectively followed by Brazil with 11% (both for water and land footprint of pets) and China with 6% (the water footprint of pets) and 7% (the land footprint of pets). Table 7 presents the result of the global water and land footprint of pets in 2016.Appendix Figure 9 and Figure **10** map the total water and footprint of pets in the world in 2016. It is evident that countries with large pet populations have a large water and land footprint.Thus, it is more interesting to look at the water and footprint per pet category.

By applying the method in equation 1 and 2, the water and land footprint of dogs and cats per breed and body weight were estimated. Table 8 shows the result of the annual food intake, water footprint of feed ingredients, water footprint of drinking water and land footprint of feed ingredients of pets. The annual averaged pet food consumption in 2016 amounted to be 24 kg/year (a cat), 49 kg/year (a small dog breed), 88 kg/year (a medium dog breed) and 153 kg/year (a large dog breed). The results show that the heavier of a body weight, the larger water and land footprint of a pet. The large breed dogs have the biggest annual average water and land footprint with 703 m^3/year and 1147 m^2/year while cats have the smallest water and land footprint with 85 m^3/year and 86 m^2/year (Table 8). Appendix IV and V present the full result of the water and land footprint of pets. Even though the population of the large breed dogs was the least among other pet categories, the large dog breeds became the biggest contributor to the global water and land footprint of pets in 2016 with 39% and 35% of overall water and land footprint of pets (see Figure 8). Meanwhile, cats which have the largest population of other three dogs categories only contribute around 12% and 11% for the global water and land footprint of pets in 2016.

Table 7. Global average water and land footprint of pets in 2016

Pet Category		Global average water footprint in 2016 ($\times 10^6$ m^3)	Global average land footprint in 2016 ($\times 10^6$ m^2)
	Cats	24	31
Dog	Small breeds	42	68
	Medium breeds	51	84
	Large breeds	76	97
	Total	193	280

Table 8. Summary of annual food intake (kg/year), water footprint of feed ingredients, and drinking water (m^3/year), and land footprint of feed ingredients of pets (m^2/year)

Pet Category		Body Weight (kg)	Total Food Intake (kg/year)	$WF_{feed\ ing}$ (m^3/year)	WF_{drink} (m^3/year)	$LF_{feed\ ing}$ (m^2/year)
	Cats	4 – 6	24	85	0.1	86
Dogs	Small breed	1 - 9	49	231	0.2	376
	Medium breed	9 - 23	88	416	0.3	683
	Large breed	> 23	153	702	0.6	1147

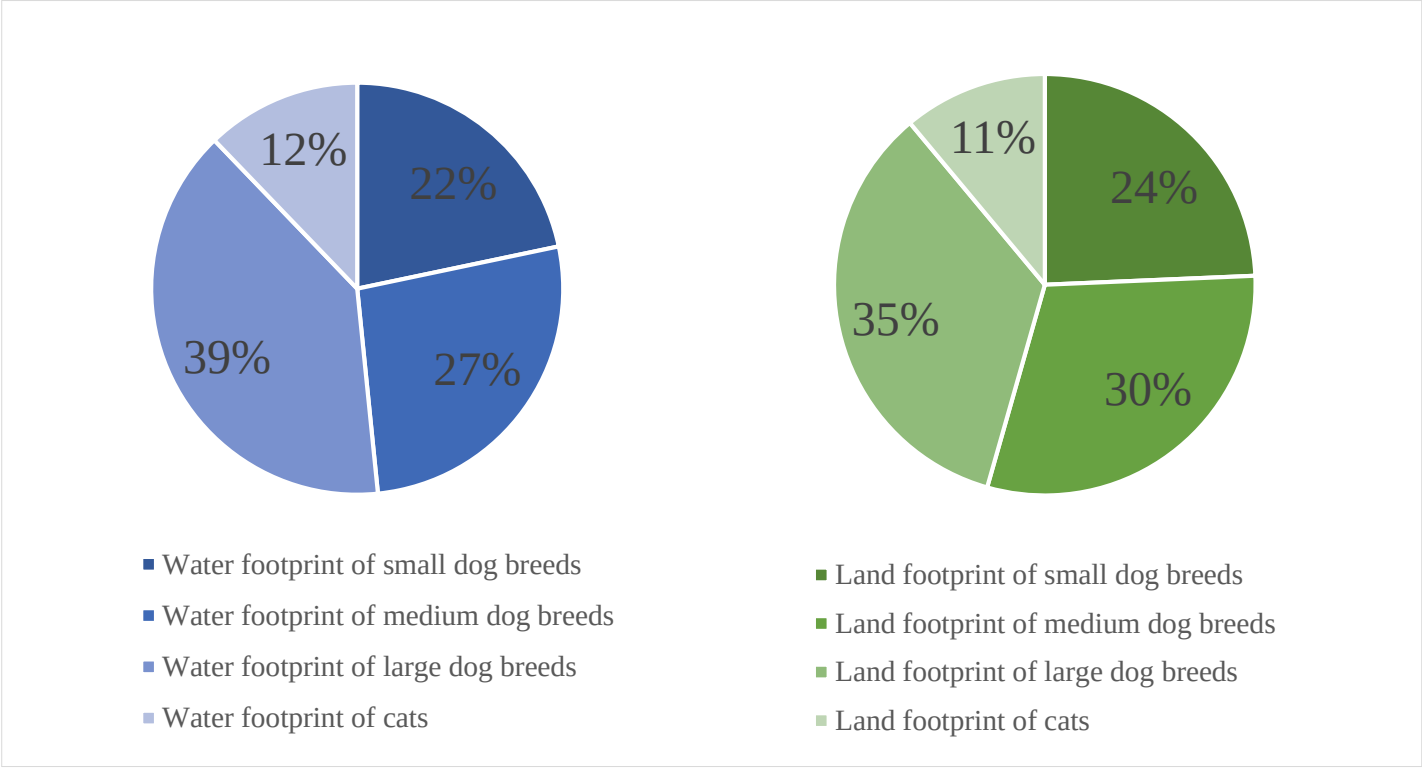

Figure 8. The proportion of the global water and land footprint of pets in 2016

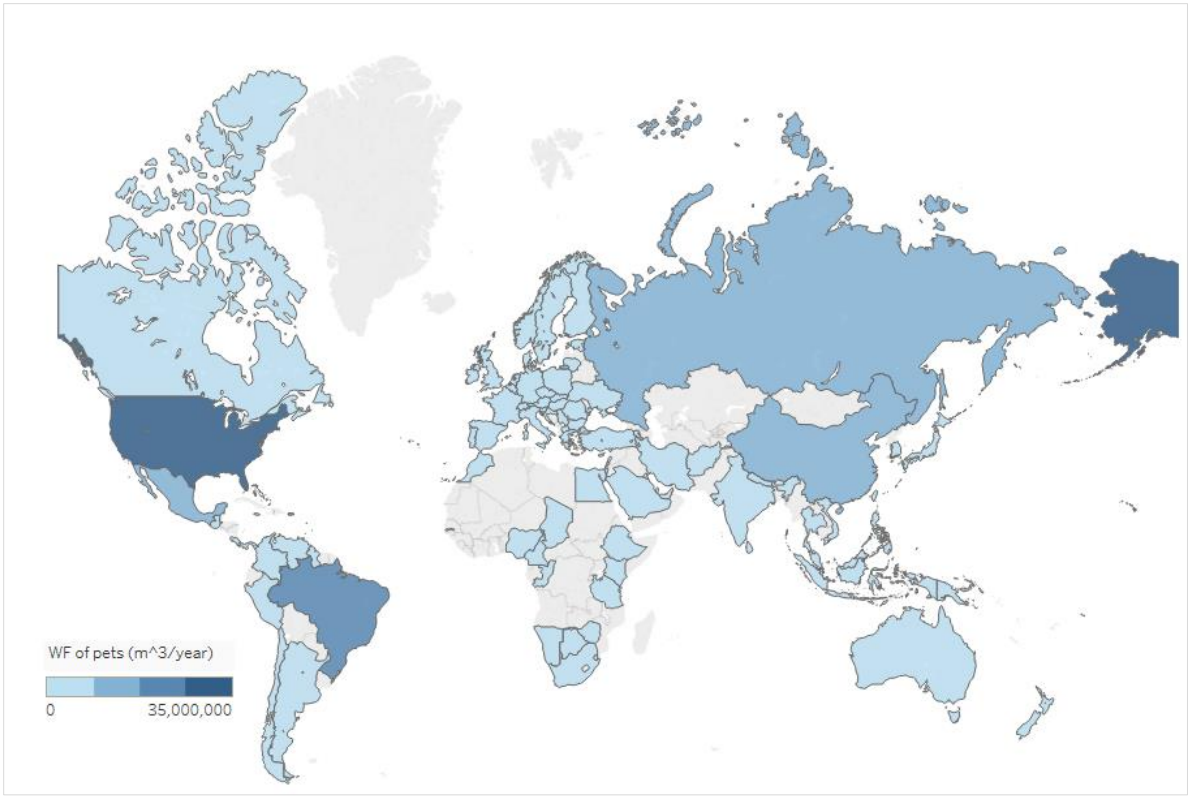

Figure 9. Global water footprint of pets in 2016 (m^3/year)

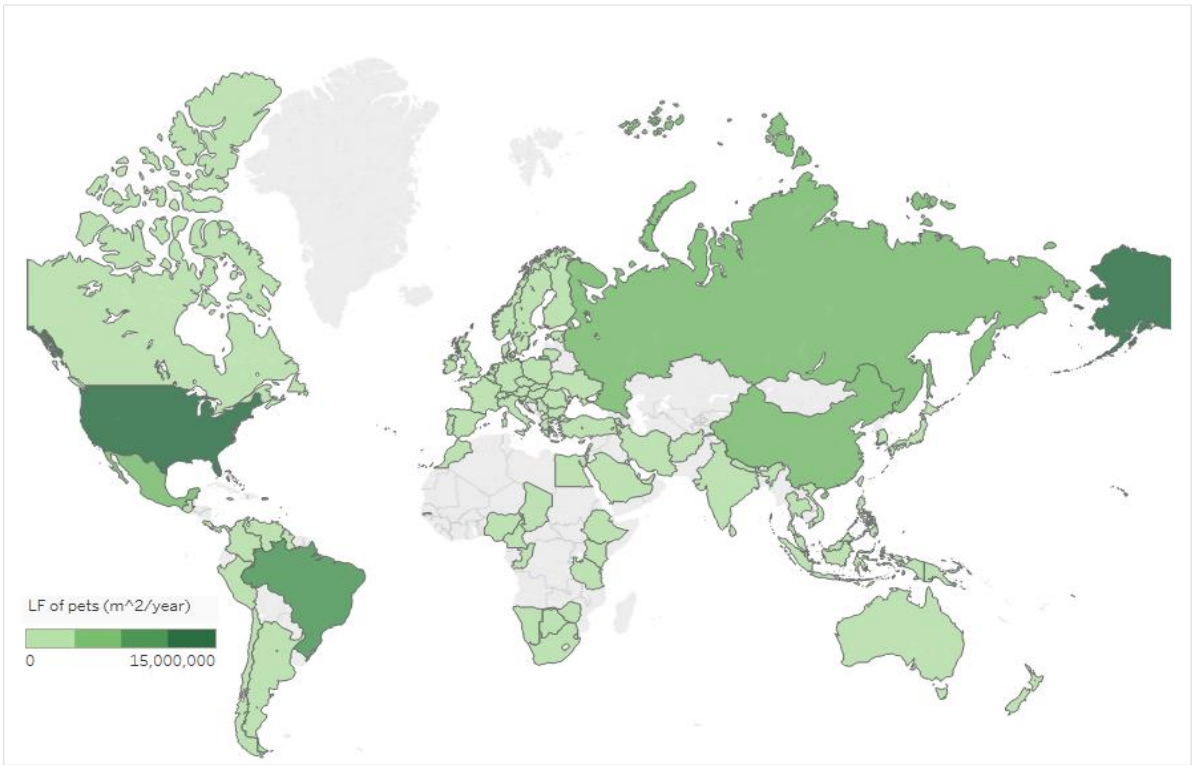

Figure 10. Global land footprint of pets in 2016 (m^2/year)

5. Discussion

In this chapter, several remarks concerning the general method and results of this research are discussed. To begin with, the results of the current study can be compared with results from earlier studies (Aivazidou et al., 2017; Rushforth et al., 2013; Vale et al., 2009). Then some issues found in this study will be evaluated.

A study conducted by Aivazidou et al. (2017) quantified the water footprint of a Maltese dog. They concluded that a 4 kg small dog breed has 156 m^3/year of water footprint from its diets. This result is slightly higher with the result of this study with 148 m^3/year. This comparison is logical because Aivazidou et al. (2017) use beef as the main meat ingredient in the pet food, while in this current study uses poultry and lamb meat as the ingredients in the dog food products where beef has higher water footprint than poultry or lamb per kilogram.

Rushforth et al. (2013) estimated for the water footprint of dog food based on several aspects: the grain, cotton and sugar cane farming, power generation, manufacturing, and cattle ranching. They report that dog food has 10 m^3/kg for the whole aspects. If the water footprint of feed ingredients is the only consideration, then it becomes 9 m^3/kg with the beef and lamb based ingredients. This result is higher than this study which is 5 m^3/kg (see Table 9). However, these results will be even closer if in the current study only consider lamb meat based ingredient and it will result in 8 m^3/kg. On the other hand, Rushforth et al. (2013) estimated the land footprint of dog food for 9 m^2/kg which is only slightly higher to the current estimation with 8 m^2/kg. Nevertheless, the current estimation will be far greater than the estimate made by Rushforth et al. (2013) if only consider lamb meat based with 21 m^2/kg. First, the value of water and land footprint of ingredients are different. The current study uses the water and land footprint of world average while Rushforth et al. (2013) only mention the United States as the reference of ingredients' origin. Second, the current study has more various ingredients used such as chicken, turkey, and lamb which make the average is lower than the result from Rushforth et al. (2013) which used beef and lamb meat as the ingredients.

Table 9. Comparison the average water (m^3/kg) and land footprint (m^2/kg) of dog food between the current study and Rushforth et al. (2013)

	Average water footprint of dog foods (m^3/kg)	Average land footprint of dog foods (m^2/kg)
Current study	5	8
Rushforth et al. (2013)	9	9

The land footprint of pets estimation in this study is very low compared to the result from Vale et al. (2009) even though the annual food intake is very close to this study (see Table 10). First, the current study uses the global average land footprint of ingredients, while Vale et al. (2009) used the land footprint of a resident in Cardiff, Wales which is higher than the global average. For example, the land footprint of chicken and lamb meat of a resident in Cardiff is 43.3 m^2/kg and 100.6 m^2/kg while for the global average of chicken and lamb meat are only 6.5 m^2/kg and 26.5 m^2/kg. Second, the current study provides more accurate estimation by providing more various ingredient composition and based on the weight fraction of the ingredient in the pet food product. Meanwhile, the estimation made by Vale et al. (2009) is only based on one meat and cereal. Also, the weight of the ingredient is based on the percentage of protein, fat and carbohydrate content by assuming that protein and fat are from meat and carbohydrate is from cereal.

Table 10. Comparison total food intake (kg/year) and land footprint of pets (m^2/year) between the current study and Vale et al. (2009)

Pet Category	Total food intake (kg/year)		Land footprint (m^2/year)	
	Current study	Vale et al. (2009)	Current study	Vale et al. (2009)
• Indoor Cat	24	26	108	1,500
• Small dog (e.g. Scottish terrier)	56	73	427	1,800
• Medium dog (e.g. Border collie)	94	110	729	2,700
• Large dog (e.g. German shepherd)	145	146	1,084	3,600

There are several uncertainties in the quantification of water and land footprint of pets and due to the lack of information, some assumptions must be made in this study. Several issues are noticed which may have a major effect on the result of this study:

- The ingredient selection, especially animal products, affects significantly to the water and land footprint of a pet food product calculation. For example, dog food product D is based on lamb meat, and this product increases the average of the water and land footprint of dog food products, while other products are based on poultry meat. Moreover, cat food product U is based on the wild-fish meat which has zero water and land footprint. This product declines the average of water and land footprint cat food products which other products are based on poultry meat. However, there are limited data sources in this study to assess the pet food ingredients due to the lack of transparency from the pet food companies. Additionally, some of the pet food companies only gave several main ingredients fraction data while for other ingredients had to be estimated roughly based on the explanation from Beynen (2014); Roudebush et al. (2010). Therefore, the lack of pet food compositions variety in this study may lead to the poor accuracy of the water and land footprint of pet food products quantification.

- The amount of the pet food and drinking water fed by the pet owners might vary considerably depending on the pet owners behaviour (Michel et al., 2008). For the case of pet food consumption, the recommendation of feeding daily intake from every pet food products is used with the assumption that all the pet owners follow the recommendation to feed their dogs and cats. Meanwhile, a method of Harrison et al. (1960); Haskins (1984) is used since it is difficult to estimate how much water the pet owners give to their pets. However, as it is expected that the result of the water footprint of drinking water as the direct water use will be much smaller than the water footprint of feed ingredients as the indirect water use similarly to the water footprint of human consumption (Hoekstra, 2013b).
- Data on the fraction of feed consumption for cattle, lamb, and poultry in every country is not available. Therefore, a rough estimation from Nijdam et al. (2012) was taken into account to estimate the land footprint of animal products. These data have the limitation that the land footprint of animal products only based on the several countries and may lead to the wrong value of land footprint of animal products in a global average.
- Euromonitor (2017) provides the most recent survey on dog and cat population around the world in 2016, but only 54 countries are covered in the survey. For countries which are not available in Euromonitor (2017), some assumptions were made to estimate the total pet population as it is explained in section 3. However, the method to collect the quantity of dog and cat population differs between Euromonitor (2017) and World Society for the Protection Animal (2008). Euromonitor (2017) uses market industry database and in-country research such as statistic from the local government, online database, and national trade reports. Meanwhile, World Society for the Protection Animal (2008) collected the samples by using questionnaire which was sent to more than 100 countries and using a statistical model to estimate the population of dog and cat. The statistics include economic status, percentage of urbanization, ageing population and death rates which were linked to pet ownership trends in each country. Due to different methods used from both sources, there has been the difference in the dogs and cats population in the same area at the same period. For example in 2008, Euromonitor (2017) has indicated the population of dogs and cats in the US are 73,044,000 and 82,849,700 while World Society for the Protection Animal (2008) reported 67,085,100 for dog population and 83,884,333 for cat population. Although the data from both sources are already combined, the data of pet population from many African countries are still missing.

6. Conclusions

This study shows that the global water and land footprint of pets are 193×10^6 m^3 and 280×10^6 m^2 in 2016. They contribute 2×10^{-21} % and 2×10^{-35} % to the total global annual average of water and land footprint of humanity with $9{,}087\times10^{27}$ m^3 (Hoekstra et al., 2012) and $9{,}903\times10^{10}$ m^2 (Lambin et al., 2011) respectively. Although the population of the large dog breeds is the least among other pet categories with 15% of the total pet population, they are the largest contributor to the global water and land footprint of pets with the proportion 39% and 35% respectively. The average of a large dog breed has much higher water and land footprint (703 m^3/year and 1,147 m^2/year) than a medium dog breed (416 m^3/year and 683 m^2/year), a small dog breed (231 m^3/year and 376 m^2/year) and a cat (85 m^3/year and 86 m^2/year). These findings confirm that the body weight which is directly related to the pets' consumption rate is an important factor affecting the global water and land footprint of pets.

Besides, the composition pet food products also play important roles to the impact of the global water and land footprint of pets. The nutrient contents and ingredient choice are related to each other in determining the footprints of pet food products. The meat content and quality of ingredients in the pet foods are two aspects that pet owners consider before buying a pet food (Laflamme et al., 2008; Michel et al., 2008). However, dogs and cats require specific nutrients requirements to live, not specific ingredients (section 2). This study finds that all the dog and cat food products exceed the requirement of protein content made by AAFCO with the dog should have 18% of protein, whereas the cat should have 26% of protein in their diet. In this study, dog foods use 58% of animal content, while cat foods use 67% of animal content in average from the whole used ingredients in the product. This indicates that the animal products in the pet food should be given the primary concern since they have larger water and land footprint value compared to the crop products.

This study discovers that the using of more animal by-products tends to have lower water and land footprint of a pet food rather than the using of more animal primary products. It is caused by the animal by-products are less valuable than animal primary products which affecting their value of water and land footprint (Hoekstra, 2011). The animal by-products which are found in this study are chicken liver, necks, and kidneys. These products are not commonly consumed by humans; thus they have advantages to reduce the burden of meat consumption which directly compete with the human food.

Moreover, the using of meat meal or dried meat generates higher water and land footprint compared to the product which contains more fresh meat. It is because of the inefficient conversion from fresh meat to the dried form. For example, to produce 1 kg of chicken meal, it requires 2.5 kg of fresh chicken which implies that more water and land are needed to produce a pet food with meat meal content rather than with fresh meat content.

Similarly to the human diet, the consumption rate and ingredient selection are the major components in determining the water and land footprint of pets. Nevertheless, unlike a human who can control their diets and pick the ingredients which have low footprints, pets cannot adjust their consumption rate and choose what to eat in the pet food as the ingredients are already blended by the manufacturers. Thus, the decision in reducing water and land footprint of pets is from the pet owners to give the proper amount of pet food and choose the best ingredients both for pets and environments.

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APPENDICES

Appendix I: Dog food composition

Qualitative semi-structured interviews were conducted with five pet food companies located in the Netherlands, Canada, and the United States. Seven dry dog food are presented in Table 11-17. Due to the confidential data, the name of the dog food products are disguised into alphabet letters (A-G).

Table 11. Dog food product A

Ingredient	Ratio
fresh chicken meat	13%
fresh turkey meat	7%
fresh whole eggs	7%
fresh chicken liver	6%
fresh whole herring	6%
fresh flounder	5%
fresh turkey liver	5%
fresh chicken necks	4%
fresh chicken heart	4%
fresh turkey heart	4%
chicken dried	4%
turkey dried	4%
whole mackarel dried	4%
whole sardine dried	4%
whole herring dried	4%
whole red lentils	1.2%
whole green lentils	1.2%
whole green peas	1.2%
lentil fiber	1.2%
whole chickpeas	1.2%
whole yellow peas	1.2%
whole pinto beans	1.2%
whole navy beans	1.2%
herring oil	1%
chicken fat	1%
chicken cartilage	1%
chicken liver freeze dried	0.2%
turkey liver freeze dried	0.2%
fresh whole pumpkin	0.2%
whole butternut squash	0.2%
fresh whole zucchini	0.2%
fresh whole parsnips	0.2%
fresh carrots	0.2%
fresh apple	0.2%
fresh pears	0.2%
fresh kale	0.2%
fresh spinach	0.2%
fresh beet greens	0.2%
fresh turnip greens	0.2%
brown kelp	0.2%

Table 12. Dog food product B

Ingredient	Ratio
fresh chicken	26%
dried poultry	19%
potato	15%
sweet potato	10%
beet pulp	6%
poultry fat	5%
dried krill	4%
dried egg	3%
chicken stock	3%
brewer's yeast	2%
linseed	1.2%
seaweed	1%
betaglucans	1%
dried cranberries	0.04%
dried apple	0.04%
dried pear	0.04%
dried broccoli	0.04%
dried tomato	0.04%

Table 13. Dog food product C

Ingredient	Ratio
chicken meal	25%
oat flakes	23%
fresh chicken	5%
fresh chicken liver, heart, kidney)	5%
red lentils	4%
green peas	4%
green lentils	4%
fresh turkey meat	4%
fresh eggs	4%
chickpeas	3%
yellow peas	3%
oats	3%
herring oil	1%
alfalfa	1%

Table 14. Dog food product D

Ingredient	Ratio
lamb meal	20%
brown rice	19%
rice	19%
chicken fat	10%
salmon	6%
green peas	5%
chicken	5%
eggs	4%
linseed	4%
beer yeast	3%
vegetable fiber	3%
minerals	1%
salmon oil	0.5%
apple	0.05%
carrot	0.05%

Table 15. Dog food product E

Ingredient	Ratio
chicken meal	12%
fresh chicken	10%
brown rice	19%
dried potato	18.6%
peas	10%
chicken fat	6%
sweet potato	5%
dried lamb	3%
dried salmon	3%
eggs	2%
salmon oil	2%
brewer's yeast	2%
linseed	2%
dried carrot	2%
inulin	0.3%
minerals	0.3%
carrot	0.3%
nettle	0.3%
echinacea	0.3%
tomato	0.2%
apple	0.2%
mango	0.2%
plum	0.2%
banana	0.2%
thyme	0.2%
bassil	0.2%
spirulina	0.2%
cranberry	0.2%
celery	0.2%

Table 16. Dog food product F

Ingredient	Ratio
fresh chicken	21%
chicken meal	21%
sweet potato	6.1%
potatoes	14.4%
turkey meal	9.5%
dried eggs	4.1%
peas	4%
chicken fat	4%
linseed	2%
brewer's yeast	1.6%
salmon oil	1.6%
minerals	0.8%
vitamins	0.5%
apple	0.1%
carrot	0.1%
peppermint	0.04%

Table 17. Dog food product G

Ingredient	Ratio
fresh chicken	44%
fresh turkey	6%
sweet potatoes	23%
dried chicken	16%
dried turkey	3%
lucerne	1%
peas	1%
linseeds	1%
chicken gravy	1%
vitamin and mineral	1%

Appendix II: Cat food composition

Table 18 - 23 present the cat food composition from different products. The data has been gathered from the interview with five pet food companies located in the Netherlands, Canada, and the United States. Due to the confidential data, the name of the dog food products are disguised into alphabet letters (P-U).

Table 18. Cat food product P

Ingredient	Ratio
fresh chicken	18%
fresh turkey	7%
fresh eggs	5%
fresh chicken liver	5%
fresh flounder	4%
fresh herring	4%
fresh turkey liver	4%
fresh chicken heart	4%
fresh turkey heart	4%
fresh chicken necks	4%
dried chicken	4%
dried turkey	4%
mackarel	4%
sardine	4%
dried herring	4%
chicken fat	3%
red lentils	1%
green peas	1%
green lentils	1%
chickpeas	1%
yellow peas	1%
lentil fiber	1%
pinto beans	1%
navy beans	1%
dried chicken cartilage	1%
herring oil	1%
dried chicken liver	0.5%
dried turkey liver	0.5%
pumpkin	0.3%
butternut squash	0.3%
zucchini	0.3%
parsnips	0.3%
carrots	0.3%
apples	0.3%
pears	0.3%
kale	0.3%
spinach	0.3%
beet greens	0.3%
turnip greens	0.3%
brown kelp	0.3%

Table 19. Cat food product Q

Ingredient	Ratio
fresh chicken	35%
dried chicken	22%
sweet potato	15%
potato	10%
flax seed	5%
dried egg	3%
chicken fat	2%
chicken broth	2%
fibers	1%
brewer's yeast	1%
minerals	1%
cranberries	1%
seaweed	1%

Table 20. Cat food product R

Ingredient	Ratio
fresh turkey	36%
dried chicken	18%
sweet potato	15%
potato	10%
chicken fat	6%
linseed	4%
dried krill	4%
dried egg	3%
chicken broth	2%
vegetable fibers	0.5%
brewer's yeast	0.2%
minerals	0.2%
cranberries	0.2%
seaweed	0.2%

Table 21. Cat food product S

Ingredient	Ratio
fresh chicken	22%
fresh duck	5%
turkey	5%
sweet potato	21%
dried chicken	17%
dried turkey	12%
chicken fat	7%
peas	5%
lucerne	3%
chicken gravy	2%

Table 22. Cat food product T

Ingredient	Ratio
fresh chicken	9%
fresh turkey	9%
fresh chicken liver	9%
chicken meal	8%
turkey meal	8%
whole herring meal	8%
green peas	5%
red lentils	5%
chickpeas	5%
chicken fat	5%
whole eggs	4%
walleye	4%
trout	4%
fresh turkey liver	4%
green lentils	2%
pinto beans	2%
yellow peas	2%
pollock oil	2%
alfalfa	1%
dried chicken cartilage	1%
dried brown kelp	0.2%
fresh pumpkin	0.2%
fresh butternut squash	0.2%
fresh parsnips	0.2%
fresh green kale	0.2%
fresh spinach	0.1%
fresh mustard greens	0.1%
fresh turnip greens	0.1%
fresh carrots	0.1%
apples	0.1%
fresh bartlett pears	0.1%
dried liver chicken	0.1%
cranberries	0.1%
blueberries	0.1%
chicory root	0.1%

Table 23. Cat food product U

Ingredient	Ratio
salmon	20%
salmon meal	20%
salmon oil	3%
peas	20%
dried potato	20%
chicken fat	7.6%
carob pods	2.5%
flax seed	2.5%
brewer's yeast	2.5%
inulin	0.3%
minerals	0.3%
carrot	0.3%
echinacea	0.3%
tomato	0.2%
apple	0.2%
mango	0.2%
prunes	0.2%
banana	0.2%
spirulina	0.20%
cranberry	0.15%
celery	0.15%
glucosamine	0.02%
chondroitin	0.02%
enterococcus faecium	0.02%

Appendix III: Global pet population 2016

Table 24 shows the estimated population of dogs and cats in 2016. This data combines from two data surveys namely: Euromonitor (2017) and World Society for the Protection Animal (2008). A modification from World Society for the Protection Animal (2008) data was conducted to estimate the pet population in 2016. The estimation was based on the trend population of pets from the past ten years (2006 – 2016) from Euromonitor (2017), then the trend population was applied to the countries that do not exist in Euromonitor (2017) but available in World Society for the Protection Animal (2008).

Table 24. Global pet population in 2016. Adapted from: Euromonitor (2017); World Society for the Protection Animal (2008)

No	Region	Country	Population (x 1000)				
			Dog			Cat	Total Pets Per Country
			Small	Medium	Large		
1	Southern Africa	South Africa	2090	3478	4540	2100	12208
2		Namibia	70	106	180	0	356
3		Swaziland	46	69	118	0	233
4		Botswana	25	38	66	23	153
5	Eastern Africa	Ethiopia	1273	1923	3276	323	6795
6		Tanzania	1273	1923	3276	2584	9055
7		Kenya	764	1154	1965	1292	5175
8		Zimbabwe	382	577	983	1292	3233
9	Western Africa	Nigeria	636	962	1638	1292	4528
10		Gambia	64	96	164	323	647
11	Northern Africa	Morocco	75	156	136	1014	1380
12		Egypt	117	203	539	1905	2764
13	Central Africa	Republic of the Congo	23	35	59	26	142
14		Cameroon	13	19	33	0	65
15		Chad	6	10	16	0	32
16	Eastern Asia	China	13780	8499	5717	11953	39949
17		Hong Kong	199	30	71	214	514
18		Japan	7708	1260	1260	10022	20249
19		South Korea	2282	158	158	435	3032
20		Taiwan	1114	596	596	699	3005
21	South Asia	India	6915	2478	6390	1452	17235
22		Sri Lanka	1284	588	1364	912	4148
23		Nepal	10	5	11	0	26
24		Afghanistan	38	45	52	129	264
25	SE Asia	Indonesia	233	92	135	21503	21962
26		Malaysia	168	75	142	650	1035
27		Philippines	10523	2413	1427	1895	16258
28		Singapore	89	6	15	72	181
29		Thailand	4471	2773	1956	2251	11451
30		Vietnam	2305	1883	665	3529	8382
31	Western Asia	Israel	175	248	90	346	859
32		Lebanon	19	22	26	61	128
33		Saudi Arabia	4	9	30	136	178
34		Cyprus	4	5	6	0	15
35		UAE	33	13	20	125	191

36		Kuwait	3	3	4	23	32
37		Qatar	1	1	2	91	95
38		Iran	0	0	0	304	304
39	South America	Brazil	31885	13826	10081	24268	80060
40		Mexico	17230	7494	2745	8548	36016
41		Argentina	4708	4056	2878	0	11642
42		Colombia	1423	2077	1082	1552	6133
43		Chile	1044	1402	827	1951	5225
44		Venezuela	1098	1574	754	1775	5201
45		Peru	1568	1855	768	1327	5518
46	Central America	Guatemala	921	1025	660	3	2608
47		Costa Rica	691	769	495	0	1954
48		Puerto Rico	368	410	264	263	1305
49		Jamaica	184	205	132	658	1179
50		Barbados	92	261	66	395	813
51		Bahamas	46	51	33	26	157
52		Grenada	14	15	10	33	72
53		Dominica	14	15	10	3	42
54		Guyana	0	0	0	0	0
55		Panama	0	0	0	16	16
56	North America	USA	29910	18594	21858	72922	143284
57		Canada	1659	1933	3075	8134	14801
58	East Europe	Russia	3625	8955	4023	23000	39603
59		Poland	1449	3834	1779	6050	13112
60		Ukraine	3900	2732	1596	9785	18013
61		Romania	1301	1452	1371	4251	8375
62		Czech	666	940	535	1097	3238
63		Hungary	677	870	505	2265	4317
64		Turkey	242	446	425	3263	4376
65		Bulgaria	274	216	254	789	1533
66		Serbia	271	385	259	543	1459
67		Slovakia	226	362	320	507	1415
68		Croatia	106	150	101	347	704
69		Lithuania	106	150	101	293	649
70		Armenia	90	128	86	0	305
71		Slovenia	78	111	75	54	319
72		Macedonia	36	51	35	0	122
73		Estonia	30	43	29	217	319
74	West Europe	Austria	197	287	287	1787	2558
75		Belgium	720	414	414	2019	3567
76		Denmark	208	182	182	679	1250
77		Finland	252	260	260	868	1640
78		France	3922	1820	1820	13161	20723
79		Germany	3058	2586	2586	12016	20246
80		Greece	457	113	113	589	1273
81		Ireland	169	176	176	320	842
82		Italy	1887	2798	2798	7482	14965
83		Netherlands	905	1303	1303	3610	7121
84		Norway	142	130	130	777	1179
85		Portugal	1176	562	562	1413	3713
86		Spain	2233	1934	1934	3832	9932
87		Sweden	221	215	215	1273	1924
88		Switzerland	189	126	126	1493	1934
89		UK	4755	2943	446	7719	15863

90		Malta	0	0	0	0	0
91		Australia	1760	980	1490	3375	7605
92		New Zealand	93	515	93	1414	2115
93	Oceania	PNG	1399	2489	1211	1055	6155
94		Samoa	276	498	246	106	1125
95		Palau	4	1	1	0	6
	Total Pets Per Category		188168	128669	110745	308296	735878

Appendix IV: The water and land footprint of dog breeds

Table 25 - 27 shows the water and land footprint of dog breeds in 2016. The dog breeds are categorized into three based on the body weight namely: small dog breeds (0 – 9 kg), medium dog breeds (9 – 23 kg) and large dog breeds (> 23 kg). The distinction of dog's breeds and their body weight based on the data from American Kennel Club (2017).

Table 25. The summary of annual food intake (kg/year), water footprint feed ingredients (m^3/year), water footprint of drinking water (m^3/year) and land footprint of feed ingredients (m^2/year) for the small dog breeds

No	Breed	Body Weight (kg)	Food Intake (kg/year)	$WF_{feed\ ing}$ (m^3/year)	WF_{drink} (m^3/year)	$LF_{feed\ ing}$ (m^2/year)
1	Affenpinschers	4	32	153	0.12	246
2	American Hairless Terriers	7	56	261	0.18	429
3	Australian Terriers	8	56	270	0.19	440
4	Bichons Frises	8	56	271	0.19	441
5	Border Terriers	7.5	56	272	0.19	442
6	Boston Terriers	9	56	269	0.21	439
7	Brussels Griffons	4.5	32	148	0.13	240
8	Cairn Terriers	7	56	272	0.17	442
9	Cavalier King Charles Spaniels	8	56	270	0.19	440
10	Cesky Terriers	9	56	267	0.21	437
11	Chihuahuas	3	31	148	0.09	238
12	Chinese Crested	5	32	153	0.14	246
13	Coton de Tulear	5.5	56	261	0.15	429
14	Dachshunds	9	56	271	0.21	441
15	English Toy Spaniels	6	56	270	0.16	440
16	Fox Terriers (Smooth)	8.5	56	271	0.20	441
17	Fox Terriers (Wire)	8.5	56	271	0.20	441
18	Havanese	5	32	153	0.14	246
19	Italian Greyhounds	5	32	154	0.14	247
20	Japanese Chin	4.5	32	152	0.13	245
21	Lakeland Terriers	8	56	273	0.20	443
22	Lhasa Apsos	8	56	272	0.19	442
23	Lowchen	7.5	56	269	0.19	438
24	Maltese	3	31	148	0.09	238
25	Manchester Terriers	9	56	271	0.21	441
26	Miniature Pinschers	4.5	32	154	0.13	247
27	Miniature Schnauzers	7.5	56	270	0.19	440
28	Norfolk Terriers	6	56	269	0.16	439
29	Norwich Terriers	6	56	271	0.16	441
30	Papillons	3.5	32	154	0.10	247
31	Parson Russell Terriers	7.5	56	271	0.19	441
32	Pekingese	7	56	270	0.18	440
33	Pomeranians	3.5	32	153	0.10	245
34	Portuguese Podengo Pequenos	5.5	56	261	0.15	429
35	Pugs	7.5	56	269	0.19	439
36	Russell Terriers	6	56	261	0.16	429
37	Schipperkes	7	56	271	0.18	441
38	Shih Tzu	6	56	271	0.16	441
39	Silky Terriers	5	32	148	0.14	240
40	Tibetan Spaniel	6	56	272	0.16	442

41	Toy Fox Terriers	3	31	149	0.09	240
42	West Highland White Terriers	9	56	271	0.21	441
43	Yorkshire Terriers	3.5	32	154	0.10	247
	AVERAGE		**48**	**231**	**0.16**	**376**

Table 26. The summary of annual food intake (kg/year), water footprint feed ingredients (m^3/year), water footprint of drinking water (m^3/year) and land footprint of feed ingredients (m^2/year) for the medium dog breeds

No	Breed	Body Weight (kg)	Food Intake (kg/year)	$WF_{feed\ ing}$ (m^3/year)	WF_{drink} (m^3/year)	$LF_{feed\ ing}$ (m^2/year)
1	American Eskimo Dogs	15	81	374	0.31	614
2	Australian Cattle Dogs	20	94	453	0.39	748
3	Basenjis	11.5	81	391	0.26	633
4	Beagles	10	56	271	0.23	441
5	Bedlington Terriers	10	56	271	0.23	441
6	Border Collies	20	94	455	0.39	750
7	Brittanys	15	81	390	0.31	632
8	Bulldogs	22.5	117	555	0.42	910
9	Canaan Dogs	22.5	117	569	0.42	927
10	Cardigan Welsh Corgis	16.5	94	440	0.33	733
11	Cirnechi dell'Etna	10.5	81	374	0.24	614
12	Dandie Dinmont Terriers	11	81	389	0.25	631
13	Finnish Lapphunds	21	117	556	0.40	912
14	Finnish Spitz	13	81	388	0.28	630
15	French Bulldogs	13	81	385	0.28	627
16	German Pinschers	15	81	388	0.31	630
17	Glen of Imaal Terriers	18	94	453	0.36	748
18	Icelandic Sheepdogs	13.75	81	374	0.29	614
19	Irish Terriers	13	81	392	0.28	634
20	Keeshonden	20	94	455	0.39	750
21	Kerry Blue Terriers	18.5	94	454	0.36	749
22	Lagotti Romagnoli	14.5	81	374	0.30	614
23	Miniature American Shepherds	15	81	374	0.31	614
24	Miniature Bull Terriers	12	81	382	0.26	623
25	Norwegian Buhunds	17	94	456	0.34	751
26	Norwegian Lundehunds	12.5	81	374	0.27	614
27	Pembroke Welsh Corgis	14.5	81	374	0.30	614
28	Petits Bassets Griffons Vendeens	16	94	440	0.33	733
29	Polish Lowland Sheepdogs	20	94	452	0.39	746
30	Portuguese Water Dogs	22	117	563	0.42	920
31	Pulik	15	81	374	0.31	614
32	Pumik	13	81	374	0.28	614
33	Pyrenean Shepherds	10	56	265	0.23	435
34	Rat Terriers	10	56	261	0.23	429
35	Retrievers (Nova Scotia Duck Tolling)	22.5	117	544	0.42	898
36	Scottish Terriers	10	56	273	0.23	444
37	Sealyham Terriers	11.5	81	389	0.26	631
38	Shetland Sheepdogs	10	56	270	0.23	440
39	Shiba Inu	10	56	270	0.23	440
40	Skye Terriers	19.5	94	454	0.38	748
41	Sloughis	22.5	117	544	0.42	898
42	Soft Coated Wheaten Terriers	17.5	94	455	0.35	751

43	Spaniels (American Water)	17.5	94	440	0.35	733
44	Spaniels (Boykin)	16	94	440	0.33	733
45	Spaniels (English Cocker)	14.5	81	374	0.30	614
46	Spaniels (English Springer)	22.5	117	544	0.42	898
47	Spaniels (Field)	22.5	117	544	0.42	898
48	Spaniels (Sussex)	20	94	440	0.39	733
49	Spaniels (Welsh Springer)	22.5	117	544	0.42	898
50	Spanish Water Dogs	20	94	440	0.39	733
51	Staffordshire Bull Terriers	15	81	390	0.31	632
52	Standard Schnauzers	20	94	440	0.39	733
53	Swedish Vallhunds	15	81	392	0.31	635
54	Tibetan Terriers	12	81	389	0.27	631
55	Welsh Terriers	9.5	56	270	0.22	440
56	Whippets	17.5	94	456	0.35	751
57	Xoloitzcuintli	22.5	117	544	0.42	898
	AVERAGE		**88**	**416**	**0.32**	**682**

Table 27. The summary of annual food intake (kg/year), water footprint feed ingredients (m^3/year), water footprint of drinking water (m^3/year) and land footprint of feed ingredients (m^2/year) for the large dog breeds

No	Breed	Body Weight (kg)	Food Intake (kg/year)	$WF_{feed\ ing}$ (m^3/year)	WF_{drink} (m^3/year)	$LF_{feed\ ing}$ (m^2/year)
1	Afghan Hounds	25	117	543	0.46	893
2	Airedale Terriers	30	124	578	0.52	954
3	Akitas	50	177	814	0.77	1329
4	Alaskan Malamutes	40	151	699	0.65	1145
5	American English Coonhounds	30	124	578	0.52	954
6	American Foxhounds	32.5	145	665	0.56	1084
7	American Staffordshire Terriers	27.5	124	578	0.49	954
8	Anatolian Shepherd Dogs	57.5	205	936	0.85	1520
9	Australian Shepherds	27.5	124	578	0.49	954
10	Basset Hounds	25	117	543	0.46	893
11	Bearded Collies	25	117	543	0.46	893
12	Beaucerons	45	171	780	0.71	1267
13	Belgian Malinois	25	117	543	0.46	893
14	Belgian Sheepdogs	30	124	578	0.52	954
15	Belgian Tervuren	32.5	145	665	0.56	1084
16	Bergamasco	37.5	151	699	0.62	1145
17	Berger Picards	30	124	578	0.52	954
18	Bernese Mountain Dogs	45	171	780	0.71	1267
19	Black and Tan Coonhounds	45	171	780	0.71	1267
20	Black Russian Terriers	50	177	814	0.77	1329
21	Bloodhounds	42.5	171	780	0.68	1267
22	Bluetick Coonhounds	32.5	145	665	0.56	1084
23	Boerboels	75	250	1136	1.04	1827
24	Borzois	42.5	171	780	0.68	1267
25	Bouviers des Flandres	45	171	780	0.71	1267
26	Boxers	31	145	665	0.54	1084
27	Briards	30	124	578	0.52	954
28	Bull Terriers	30	124	578	0.52	954
29	Bullmastiffs	57.5	205	936	0.85	1520
30	Cane Corso	47.5	177	814	0.74	1329
31	Chinese Shar-Pei	25	117	543	0.46	893

32	Chinooks	35	145	665	0.59	1084
33	Chow Chows	30	124	578	0.52	954
34	Collies	32.5	145	665	0.56	1084
35	Dalmatians	30	124	578	0.52	954
36	Doberman Pinschers	42.5	171	780	0.68	1267
37	Dogues de Bordeaux	50	177	814	0.77	1329
38	English Foxhounds	35	145	665	0.59	1084
39	Entlebucher Mountain Dogs	30	124	578	0.52	954
40	German Shepherd Dogs	35	145	665	0.59	1084
41	Giant Schnauzers	32.5	145	665	0.56	1084
42	Great Danes	70	230	1052	0.99	1702
43	Great Pyrenees	52.5	198	902	0.80	1458
44	Greater Swiss Mountain Dogs	52.5	198	902	0.80	1458
45	Greyhounds	32.5	145	665	0.56	1084
46	Harriers	25	117	543	0.46	893
47	Ibizan Hounds	24	117	543	0.44	893
48	Irish Wolfhounds	56	205	936	0.84	1520
49	Komondorok	52.5	198	902	0.80	1458
50	Kuvaszok	47.5	177	814	0.74	1329
51	Leonbergers	65	224	1018	0.94	1641
52	Mastiffs	87.5	283	1288	1.17	2074
53	Neapolitan Mastiffs	65	224	1018	0.94	1641
54	Newfoundlands	62.5	224	1018	0.91	1641
55	Norwegian Elkhounds	26	124	578	0.47	954
56	Old English Sheepdogs	40	151	699	0.65	1145
57	Otterhounds	49	177	814	0.75	1329
58	Pharaoh Hounds	25	117	543	0.46	893
59	Plotts	26	124	578	0.47	954
60	Pointers	30	124	578	0.52	954
61	Pointers (German Shorthaired)	30	124	578	0.52	954
62	Pointers (German Wirehaired)	30	124	578	0.52	954
63	Poodles	27.5	124	578	0.49	954
64	Redbone Coonhounds	30	124	578	0.52	954
65	Retrievers (Chesapeake Bay)	35	145	665	0.59	1084
66	Retrievers (Curly-Coated)	40	151	699	0.65	1145
67	Retrievers (Flat-Coated)	32.5	145	665	0.56	1084
68	Retrievers (Golden)	32.5	145	665	0.56	1084
69	Retrievers (Labrador)	35	145	665	0.59	1084
70	Rhodesian Ridgebacks	39	151	699	0.63	1145
71	Rottweilers	52.5	198	902	0.80	1458
72	Salukis	27.5	124	578	0.49	954
73	Samoyeds	25	117	543	0.46	893
74	Scottish Deerhounds	45	171	780	0.71	1267
75	Setters (English)	30	124	578	0.52	954
76	Setters (Gordon)	30	124	578	0.52	954
77	Setters (Irish Red and White)	25	117	543	0.46	893
78	Setters (Irish)	32.5	145	665	0.56	1084
79	Siberian Huskies	24	117	543	0.44	893
80	Spaniels (Clumber)	34	145	665	0.57	1084
81	Spaniels (Irish Water)	28.5	124	578	0.50	954

82	Spinoni Italiani	28	124	578	0.50	954
83	St. Bernards	72.5	250	1136	1.02	1827
84	Tibetan Mastiffs	57.5	205	936	0.85	1520
85	Treeing Walker Coonhounds	30	124	578	0.52	954
86	Vizslas	27.5	124	578	0.49	954
87	Weimaraners	36	151	699	0.60	1145
88	Wirehaired Pointing Griffons	25	117	543	0.46	893
89	Wirehaired Vizslas	27.5	124	578	0.49	954
	AVERAGE		**153**	**702**	**0.62**	**1147**

Appendix V: The water and land footprint of cat breeds

Table 28 presents the water and land footprint of cats in 2016. There is no categorization in the cat breeds due to the body weight of cat breeds are almost similar between 4-6 kg. The data of cat breeds and their body weight are obtained from Kienzle et al. (2011); The International Cat Association (2016).

Table 28. The summary of annual food intake (kg/year), water footprint feed ingredients (m^3/year), water footprint of drinking water (m^3/year) and land footprint of feed ingredients (m^2/year) for the cat breeds

No	Breed	Body Weight (kg)	Food Intake (kg/year)	$WF_{feed\ ing}$ (m^3/year)	WF_{drink} (m^3/year)
1	Abyssinian	24	85	0.09	107
2	American bobtail	30	108	0.13	136
3	American curl	24	85	0.09	107
4	American shorthair	31	111	0.13	140
5	American wirehair	31	111	0.13	140
6	Australian Mist	30	108	0.13	136
7	Balinese	19	72	0.09	92
8	Birman	31	111	0.13	140
9	Bombay	31	111	0.13	140
10	Brititsh Shorthair	26	94	0.10	118
11	Burmese	24	85	0.09	107
12	Chartreux	26	94	0.11	118
13	Colorpoint Shorthair	19	72	0.08	92
14	Cornish Rex	24	85	0.10	107
15	Devon Rex	19	72	0.08	92
16	Egyptian Mau	24	85	0.10	107
17	European Burmese	24	85	0.10	107
18	Exotic	19	72	0.09	92
19	Havana Brown	19	72	0.09	92
20	Japanese Bobtail	19	72	0.09	92
21	Javanese	19	72	0.09	92
22	Korat	18	69	0.08	87
23	LaPerm	24	85	0.09	107
24	Maine Coon	30	108	0.12	136
25	Manx	19	72	0.09	92
26	Norwegian Forest Cat	26	94	0.10	118
27	Ocicat	24	85	0.09	107
28	Oriental	19	72	0.09	92
29	Persian	24	85	0.09	107
30	RagaMuffin	27	98	0.12	123
31	Ragdoll	24	85	0.10	107
32	Russian Blue	24	85	0.09	107
33	Scottish Fold	16	61	0.07	78
34	Selkirk Rex	19	72	0.09	92
35	Siamese	19	72	0.08	92
36	Siberian	26	94	0.11	118
37	Singapura	19	72	0.09	92
38	Somali	24	85	0.09	107
39	Sphynx	19	72	0.09	92
40	Tonkinese	19	72	0.09	92
41	Turkish Angora	27	98	0.12	123
42	Turkish Van	24	85	0.10	107
AVERAGE			**85**	**0.10**	**108**

Appendix VI: The water footprint of pets per nation in 2016

Table 29 shows the result of the calculation of water footprint of pets per nation in 2016. The calculation is based on the total population of dogs and cats. For the dog population, it is divided into three categories based on the body weight (small, medium, large breeds) per nation. Meanwhile, cat population is only in one category per nation.

Table 29. The summary of the water footprint of pets per nation in 2016

No	Region	Country	Water footprint (m^3/year)				
			Dog			Cat	Total water footprint of Pets Per Country
			Small	Medium	Large		
1	Southern Africa	South Africa	464649	1390157	3114031	160041	5128878
2		Namibia	15563	42280	123579	0	181423
3		Swaziland	10187	27674	80888	0	118749
4		Botswana	5659	15375	44938	1772	67744
5	Eastern Africa	Ethiopia	282964	768733	2246897	24613	3323207
6		Tanzania	282964	768733	2246897	196900	3495495
7		Kenya	169779	461240	1348138	98450	2077607
8		Zimbabwe	84889	230620	674069	98450	1088029
9	Western Africa	Nigeria	141482	384367	1123449	98450	1747747
10		Gambia	14148	38437	112345	24613	189542
11	Northern Africa	Morocco	16652	62353	93078	77254	249337
12		Egypt	26011	81139	369705	145180	622036
13	Central Africa	Republic of the Congo	5093	13837	40444	1969	61344
14		Cameroon	2830	7687	22469	0	32986
15		Chad	1415	3844	11234	0	16493
16	Eastern Asia	China	3063570	3397050	3921347	910938	11292906
17		Hong Kong	44131	11991	48905	16286	121313
18		Japan	1713576	503462	863972	763784	3844794
19		South Korea	507312	62993	108099	33144	711548
20		Taiwan	247642	238221	408802	53301	947967
21	South Asia	India	1537432	990537	4382759	110642	7021369
22		Sri Lanka	285486	235096	935320	69501	1525403
23		Nepal	2284	1881	7483	0	11647
24		Afghanistan	8459	17812	35719	9857	71846
25	SE Asia	Indonesia	51712	36613	92529	1638744	1819597
26		Malaysia	37350	29978	97674	49537	214537
27		Philippines	2339384	964596	978519	144441	4426940
28		Singapore	19698	2478	10083	5449	37708
29		Thailand	994082	1108488	1341434	171541	3615545
30		Vietnam	512448	752635	456130	268945	1990158
31	Western Asia	Israel	38950	99206	61595	26353	226104
32		Lebanon	4229	8906	17859	4638	35633
33		Saudi Arabia	823	3477	20577	10365	35242
34		Cyprus	930	1959	3929	0	6819
35		UAE	7337	5276	13581	9503	35697
36		Kuwait	592	1247	2500	1739	6079
37		Qatar	254	534	1072	6958	8817
38		Iran	0	0	0	23192	23192
39	South America	Brazil	7088651	5526332	6914659	1849434	21379076
40		Mexico	3830462	2995272	1882754	651428	9359916

41		Argentina	1046594	1621143	1974118	0	4641854
42		Colombia	316317	830017	742086	118255	2006675
43		Chile	232169	560379	567316	148709	1508573
44		Venezuela	244196	629088	516902	135265	1525451
45		Peru	348553	741603	526573	101138	1717868
46	Central America	Guatemala	204693	409581	452600	201	1067075
47		Costa Rica	153520	307186	339450	0	800156
48		Puerto Rico	81877	163832	181040	20050	446800
49		Jamaica	40939	81916	90520	50125	263500
50		Barbados	20469	104133	45260	30075	199938
51		Bahamas	10235	20479	22630	2005	55349
52		Grenada	3070	6144	6789	2506	18509
53		Dominica	3070	6144	6789	201	16204
54		Guyana	20	41	45	0	107
55		Panama	0	0	0	1203	1203
56	North America	USA	6649591	7432022	14992621	5557386	34631619
57		Canada	368829	772620	2109173	619877	3870499
58	East Europe	Russia	805910	3579314	2759416	1752830	8897469
59		Poland	322097	1532610	1219960	461048	3535714
60		Ukraine	867048	1091980	1094712	745715	3799456
61		Romania	289305	580364	940383	323969	2134021
62		Czech	148065	375598	366962	83602	974227
63		Hungary	150511	347739	346385	172616	1017250
64		Turkey	53801	178266	291512	248673	772253
65		Bulgaria	60916	86335	174221	60130	381602
66		Serbia	60348	153982	177897	41376	433603
67		Slovakia	50244	144492	219491	38661	452888
68		Croatia	23469	59882	69182	26480	179013
69		Lithuania	23469	59882	69182	22343	174876
70		Armenia	20116	51327	59299	0	130742
71		Slovenia	17434	44484	51392	4138	117448
72		Macedonia	8046	20531	23720	0	52297
73		Estonia	6705	17109	19766	16550	60131
74	West Europe	Austria	43819	114634	196719	136195	491367
75		Belgium	159981	165596	284173	153845	763595
76		Denmark	46243	72546	124493	51747	295027
77		Finland	56025	103922	178337	66150	404434
78		France	871850	727454	1248356	1003023	3850683
79		Germany	679943	1033664	1773832	915701	4403141
80		Greece	101534	45286	77714	44903	269436
81		Ireland	37572	70427	120857	24402	253259
82		Italy	419518	1118361	1919176	570203	4027258
83		Netherlands	201200	520809	893741	275118	1890868
84		Norway	31569	51961	89168	59215	231914
85		Portugal	261448	224711	385619	107685	979463
86		Spain	496352	772860	1326276	292037	2887524
87		Sweden	49133	85936	147471	97015	379554
88		Switzerland	42018	50362	86425	113782	292587
89		UK	1057221	1176117	305916	588235	3127488
90		Malta	3	8	11	0	22
91	Oceania	Australia	391283	391706	1022006	257209	2062204
92		New Zealand	20676	205766	63515	107791	397748
93		PNG	311129	994807	830787	80438	2217161
94		Samoa	61360	198961	168827	8044	437193
95		Palau	866	462	848	0	2177
	Total water footprint of pets		41833449	51429095	75961121	23495276	192718942

Appendix VII: The land footprint of pets per nation in 2016

Table 30 shows the result of the calculation of land footprint of pets per nation in 2016. The calculation is based on the total population of dogs and cats. For the dog population, it is divided into three categories based on the body weight (small, medium, large breeds) per nation. Meanwhile, cat population is only in one category per nation.

Table 30. The summary of the land footprint of pets per nation in 2016

No	Region	Country	Land Footprint (m^2/year)				
			Dog			Cat	Total land footprint of Pets Per Country
			Small	Medium	Large		
1	Southern Africa	South Africa	758189	2281290	3968913	211281	7219673
2		Namibia	25395	69383	157505	0	252283
3		Swaziland	16622	45415	103094	0	165131
4		Botswana	9235	25230	57275	2339	94079
5	Eastern Africa	Ethiopia	461726	1261515	2863728	32493	4619462
6		Tanzania	461726	1261515	2863728	259941	4846911
7		Kenya	277036	756909	1718237	129971	2882153
8		Zimbabwe	138518	378455	859118	129971	1506062
9	Western Africa	Nigeria	230863	630758	1431864	129971	2423456
10		Gambia	23086	63076	143186	32493	261841
11	Northern Africa	Morocco	27171	102324	118630	101988	350114
12		Egypt	42444	133152	471199	191662	838457
13	Central Africa	Republic of the Congo	8311	22707	51547	2599	85165
14		Cameroon	4617	12615	28637	0	45870
15		Chad	2309	6308	14319	0	22935
16	Eastern Asia	China	4998971	5574664	4997859	1202591	16774085
17		Hong Kong	72010	19678	62331	21500	175519
18		Japan	2796122	826197	1101155	1008323	5731798
19		South Korea	827805	103373	137775	43755	1112709
20		Taiwan	404090	390928	521029	70367	1386414
21	South Asia	India	2508700	1625501	5585940	146066	9866206
22		Sri Lanka	465841	385800	1192089	91753	2135484
23		Nepal	3727	3086	9537	0	16350
24		Afghanistan	13802	29230	45525	13013	101569
25	SE Asia	Indonesia	84380	60082	117931	2163417	2425810
26		Malaysia	60945	49194	124488	65397	300023
27		Philippines	3817284	1582932	1247148	190686	6838049
28		Singapore	32141	4067	12851	7194	56253
29		Thailand	1622090	1819063	1709692	226463	5377308
30		Vietnam	836185	1235097	581350	355053	3007685
31	Western Asia	Israel	63557	162799	78504	34791	339652
32		Lebanon	6901	14615	22762	6124	50402
33		Saudi Arabia	1342	5707	26226	13683	46958
34		Cyprus	1518	3215	5008	0	9741
35		UAE	11971	8658	17309	12546	50485
36		Kuwait	966	2046	3187	2296	8495
37		Qatar	414	877	1366	9185	11842
38		Iran	0	0	0	30618	30618
39	South America	Brazil	11566885	9068881	8812911	2441563	31890241
40		Mexico	6250346	4915333	2399619	859994	14425292

41		Argentina	1707776	2660346	2516064	0	6884186
42		Colombia	516149	1362083	945808	156117	2980157
43		Chile	378841	919600	723059	196320	2217820
44		Venezuela	398467	1032352	658805	178573	2268196
45		Peru	568751	1216994	671131	133520	2590395
46	Central America	Guatemala	334007	672135	576850	265	1583257
47		Costa Rica	250505	504102	432638	0	1187245
48		Puerto Rico	133603	268854	230740	26470	659667
49		Jamaica	66801	134427	115370	66174	382773
50		Barbados	33401	170886	57685	39704	301676
51		Bahamas	16700	33607	28843	2647	81797
52		Grenada	5010	10082	8653	3309	27054
53		Dominica	5010	10082	8653	265	24010
54		Guyana	33	67	58	0	158
55		Panama	0	0	0	1588	1588
56	North America	USA	10850451	12196176	19108482	7336682	49491792
57		Canada	601835	1267893	2688196	818342	5376266
58	East Europe	Russia	1315041	5873764	3516947	2314030	13019782
59		Poland	525581	2515060	1554870	608660	5204171
60		Ukraine	1414803	1791973	1395239	984469	5586484
61		Romania	472073	952396	1198542	427693	3050703
62		Czech	241605	616368	467702	110369	1436044
63		Hungary	245595	570650	441476	227882	1485603
64		Turkey	87790	292540	371539	328290	1080160
65		Bulgaria	99399	141679	222049	79381	542508
66		Serbia	98473	252689	226734	54623	632519
67		Slovakia	81986	237115	279747	51039	649888
68		Croatia	38295	98268	88174	34959	259696
69		Lithuania	38295	98268	88174	29496	254234
70		Armenia	32824	84230	75578	0	192632
71		Slovenia	28448	72999	65501	5462	172410
72		Macedonia	13130	33692	30231	0	77053
73		Estonia	10941	28077	25193	21849	86060
74	West Europe	Austria	71502	188118	250723	179800	690143
75		Belgium	261049	271748	362185	203101	1098084
76		Denmark	75456	119049	158669	68314	421489
77		Finland	91418	170539	227295	87329	576581
78		France	1422639	1193774	1591062	1324158	5531634
79		Germany	1109496	1696275	2260794	1208879	6275444
80		Greece	165677	74316	99048	59279	398320
81		Ireland	61308	115573	154036	32215	363132
82		Italy	684547	1835264	2446040	752764	5718615
83		Netherlands	328307	854664	1139096	363202	2685268
84		Norway	51513	85270	113647	78174	328604
85		Portugal	426618	368758	491481	142162	1429019
86		Spain	809920	1268287	1690372	385538	4154117
87		Sweden	80172	141023	187955	128077	537227
88		Switzerland	68564	82646	110150	150211	411571
89		UK	1725116	1930045	389898	776568	4821627
90		Malta	5	13	14	0	32
91	Oceania	Australia	638475	642802	1302573	339559	2923408
92		New Zealand	33738	337668	80952	142303	594660
93		PNG	507684	1632508	1058859	106192	3305244
94		Samoa	100125	326502	215175	10619	652420
95		Palau	1414	758	1081	0	3253
	Total land footprint of pets		68261607	84396728	96814410	31017711	280490455