# POLITECNICO DI TORINO

*Department of Environmental, Territorial and Infrastructural Engineering*
*DIATI*


MASTER’S DEGREE IN CIVIL ENGINEERING

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# GLOBAL AND MULTIYEAR ASSESSMENT OF THE WATER FOOTPRINT OF FARM ANIMAL PRODUCTS


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# TABLE OF CONTENTS

# 1. INTRODUCTION AND GENERAL FRAMEWORK

Water is the primary resource available on earth, fundamental and indispensable for the survival of mankind, as well as any living form.

Water consumption is not only linked to that used directly by man (namely, domestic water use for drinking, cooking, washing): this component, in fact, is only 10% of the total use and it is the smallest fraction compared to the total amount of water consumed worldwide (http://www.fao.org/water/en/). The industrial sector also uses a low percentage of the total water used (only 20%) in order to produce secondary sector good, while the agricultural and zootechnical sectors accounts for about 70% of all the water consumed by human being.

In this perspective, it is useful to introduce and make use of the concept of water footprint, introduced in 2002 by A. Hoekstra and A. Chapagain (Hoekstra, 2003): it is defined as the amount of fresh water needed to produce any good. This concept is very powerful and can be applied in several sectors, in fact there are many researches and publications that take advantage of it. In agriculture, the total water footprint can be split into three components: the blue component, which defines the volumes of water withdrawn from surface or underground water bodies; the green component, which refers to soil-infiltrated rainwater volumes; and, the grey component, which identifies the volumes of water necessary to dilute the pollutants at standard concentration levels (Hoekstra *et al.*, 2011). The goods derived from the primary sector are mainly crops and farm animal products. The world average water footprint for cereal crops is 1644 $\frac{m^3}{ton}$, i.e., uWF of wheat is 1827 $\frac{m^3}{ton}$, while that of the maize it is 1222 $\frac{m^3}{ton}$ (Mekonnen and Hoekstra, 2011). On the other hand, the order of magnitude of farm animal products unit water footprint varies according to the product considered, and it is 1000 $\frac{m^3}{ton}$ for milk, 3300 $\frac{m^3}{ton}$ for eggs and 15400 $\frac{m^3}{ton}$ for beef (Mekonnen and Hoekstra, 2012).

In this thesis, the goal that has been pursued has been to deepen the knowledge about the water footprint of animals and their derived products, mainly meat and milk. In fact, animals not only consume water by drinking it, but indirectly they use the water that the ingredients of their diet consumed to grow. The interest in this topic is of particular importance, especially in more arid countries. In addition to this, it is also necessary to consider the spread of meat-based diets and the growth of the worldwide population, which are increasing the world consumption of meat, the animal-derived product that most requires water to be produced (Tilman *et al.*, 2011): consequently, larger volumes of water are needed.

This work started with the partnership between DIATI (Department of Environmental, Territorial and Infrastructural Engineering, Politecnico di Torino) and CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia). In particular, carrying out a three-month research period in the Brisbane's location, it was possible to interact personally with the research team that deals with food and agriculture issues. The collaboration with The Chief Research Scientist of 'Agriculture and Food' sector, Mario Acosta Herrero, it was very useful for the work done, as he shared his experience and suggested important considerations, as well as providing us with the database relating to the composition of the animal diet.

In order to chase the objectives of the thesis, a considerable amount of data from different databases (CWASI, FAOSTAT, WaterStat) was collected and preprocessed. Subsequently, applying the method described in Chapter 4, a database was created, which contains the unit water footprint (water footprint per tons of product) of the main animals and their primary derived products, with a national spatial variability and defined annually from 1986 to 2016.

The results obtained allow one to make a number of analyses considering different spatial scale and exploring the temporal pattern. Firstly, considering results on a global scale, it is possible to evaluate the temporal evolution of the water footprint, whose unit counterpart has decreased over time; however, due to the increase in production, a generally positive trend is observed in the total volumes of water consumed.

Subsequently, although the data on a national scale were obtained for all the products and for the whole time span considered, a more accurate analysis was carried out on the products showing the greatest demand of water (cattle meat, cow milk, pig meat and poultry meat), analyzing the results on a national scale only in relation to the 1986 and 2016 years. In this way, it was possible to highlight the countries with good water use efficiency and understand if these are concentrated in certain regions or continents, in addition to highlighting countries in which a deterioration has been observed over time.

Finally, a comparison with previous studies (Mekonnen and Hoekstra, 2010),(Mekonnen and Hoekstra, 2012) was carried out, in order to test our methodology. Figures in Chapter 6.3 show the similarities and differences between the results obtained in this thesis and those available in the literature.

Furthermore, it is important to consider that agricultural products are not all consumed and used locally, but on the contrary they are traded all over the world. In fact, the quantity of agricultural products exported through international trade is about a quarter of the total amount produced (D'Odorico *et al.*, 2014). As a result, even the animal feed is not entirely of local origin, but portions imported from other countries may be present. For this reason, the effect of feed trade was assessed as well, observing how this is perceptible only in countries characterized by low production, while large producers are not affected in any way. The role of the trade is fundamental, because in addition to reducing (and in some cases completely solving) the food scarcity in the less self-sufficient nations (D'Odorico *et al.*, 2014), it allows to reduce the impact of global food production on withdrawal points over time. For example, it was found an average annual global saving of riverine environmental value of 11% due to the international food trade (Soligno, Ridolfi and Laio, 2019).

As regard the structure of this work, Chapter 2 is focused on the concept of water footprint, deepening its knowledge and defining its components; it is also related to the concept of trade by identifying the effect that the latter has on the water content of a product.

Chapter 3 introduces and describes all the sources and datasets used to carry out subsequent analyzes, emphasizing on their high spatial variability and describing how the temporal variability of some of these has been achieved.

Then, Chapter 4 describes how the collected data were processed and what is the methodology that was adopted to calculate the water footprint of farm animal products, making the distinction between the one that considers the role of trade and the other one that assume a scenario with no-trade, i.e., a scenario in which all the feed is produced locally.

Finally, Chapter 5 presents the observations deduced from the pre-processing process, with statistical analyzes concerning the distribution of animals and production systems, as well as critically analyzing the composition of the diets used and assessing the per capita consumption of the products considered. Chapter 6 collects all the results previously described and contains further analyzes carried out, with the exception of those concerning the effect of the trade, which were discussed in Chapter 7.

# 2. WATER FOOTPRINT CONCEPT

This chapter deals with the description of the concept of water footprint, with a particular focus on its use for the purpose of this research. The breakdown into the three components (blue, green and grey water) is also investigated, having a special consideration for the agriculture sector; in addition, the effect that trade has on the water footprint of the products and consequently on the environmental impact is described.

## 2.1. What is the water footprint?

Water is the most used resource by human being as it guarantees its survival, and it is mainly used in agriculture, allowing the growth of plants, trees and crops, of which man feeds directly or indirectly.

In order to assess the quantity of freshwater used to obtain a product or to guarantee a service, the concept of water footprint was introduced in 2002, expanding and enhancing the concept of "virtual water" introduced in the last decade of the twentieth century (Allan, 1993). The WF idea "looks not only at direct water use of a consumer or producer, but also at the indirect water use" (Hoekstra *et al.*, 2011). Depending on the purpose for which you want to use the water footprint and on the accuracy of the data available, this can be defined by unit of product obtained (e.g., $\frac{liter}{kg}$ or $\frac{m^3}{ton}$), or referring to a particular production sector or productive process, or relating to a nation rather than a region.

In the agricultural sector, it is interesting to note that mankind, by feeding on products of animal origin, such as meat, is indirectly consuming the water that was necessary to complete the production cycle: this is not only the water that animals have drunk during their life (which can be considered consumed directly), but also that which is virtually contained in the crops and grass with which the animals were bred (indirect consumption), and that used for livestock services or for dilute the pollutants.

As it is in the agricultural sector that the greatest use of water is concentrated, numerous researches have been carried out to deepen the knowledge in this area and to identify production methods and practices aimed at reducing water consumption, e.g., (Owusu-Sekyere, Jordaan and Chouchane, 2017) and (Weindl *et al.*, 2017). This direction in research is also influenced by other factors, such as the growth of the population, the influence of climatic conditions and the increase in consumption of products of animal origin. Confirmed the increase in production between 1961 and 2016 (FAOSTAT website), several studies, including (Steinfeld *et al.*, 2006), affirm that it is likely that production will double in 2050 compared to that recorded in 2000.

The water footprint is defined as the sum of three components (2.1) which are described below:

$$WF = WF_{blue} + WF_{green} + WF_{grey} \qquad \left[\frac{volume}{mass}\right] \tag{2.1}$$

- The blue component refers to consumption of blue water resources (surface and groundwater). The water contained in lakes, rivers or underground aquifers is withdrawn, and is almost totally used for irrigation and agricultural purposes (70% according to FAO estimates). Obviously, the nations that use a higher percentage of blue water are those characterized by arid climates and water scarcity problems;
- The volumes related to rainfall that are not stored are part of the evapotranspiration process of the plants and are defined as green water; by definition, they are volumes of water closely linked to agricultural production;
- Finally, the grey water footprint represents the volume of polluted water, quantified as the volume of water necessary to dilute the pollutants to the point that the quality of the water returns above the quality standards.

As described in (Hoekstra *et al.*, 2011), the grey component is calculated as follows in a generic way for each production sector:

$$WF_{grey} = \frac{L}{c_{max} - c_{nat}} \tag{2.2}$$

In which:

- $L \left[\frac{mass}{time}\right]$ is the pollutant load;
- $c_{max}$ and $c_{nat}$ $\left[\frac{mass}{volume}\right]$ are respectively the maximum and natural concentrations of pollutants in a water body.

Concerning the water footprint of products derived from agriculture (crops, trees, grass), in this study the grey component was not considered, of which the calculation is not deepened; however, the blue and the green portions are calculated by dividing the blue (or green) component of crop water use ($CWU_{blue/green}$ $\left[\frac{m^3}{ha}\right]$) by the crop yield ($Y$ $\left[\frac{ton}{ha}\right]$):

$$WF_{blue/green} = \frac{CWU_{blue/green}}{Y} \qquad 2.3$$

The crop water use is evaluated as a function of the evapotranspiration process of crops over the complete growing period, while the yield defines the amount of crops that is provided by a hectare of cultivated and harvested land. Obviously, these factors are highly spatially variable, so it is necessary to use high detail scales in order to correctly evaluate the water footprint.

The distinction between the three components is of considerable interest; in particular, blue water has a greater environmental impact than green water, as it refers to the amount of irrigation water withdrawn from surface and ground water bodies. The study of blue water is of particular relevance given that on a global average blue water resources are being used at a faster rates than their renewability rates (Gleeson *et al.*, 2012; Tuninetti, Tamea and Dalin, 2019). On the contrary, green water is a resource that cannot be reallocated and used in any other way, making production in humid areas more efficient and sustainable.

The water footprint of an agricultural products, therefore, is strongly influenced by climatic conditions, which influence the evapotranspiration process, and by the production techniques used, such as the presence of irrigation systems. As regards the water footprint of farm animal products, on the other hand, has been observed in (Gerbens-Leenes, Mekonnen and Hoekstra, 2011) that it is closely related to the yield of animals and their diet, not only from the quantitative point of view but also from its composition.

The factors that influence the water content are many, and they all have a strong spatial and temporal dependence. Depending on the data available, it is possible to calculate the water footprint with different levels of precision (cell, national, regional, world) and relative to a single year or to the average of several years.

There are numerous studies that have been concerned with calculating the uWF of agricultural and food products, most of which focusing on individual countries. However, in (Mekonnen and Hoekstra, 2010) and (Mekonnen and Hoekstra, 2011) a systematic methodology has been proposed, which was useful to calculate the water footprint of all agricultural and livestock products in each individual world nation, using data averaged over a 10-year period (1996-2005). The study is briefly described in Chapter 3.4, and the results are grouped in the WaterStat database which was used to validate the values obtained in this work (Chapter 6.3).

## 2.2. Virtual water trade

The concept of water footprint is closely related to that of virtual water trade, which effects the environmental impact of the goods produced.

The world economic system is based on the exchange and sale of goods, both nationally and internationally. However, it is also important to understand that, by trading a finished good, the water that has been used for its production and realization is being indirectly traded as well. Taking advantage of this simple phenomenon, "nations should export products in which they possess a relative or comparative advantage in production, while they should import products in which they possess a comparative disadvantage" (Wichelns, 2001). In this way, the countries where the production of goods is more efficient from a water point of view should export to those where, for the same result, a greater quantity of water is consumed.

However, the commercial network is also guided by other factors, such as, for example, commercial agreements, closeness between nations, etc. As a result, therefore, cases can be observed in which inefficient or drought-affected countries (or regions) export towards more developed nations. The case of Indian regions has been studied (Verma *et al.*, 2009), and highlights this particularity.

Deepening this topic from a food point of view, a distinction must be made between products derived from agriculture and those from livestock. Regarding crops, since they need water mainly related to precipitation, they are not produced using imported volumes and all the water is local; the blue component is also of local origin, as it is collected from the nearest water body.

On the contrary, the discourse relating to animals and their derived products is more complex. Excluding the component intended for watering and services (which are however in a very low percentage), the water footprint of a livestock product is a function of the water content of the feed consumed by the animals. In this perspective, the type of breeding has a great impact on the final result, since if the animals are mainly grown extensively and with large quantities of grass, they are not affected by the effect of the trade (in fact, the grass is not traded if not in a very local way); if, on the other hand, the diet of animals includes a large (or total) component of crops, the trade in these products affects the water footprint.

In Chapter 7 of this research, this question was studied in depth, evaluating the difference between the real water footprint and that relating to a hypothetical scenario in which the commercial network does not exist and the animals are fed with locally produced crops; the analysis was carried out at various scales (worldwide, regional and national), and the results obtained were discussed allowing important conclusions to be drawn.

# 3. SOURCES AND PREVIOUS STUDIES

In the following sections the main sources of data and researches referred to in this study are described. In the study, we have considered the following datasets:

- A global-scale dataset of animal diets centred on year 2000 and specific for animal species provided by (Herrero *et al.*, 2013b);
- the CWASI dataset (https://watertofood.org/data/), from which information such as the water footprint of agricultural products and their detailed trade were extrapolated;
- the FAOSTAT website (http://www.fao.org/faostat/en/#data): it is the statistical component of FAO website, from which it was possible to obtain a considerable amount of information, concerning, for example, animal yields and national productions of the various products;
- the WaterStat database (https://waterfootprint.org/en/resources/waterstat/), from which the results obtained through a previous analysis were extracted, and with which comparisons were made with the values obtained through the procedure proposed in this study.

## 3.1. The dataset of animal distribution and feed

One of the most important data needed to calculate correctly the water footprint of animal products is the diet of the animals. It's important to know the percentages and the quantity of every feed ingredient (e.g., maize, rice, wheat, peas) that makes up the diet differentiated by animal species and livestock production system (e.g., intensive and extensive). In addition, it is also important to understand if there is a temporal variability in the composition of the diet, which would be one of the main causes of the variation of the unitary water footprint over time. Moreover, the diet quality is another fundamental aspect to consider, because it's directly linked with the animal productivity and feed-use efficiencies: it is obvious to think that if an animal is bred with feed characterized by poor nutritional values, it will need to eat more food (and therefore consume more virtual water) to grow like an animal fed more efficiently in order to produce the same quantity of derived products.

The study by (Herrero *et al.*, 2013b) elaborated a "unique, biologically consistent, spatially disaggregated global livestock dataset containing information on biomass use, production, feed efficiency, excretion, and greenhouse gas emissions". The results that derive from it add knowledge not only linked to the water footprint, but have also biophysical, economic and social aspects.

The purposes of this research were related to the importance of the livestock sector for human supplying. Because of the important role it plays in economic growth related to the increasing of global agricultural and breeding gross domestic product (caused by the increase in human consumption of meat), it is necessary to keep improving performances of the system, and to do this it was first of all necessary to guarantee new, more detailed and specific knowledge about livestock data. Another reason that led to the realization of this research was to respect and improve global sustainability goals like ecosystem protection, mitigation of greenhouse gases and adaptation to climate change.

The publication assumes a unique and fundamental role in scientific research, as it provides numerous additional data and information with a high degree of heterogeneity in considering several livestock production systems and management practices all over the world; moreover, these data can be used to deepen knowledges concerning fields that are not strictly connected to each other.

Numerous publications make use of these information: as the paper particularly fully explore the environmental aspect and focuses on the emissions caused by livestock production systems, obtaining a lot of useful information, most of the paper deepen greenhouse gases emissions and how they are related with climate changes; some of them focus on water footprint of animals and animal products, but only with national or sub-national resolution with most of the data obtained with surveys and direct measurements (Lu *et al.*, 2018),(Palhares, Morelli and Junior, 2017),(Weindl *et al.*, 2017),(Bosire *et al.*, 2015),(Bosire *et al.*, 2017),(Ibidhi and Ben Salem, 2019),(Murphy *et al.*, 2017),(Mekonnen *et al.*, 2019). Moreover, just a few of them try to analyze time variations (Mekonnen *et al.*, 2019),(Bosire *et al.*, 2017). However, none of these apply a methodological procedure based on a high-resolution dataset and considering at the same time the temporal variability, as done in this thesis.

The dataset is created considering 29 regions, 8 livestock production systems, 4 animal species and 3 livestock products calibrated with livestock products referred to the year 2000. This year is one of the most important in livestock analysis, because this is the most frequent reference year in global datasets and a great amount of data are available. The results have been aggregated to 9 global regions to facilitate the comprehension, but data with greater details are available too. Moreover, in addition to the percentage of every kind of feed composing the diets, the amount of biomass expressed in $[\frac{kgDM}{(tlu*y)}]$ is available; in particular, this data is fundamental to quantify the kg of feed eaten by animals and to relate it to the unitary water footprint of each component. In order to make numeric values uniform among animal categories, the tropical livestock unit of measure is utilized; it is defined like an animal head of a mature animal weighing 250 kg.

The animal distributions and livestock production systems considered in the publication, as well as the composition of the diet, are described below.

### 3.1.1. Animal distribution

Concerning the animal distribution data, the paper refers to another source, which is the "Gridded Livestock of the World" (GLW) available on FAO website (http://www.fao.org/livestock-systems/global-distributions/en/). Data refers to the year 2000, in which a large census was made. In this study, the animal distribution was considered unchanged during the analysis period, assuming there have been no nasty changes in farms from 1986 to 2000.

In (Wint and Robinson, 2007) the steps that have been followed to create this distribution are described. Briefly, subnational livestock statistics have been collected when available; in circumstances where these data were not open, a correction with statistics at a lower resolution was done. Subsequently, land use was defined identifying lands suitable for livestock production considering different parameters like slope, temperature, urbanized or protected area.

In the study, four species of animal have been considered: ruminants, small ruminants, pigs and poultry; in order to match this classification with the FAOSTAT data, cattle and buffaloes are considered like ruminants, instead as regards the small ruminants, these are sheep and goats; at last, poultry refers to chickens.

For distributing census data at the pixel level (high-spatial resolution, with a resolution of 0.083333 decimal degrees), two procedures based on two different methods described in literature are been used: the areal-weighted method and the dasymetric method.

In the Areal-Weighted (AW) method, all pixels of the census area are equally suitable, and for this reason an equal weight is assigned. In this way, the number of animals in each pixel corresponds to the density of animals $[\frac{n}{km^2}]$ in the census unit multiplied by the pixel area expressed in $[km^2]$. With this approach, the AW model is free of the errors that can derive from incorrect use of variables, but in the other hand can produce more unrealistic distribution patterns, like in large areas characterized by a variety of different land-use and farming conditions.

Regarding the Dasymetric Model (DA), instead, puts on different weight to each pixel, considering high resolution environmental predictor variables and the Random Forest model, which is a machine learning way. In this way, the data census counts are distributed according to these weights, providing a better estimation of how livestock species may be distributed within census data. The weak point of DA model is the correct estimate of weights, which in turn depends on several variables. A value calculated in incorrect way could introduce some uncontrolled and confounding effects on the distribution of animals.

In Figure 3.1 it is shown the cattle density distribution calculated with the Areal-Weighted, instead in Figure 3.2 the same density, calculated with the Dasymetic model.

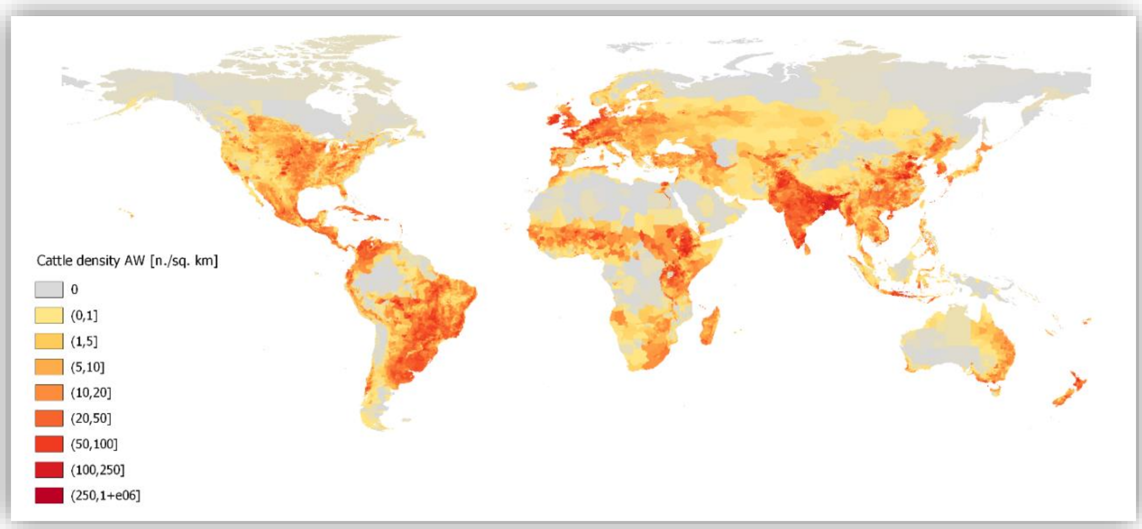



*Figure 3.1 – Cattle density $[\frac{n.}{km^2}]$ valued with the AW model*

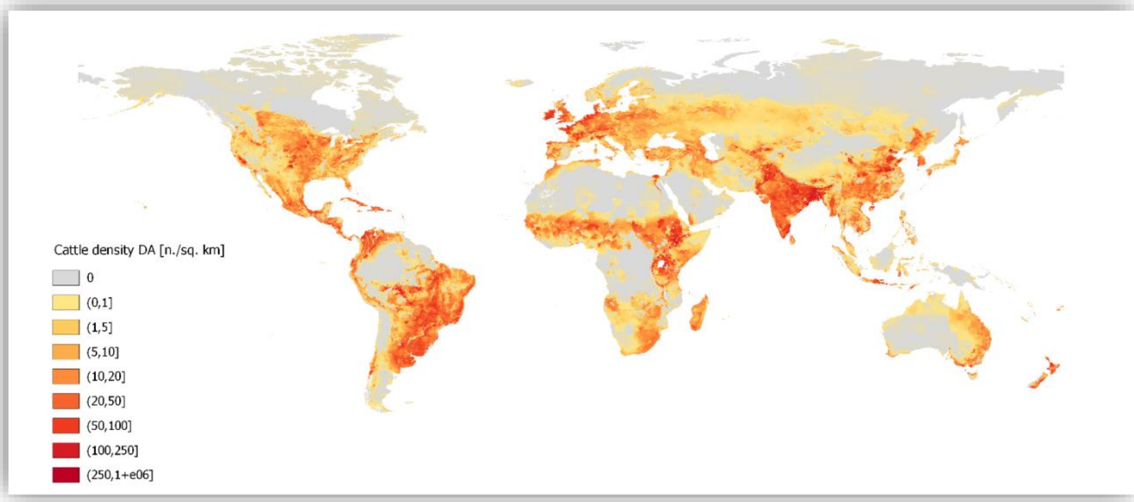



*Figure 3.2 - Cattle density [$\frac{n.}{km^2}$] valued with the DA model*

Great differences are not noticed, but looking carefully the two maps, it can be seen there are some area in central and south Africa, in south America and in India, that are considered unsuitable for the DA model according to land conditions, meanwhile the AW model, by not considering that, shows values other than zero.

Multiplying the density value by the dimension of each pixel (remember that the size of pixels changes as a function of the latitude; at the equator the area is about 10 $km^2$) it is possible to obtain the number of animals.

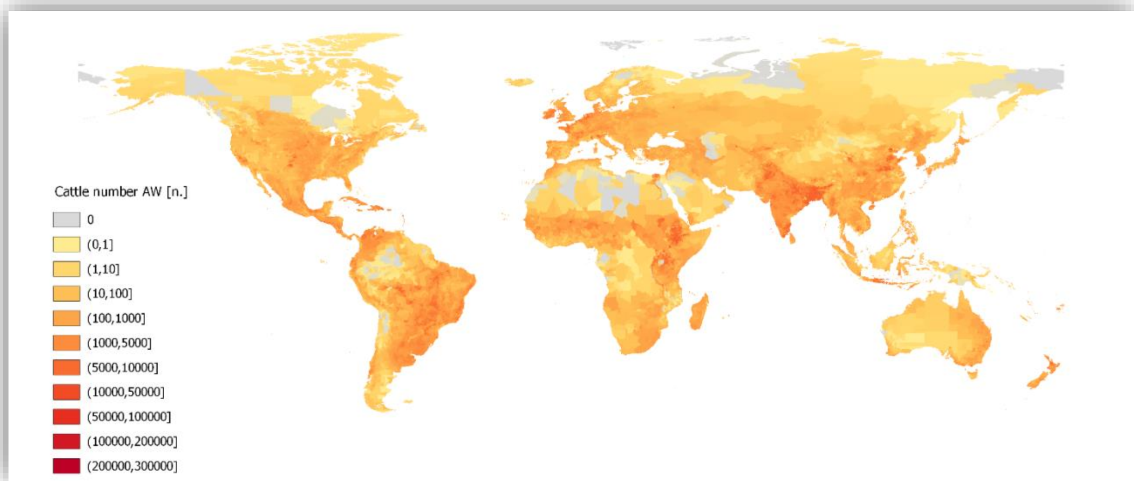



*Figure 3.3 – Cattle number [n.] valued with the AW model*

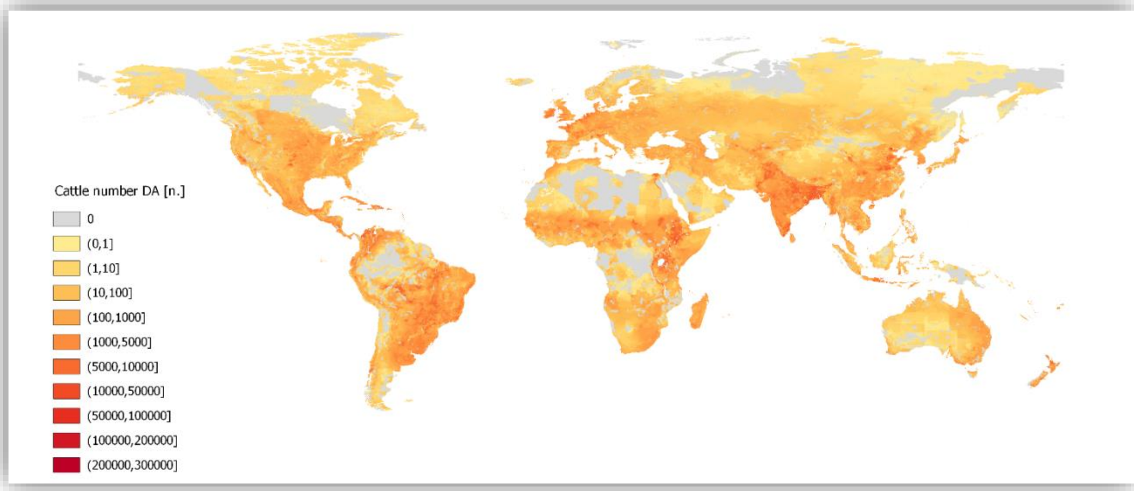



*Figure 3.4 – Cattle number [n.] valued with the DA model*

In this case, the AW model shows a higher percentage of land covered, with lower numeric values; on the other hand, like previously said, the DA model locates the unsuitable areas and consequently displays small areas with higher values in order to respect the census data.

### *3.1.2. Livestock production systems*

Another important input data to be defined and classified are livestock production systems. In the paper by (Herrero *et al.*, 2013b), two different classifications are adopted: in order to sort ruminants and small ruminants, the authors decided to use the classification developed by (Robinson *et al.*, 2011) because it is the most recent that has been realized; regarding pigs and poultry, a distinction between smallholders and industrial systems has been done.

About ruminant classification, the first main distinction is between solely livestock systems and mixed crop-livestock systems. The discriminating factor which characterizes one system rather than the other is the percentage of the total value of production coming from non-livestock farming activities: in solely livestock systems, this value is less than 10%. In addition, solely livestock systems are those in which more than 90 percent of animal feed comes from rangelands, pastures, annual forages and purchased feed, meanwhile mixed farming systems are those in which more than 10 percent of the feed comes from crop by-products. A schematic description is presented in Table 3-1. In turn, these two systems are divided into other two subsystems: the solely livestock systems could be classified in grassland-based or landless depending on the presence of grass in breeding fields; the mixed ones, instead, are split in rain-fed mixed farming and irrigated mixed farming systems. The grassland-based systems are those in which more than 10% of the dry matter fed to animals is produced on the farm (Herrero *et al.*, 2013b), vice versa for the landless systems. About the second classification, this is obtained considering the origin of most (90%) of the value of non-livestock farm production which, as the names imply, is from irrigated land use or rainfed one. To the aim of the analysis carried out in this research, in line with what was done in the publication on the diet, only the distinction between solely and mixed crop-livestock system was considered.

Simultaneously, the systems are classified also according agro-climatology aspects, directly linked with temperature and length of growing period (LGP): the arid and semi-arid systems, in which LGP is less than 180 days; the humid and sub-humid systems, with LGP higher than 180 days; in the end, the tropical highlands or temperate systems.  Areas of first subclass are characterized by a daily mean temperature, during the growing period, of between 5 and 20 °C; on the other hand, the temperate systems are those with one month or more with monthly mean temperature, corrected to the sea, below 5 °C.

In the end, two other systems are considered: the urban one, defined in turn by the GRUMP dataset (CIESIN, 2005) and characterized by numerous farmed areas with high livestock density; the secondo one is generically called 'Other' and it includes lands that are not predominantly crop or rangeland based, and for this reason they cannot be part of the previous systems.

Figure 3.5 shows the distribution of the production systems described so far:

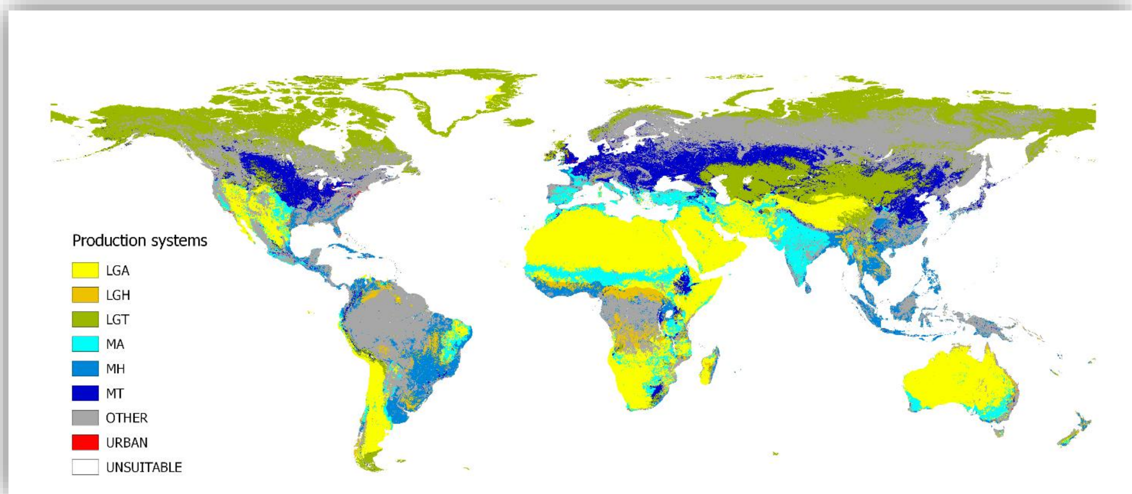



*Figure 3.5 - Livestock production systems on a global scale. Keys to the production systems' names are provided in Table 3-1.*

For greater clarity, it is emphasized that LG and M abbreviations stands respectively for solely livestock system and mixed-crop livestock system, meanwhile A, H, T are for Arid, Humid and Temperate areas.

*Table 3-1 List of livestock production systems and brief description*

| | | | |
|---|---|---|---|
| Solely livestock systems | Arid | LGA | More than 90% feed comes from rangelands, pastures, annual forages and purchased feed |
| | Humid | LGH | |
| | Temperate | LGT | |
| Mixed crop-livestock systems | Arid | MA | More than 10% feed comes from crop by-products |
| | Humid | MH | |
| | Temperate | MT | |
| Urban | | | Farmed areas with high livestock density |
| Other | | | Areas no predominantly crop or rangeland based |

As already mentioned, poultry and pigs are partitioned between industrial systems and smallholder. In other words, these two categories of animals can be considered bred in an industrial way when the production of their derivative products, like meat and/or egg, derives from farms carried out in confined environments and it is used for large-scale trade purposes; on the other hand, the backyard or smallholder systems, in which the animals are mainly bred with grazing, are those which direct the production towards home consumption and local scale.

The dimension of the farms entails also other features, like animal health and diet which in turn influences yields. From a statistical point of view, small farmers own 85% of the world farms, making them numerically the most important category of farm (Grace *et al.*, 2008).

The following figures show the distribution of pigs and poultry for both production systems considered:

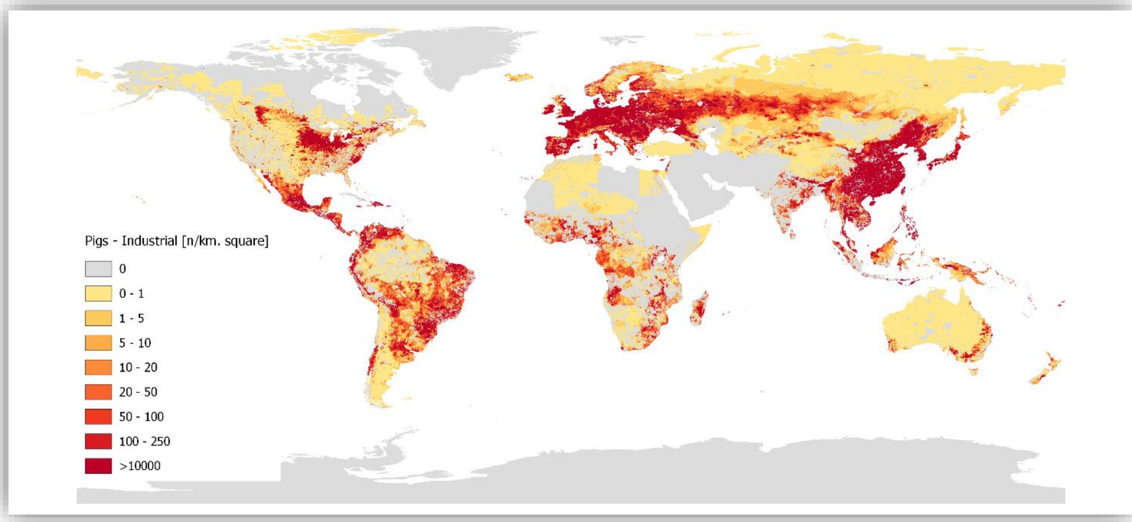



*Figure 3.6 – Pigs distribution for industrial system* $[\frac{n}{Km^2}]$

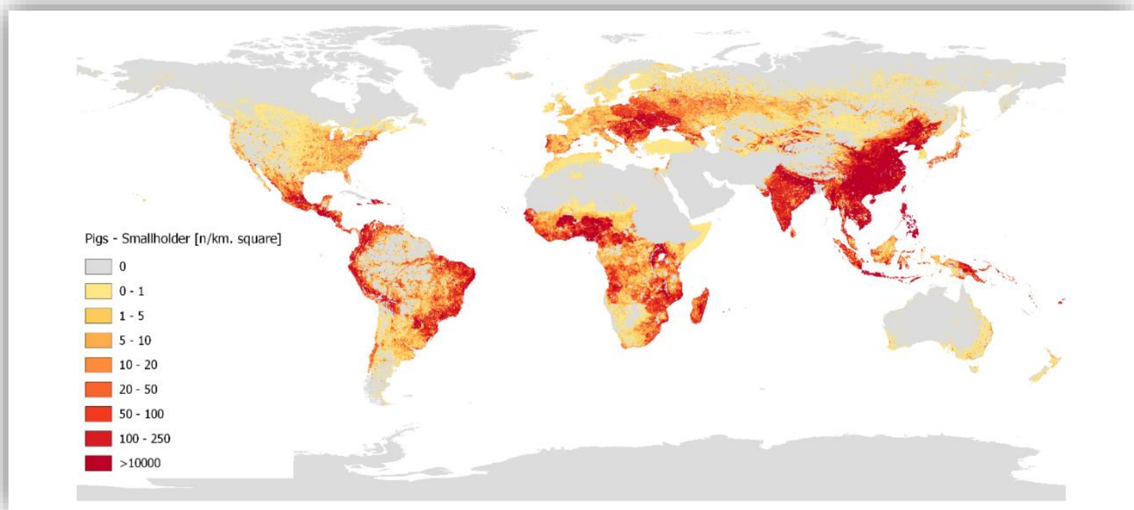



*Figure 3.7 - Pigs distribution for smallholder system* $[\frac{n}{Km^2}]$

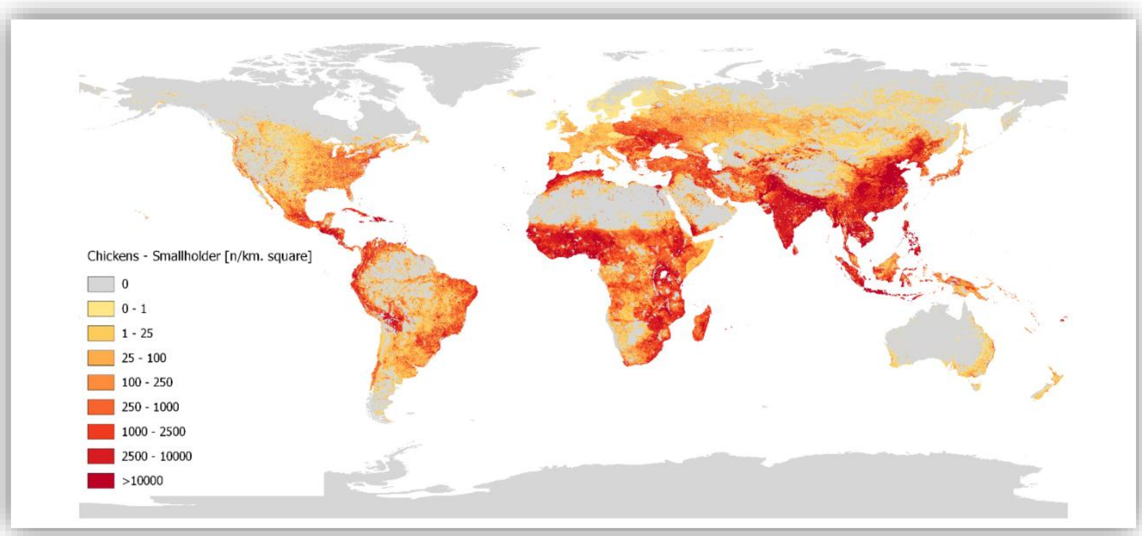



*Figure 3.8 - Chickens distribution for industrial system* $[\frac{n}{Km^2}]$

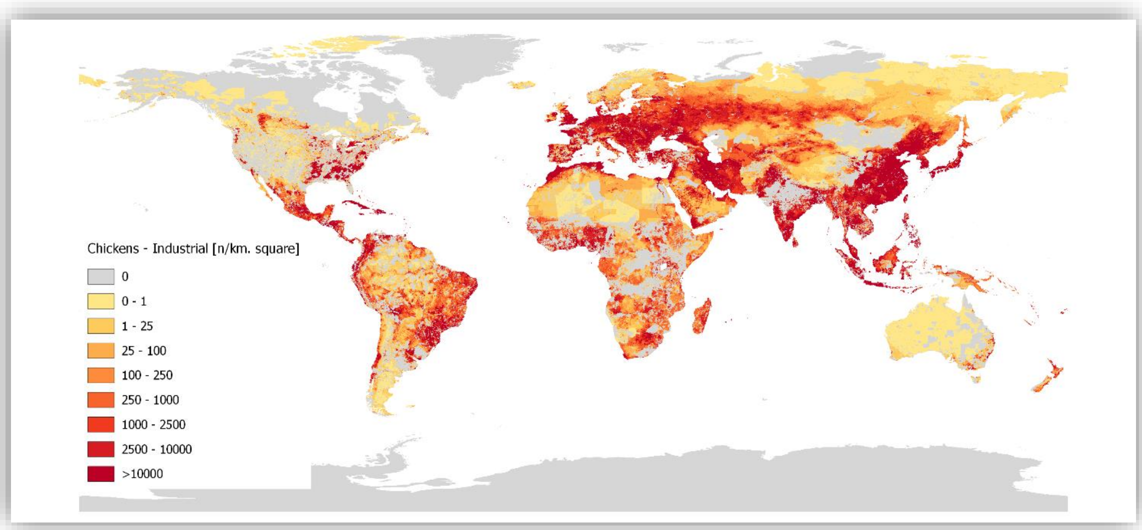



*Figure 3.9 - Pigs distribution for smallholder system* $[\frac{n}{Km^2}]$

### 3.1.3. Composition of the diets

Using a model which simulates animal digestion, (Fawcett *et al.*, 2004) and setting parameters that take into account different variables to which the animal is subject, it is possible to predict potential intake, digestion and animal performance.

For greater accuracy in providing data, a different diet has been obtained in the case of animals raised for the purpose of producing meat (ruminants/small ruminants for meat) and milk (dairy ruminants/small ruminants); in calculating the unit water footprint, it should not be forgotten, however, that products such as meat can be obtained not only from beef cattle but also from dairy ruminants.

It was possible to make the distinction between the two types of animals by knowing the livestock demographic data provided on the FAOSTAT website and described in 3.1.1, and applying a dynamic model developed in (Illius *et al.*, 1994); it was also necessary to set several parameters obtained by literature, like mortality rates. In an extremely synthetic way, the model allows to estimate the number of followers in the dairy herds, and, for difference, the followers for beef production are calculated. For what concern pigs and poultry diet, it was not necessary, for obvious reasons, to make any discrimination about dairy and meat herds.

To obtain animal diets, a great deal of data collection work was done; in particular, the analysis focuses on the year 2000, for which numerous databases have been made available. Therefore, the composition of the diet is not temporally variable; however, a similar analysis was carried out for the year 2010 and did not show substantial differences, which is why the hypothesis of invariance over time for the purposes investigated here can be considered reasonable.

In order deal with the lack of data and corrupt or inaccurate ones which mainly concerned small-sized or poorly produced countries, the world nations have been grouped into regions, in which the same diet is considered. The biggest and most important country were considered on their own (e.g. Canada, USA, China, Brazil, Japan, India, Mexico, South Korea, Turkey); Europe countries were categorized into 8 classes, Sub-Saharan Africa into 4 regions, etc. In this way, the world has been mapped into 29 regions, each of which characterized with a specific feed composition and feed consumptions. For the purpose of this work, these data are been used. However, in the paper the results are further aggregated into 9 macro-regions (i.e. Europe, Oceania, North American Region, etc) in order to facilitate reading, while detailed values are given in the additional material (Herrero *et al.*, 2013a). The regions considered in the paper are shown in Table 3-2

*Table 3-2 List of regions used in the analysis and mapping of countries* (Herrero *et al.*, 2013a)

| Region | Data analysis level | Countries |
|---|---|---|
| EUR | EU Baltic | Estonia, Latvia, Lithuania |
| | EU Central East | Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia |
| | EU Mid-West | Austria, Belgium, Germany, France, Luxemburg, Netherlands |
| | EU North | Denmark, Finland, Ireland, Sweden, United Kingdom |
| | EU South | Cyprus, Greece, Italy, Malta, Portugal, Spain |

| | | |
|---|---|---|
| | Former USSR | Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgystan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan |
| | RCEU | Albania, Bosnia and Herzegovina, Croatia, Macedonia, Serbia-Montenegro |
| | ROWE | Gibiltar, Iceland, Norway, Switzerland |
| OCE | ANZ | Australia, New Zealand |
| | Pacific Islands | Fiji Islands, Kiribati, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu |
| NAM | Canada | |
| | USA | |
| LAM | Brazil | |
| | Mexico | |
| | RCAM | Bahamas, Barbados, Belize, Bermuda, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Netherland Antilles, Panama, St Lucia, St Vincent, Trinidad and Tobago |
| | RSAM | Argentina, Bolivia, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela |
| EAS | China | |
| | Japan | |
| | South Korea | |
| SEA | RSEA OPA | Brunei Daressalaam, Indonesia, Singapore, Malaysia, Myammar, Philippines, Thailand |
| | RSEA PAC | Cambodia, Korea DPR, Laos, Mongolia, Vietnam |
| SAS | India | |
| | RSAS | Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan, Sri Lanka |
| MNA | MENA | Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, Yemen |
| | Turkey | |
| SSA | Congo Basin | Cameroon, Central African Republic, Congo Republic, Democratic Republic of Congo, Equatorial Guinea, Gabon |
| | Eastern Africa | Burundi, Ethiopia, Kenya, Rwanda, Tanzania, Uganda |
| | South Africa | |
| | Sothern Africa | Angola, Botswana, Comoros, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Swaziland, Zambia, Zimbabwe |

| | | |
|---|---|---|
| | West and Central Africa | Benin, Burkina Faso, Cape Verde, Chad, Cote d'Ivoire, Djibouti, Eritrea, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Somalia, Sudan, Togo |

In Table 3-3, as an example, it is shown the feed composition of dairy ruminants per production system for the Australian and New Zealand macro-region:

*Table 3-3 – Feed consumption per production system of dairy ruminants in ANZ*

| ANZ - BOVD | GRAZING | STOVER | OCCASIONAL | GRAINS |
|---|---|---|---|---|
| LGA | 100% | 0% | 0% | 0% |
| LGH | 90% | 0% | 0% | 10% |
| LGT | 82% | 0% | 0% | 18% |
| MRA | 100% | 0% | 0% | 0% |
| MRH | 91% | 0% | 0% | 9% |
| MRT | 81% | 0% | 0% | 19% |
| Other | 94% | 0% | 0% | 6% |
| URBAN | 0% | 0% | 97% | 3% |

For clarity, stover are the leaves and stems of field crops that are left in a field after the harvesting; occasional feed refers to the waste relating to the other three categories.

The paper also provides another important information without which it would not be possible to calculate the unit water footprint of animal feed: the inclusion of feed ingredients in feed concentrates. For the same regions already described, the ratio of the most common grains that animals eat has been calculated. As done previously, data about dairy ruminants in Australia and New Zealand are reported in Table 3-4.

*Table 3-4 – Percentage of feed ingredients in grain per production system of dairy ruminants in ANZ*

| ANZ BOVD | Barley | Maize | Pulses | Rice | Sorghum Millet | Soya | Wheat | CerO | OlsO | CrpO | Animal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LGA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| LGH | 7% | 19% | 5% | 0% | 3% | 13% | 19% | 17% | 5% | 6% | 6% |
| LGT | 7% | 19% | 5% | 0% | 3% | 13% | 19% | 17% | 5% | 6% | 6% |
| MRA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| MRH | 7% | 19% | 5% | 0% | 3% | 13% | 19% | 17% | 5% | 6% | 6% |
| MRT | 7% | 19% | 5% | 0% | 3% | 13% | 19% | 17% | 5% | 6% | 6% |
| Other | 7% | 19% | 5% | 0% | 3% | 13% | 19% | 17% | 5% | 6% | 6% |
| URBAN | 7% | 19% | 5% | 0% | 3% | 13% | 19% | 17% | 5% | 6% | 6% |

It is important to specify the meaning of “other cereals”, “other oils”, “other crops” and “animal products”. These items enclose all the other grains which have not been specified because of the small percentage they hold; however, to the aim of this study, only the majority component of the items is been considered. In this way, “other cereals” represents rye, “other oils” are rapeseed, “other crops” is peas and at last “animal products” is fishmeal.

In the end, the quantities of each element of the diet are calculated $\left[\frac{kgDryMass}{tlu*y}\right]$; for consistency with the data shown above, the same region and category of animals are reported.

*Table 3-5 Feed ingredients per production systems of dairy ruminants in ANZ*

| BOVD | | GRAZING | STOVER | OCCASIONAL | GRAINS | BOVD | BOVDh |
|---|---|---|---|---|---|---|---|
| | | [kgDM/TLU/y] | | | | [1000 TLU] | |
| ANZ | LGA | 3865 | | | | 1029 | 1543 |
| | LGH | 3801 | | | 411 | 698 | 1047 |
| | LGT | 3787 | | | 823 | 71 | 111 |
| | MRA | 3500 | | | | 321 | 474 |
| | MRH | 4107 | | | 411 | 777 | 1173 |
| | MRT | 3435 | | | 823 | 18 | 28 |
| | Other | 3264 | | | 205 | 1040 | 1565 |
| | URBAN | | | 7533 | 205 | 1068 | 1614 |

| BOVD | | Barley | Maize | Pulses | Rice | Sorghum Millet | Soya | Wheat | CerO | OlsO | CrpO | Anim |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | [kgDM/TLU/y] | | | | | | | | | | |
| ANZ | LGA | | | | | | | | | | | |
| | LGH | 30 | 77 | 18 | | 12 | 52 | 79 | 70 | 20 | 26 | 22 |
| | LGT | 61 | 154 | 37 | | 24 | 105 | 159 | 140 | 41 | 52 | 45 |
| | MRA | | | | | | | | | | | |
| | MRH | 30 | 77 | 18 | | 12 | 52 | 79 | 70 | 20 | 26 | 22 |
| | MRT | 61 | 154 | 37 | | 24 | 105 | 159 | 140 | 41 | 52 | 45 |
| | Other | 15 | 38 | 9 | | 6 | 26 | 39 | 35 | 10 | 13 | 11 |
| | URBAN | 15 | 38 | 9 | | 6 | 26 | 39 | 35 | 10 | 13 | 11 |

Table 3-5 also shows the number of animals $[1000\ TLU]$ that are part of the flock intended to produce meat or milk, and it is in turn divided into mature animals or young followers (please note that this distinction does not apply to pig and poultry).

## 3.2. CWASI dataset: agriculture WF from 1961 to 2016

The information regarding the crop water footprint was extrapolated from the CWASI database, which is an open source database of the consumptive water footprint of agricultural products and the virtual water trade. Results are reported on a country scale and they refer to the years between 1961 and 2016 in the case of the uWF of crops, whereas detailed data regarding trade pertain to the 1986-2016 time span.

This database, to be realized, has in turn used data obtained from other sources: the FAOSTAT website (described in 3.3) and the WaterStat database (illustrated in chapter 3.4). The first source was used to obtain the agricultural yields of the various products considered (maize, wheat, etc.): this data is available on a national scale, annually variable starting from 1961, for all countries. From the second database, the unit water footprints of the same products were extrapolated, expressed in cubic meters per ton, and calculated using the procedure described in (Mekonnen and Hoekstra, 2011): it is important to note that this database shows the uWF of products calculated starting from data averaged over a period of time between 1996 and 2005 and centered in the year 2000.

The procedure used to calculate the uWF is named Fast Track approach and it is described in (Tuninetti *et al.*, 2017). Briefly, the procedure is based on the hypothesis (confirmed in the publication) that the variation in the evapotranspiration depth (ET) does not appreciably influence the variation in the virtual water content, but that this is conditioned only by the variation in the agricultural yield (Y). In this way, considering the definition of virtual water content valid for every i-th product and j-th year:

$$CWF_{i,j} = 10 * \frac{ET_{i,j}}{Y_{i,j}} \left[\frac{m^3}{ton}\right] \qquad 3.1$$

since the unit water footprint in (Mekonnen and Hoekstra, 2011) ($\overline{CWF_i}$) was evaluated considering an average evapotranspiration value between years 1996 and 2005 ($\overline{ET_i}$), an average yield was calculated over the same time span ($\overline{Y_i}$); finally, in order to obtain the temporal variation, data provided in the WaterStat database were corrected as follows:

$$CWF_{i,j} = \frac{\overline{CWF_{i,j}} * \overline{Y_i}}{Y_{i,j}} \left[\frac{m^3}{ton}\right] \qquad 3.2$$

Regarding the virtual water trade, after collecting the import and export data for each country, it was necessary to use a data-based approach to solve problems related to the lack of data or double records (in some cases it is observed the tons data related to the export from an i-th nation towards a j-th one are different from those which they quantify the tons that the same j-th nation imports from same i-th nation). The model, described in (Gehlhar, 1996), it is based on the use of a reliability index, which allows to combine the two import and export matrices choosing for each element the one with the highest index.

Detailed information on trade flows for each nation is only available from 1986: it is for this reason that, even if the unit water footprint of crops was available from 1961, the first 25 years were cut off from the analysis.

## 3.3. FAOSTAT dataset

One of the most important and rich sources of information used for the research carried out in this study is FAOSTAT website. It is the statistical section of FAO and it provides annually data at country resolution about several components of food and agriculture aspects: it is possible to find and download for free data about production of crops and animal, trade information, yields, economic values, fertilizer and pesticides use, emission, land use, etc.

In data section, you can select different domains. As described in the previous chapter, CWASI database is based on data provided by FAOSTAT regarding crop yield (from 1961 to 2016) and the tons of products exchanged between nations (from 1986 to 2016).

For the purpose sought in this study, the following data were downloaded (from 1986 to 2016):

- animal yield, which measures the quantity of product that can be obtained from the slaughtering of an animal (meat) or from its breeding (milk, eggs);
- derivative product quantity;
- animal number.

Table 3-6 shows the animals and related products considered:

*Table 3-6 Considered products*

| Products | Buffalo | Cattle | Pig | Poultry | Sheep | Goat |
|---|---|---|---|---|---|---|
| Heads | x | x | x | x | x | x |
| Meat | x | x | x | x | x | x |
| Milk | x | x | | | x | x |
| Eggs | | | | x | | |

Below the procedure needed to download tables is described, taking yields of livestock primary as an example.

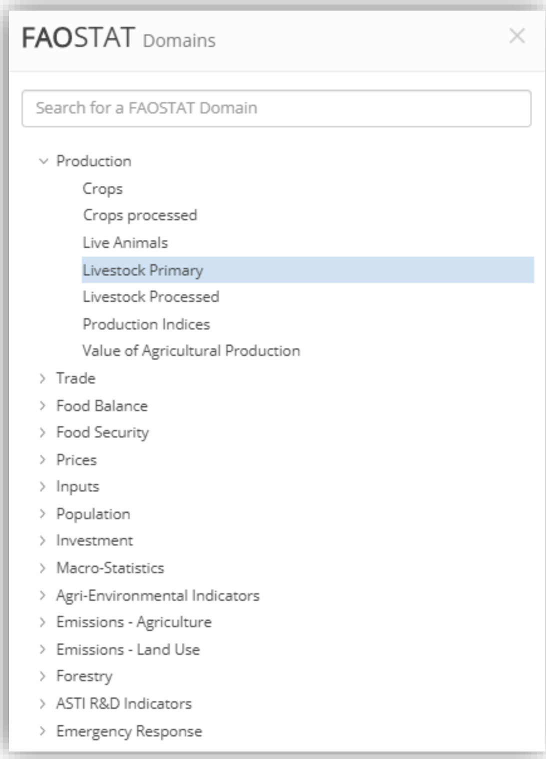



*Figure 3.10 – Screenshot of FAOSTAT webstite – Domain section*

The first step to attempt is to select the desired domain: in Figure 3.10 production domain was selected, and it showed several subcategories; choosing crops, it is possible to download production quantity, area harvested and yield; the live animals part provides stocks data, etc.

In this example, in Figure 3.11, the livestock primary section is studied in deep. The page is quite intuitive, but a brief description can be useful. On the top left list you can choose the countries for which you need data; on the top right you choose the quantity that you want to explore, and in the bottom left the item to which it refers; in the end, in the bottom right, there is the opportunity to select the year (data are available from 1961). The website also allows to do multiple selections, if needed; you can also decide to select countries aggregated into regions or special groups, and to aggregate items.

It is specified that among the nations there are "Neutral Zone" and "Unspecified" voices, which refer to territories not precisely specified and for which no data are available, and several voices related to China: "China, Mainland", "China, Hong Kong SAR", "China, Macao SAR", "China, Taiwan Province of", and in the end "China", which corresponds to an aggregation of the previous entries (in this research, "China" has been considered).

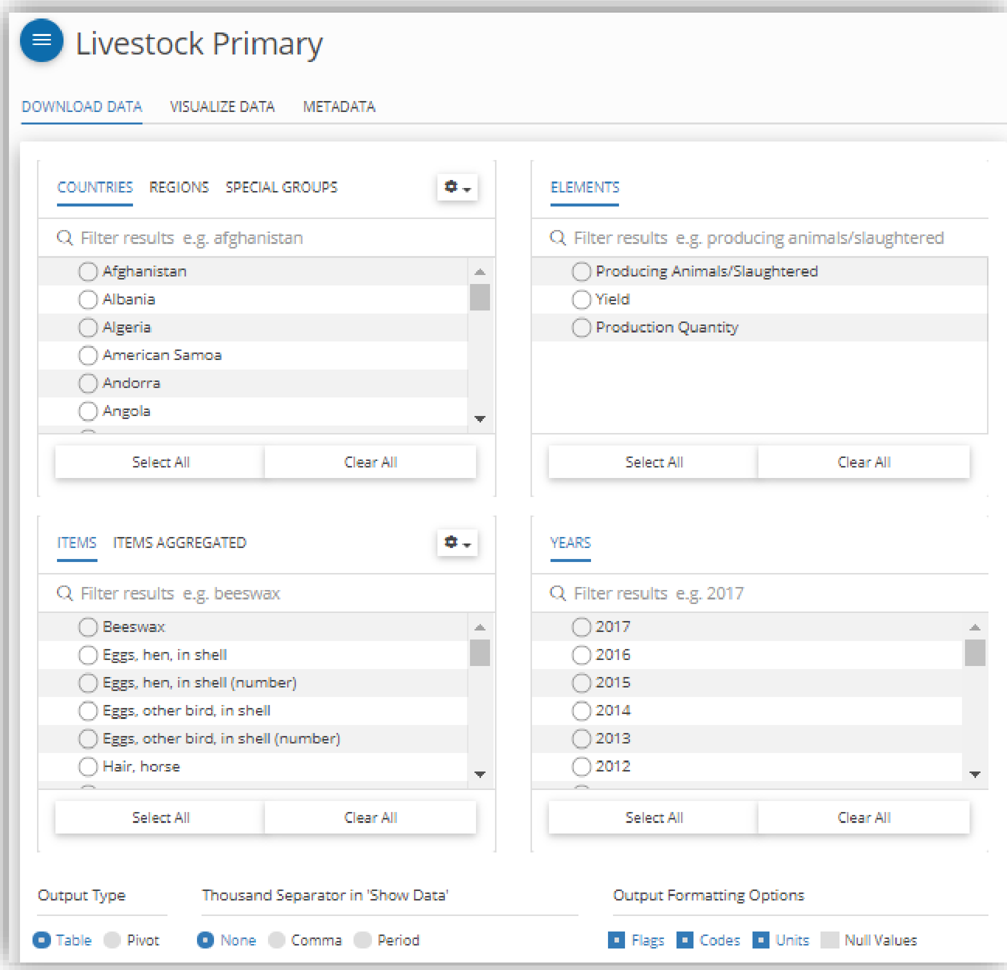



*Figure 3.11 – Screenshot of FAOSTAT website -Data section*

The output file is a .csv file, in which the values relating to the choices made are shown; the website also provides the option to modify the output type (it is possible to choose between table or pivot output) and to omit some information, like null values, units of measure and FAO codes.

## 3.4. WaterStat database

The water footprint of animal products does not represent an area where research has not already entered: in effect several publications have been published for the purpose of clarify this topic, but, as previously said in 2.1, many of these focus on individual countries without providing an unique methodology useful for all the world.

However, the WaterStat database contains all the information relating to the water footprint obtained so far; a publication that has significantly increased the information available is that written by Mekonnen and Hoekstra (Mekonnen and Hoekstra, 2010), which "provides a comprehensive account of the global green, blue and grey water footprints of different sorts of farm animals and animal products, distinguishing between different production systems and considering the conditions in all countries of the world separately".

The methodology and the results obtained in this way are of great use also for this analysis, as they allow to compare the two procedures and to validate what has been calculated in this research, emphasizing similarities and differences.

In order to clarify the method used in this approach, the main steps followed are described below.

The water footprint of the i-th animal bred in the c-th country with a s-th production system is calculated as follows:

$$uWF_{i,c,s} = uWF_{Feed_{i,c,s}} + uWF_{Drink_{i,c,s}} + uWF_{Serv_{i,c,s}} \qquad 3.3$$

where the feed component is calculated as:

$$uWF_{Feed_{i,c,s}} = \frac{\sum_j \left(Feed_{i,j,c,s} * uWF_{prod_i}\right) + WF_{mixing}}{Pop_{i,c,s}} \qquad 3.4$$

While the others refer to:

- $uWF_{drink}$, the water properly drunk by animals;
- $uWF_{serv}$, referring to the water used to clean the farmyard, wash the animal and carry out other services necessary to maintain the environment;
- $WF_{mixing}$, which is the needed for mixing the feed, necessary for calculating the water footprint of feed;

The parameters are analyzed below:

$$Feed \left[\frac{ton}{y}\right] = FCE * P \qquad 3.5$$

The quantity of feed consumed by a specific animal category, in a country and with a production system is calculated multiplying the feed conversion efficiency [$\frac{kgDM}{kg_{product}}$] by the total amount of product produced by the same animal category in the same country and production system [$\frac{ton}{y}$].

In turn, the feed conversion efficiency is calculated as the ratio between the feed intake per head ($FI$) and the product output per head ($PO$), the latter representing the ratio between the total amount of production ($P$) and the total population of the animal class considered ($Pop$).

$$FCE = \frac{FI\ [\frac{kgDM}{animal * y}]}{PO\ [\frac{kg\ product}{animal * y}]} = \frac{\frac{FI}{P\ [\frac{kg}{y}]}}{Pop\ [animal]} \qquad 3.6$$

As regards the water footprint of crops, this is also provided in the WaterStat database, and has been calculated in (Mekonnen and Hoekstra, 2011) aggregating on a national scale the results that have been obtained on a cell scale using a "grid-based dynamic water balance model" which "takes into account the daily soil water balance and climatic conditions for each grid cell".

In order to differentiate the origin of the feed, the volume of feed consumed has been subdivided into concentrate and roughage. Concentrates feed contain a high level of nutrients and they all are derived from crops; contrariwise, the roughages feed has a low density of nutrients. The main roughages are pastures (grass), harvested roughages (fodder) and crop residues.

The volume of concentrate feed has calculated by using a fraction:

$$Concentrate\ [\frac{ton}{y}] = Feed * f_c \qquad 3.7$$

The fraction of concentrate values has been obtained by literature (Hendy *et al.*, 1995), (Bouwman *et al.*, 2005) and (Wheeler *et al.*, 1981); by the way, they were not provided with information about the global coverage on the composition of feed, so several assumption have been done. In conclusion, cereals and oilmeals are considered like the prevailing concentrate feed, all the other ones are included in the "other concentrates" category.

The composition of the roughage feed has been estimate by literature (Bouwman *et al.*, 2005) as well.

In the end, the production of goods is calculated by multiplying the carcass yield per slaughtered animal $C_y$ by the annual number of animal slaughtered $S_a$ (in the case of products such as meat):

$$P = C_y * S_a \qquad 3.8$$

For products for which it is not necessary to kill the animal, such as eggs or milk, the production is calculated using the fraction of good $f_{prod}$ produced instead of the carcass yield:

$$P = f_{prod} * S_a \qquad 3.9$$

The result is the composition of the diet is shown in Figure 3.12, calculated for the four main animal categories (cattle and buffaloes, sheep and goats, pigs, poultry) on a global scale.

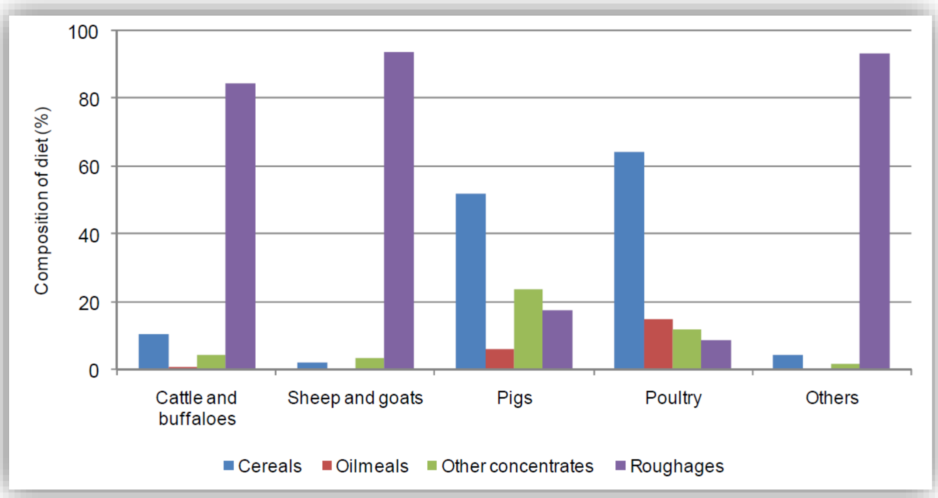



*Figure 3.12 – Composition of the diets (Wheeler et al., 1981)*

After doing this, an average of the water footprint weighted according to the relative volumes of domestic production and import have been calculated.

Moreover, portion of water not related to the food component ($uWF_{drink}$, $uWF_{serv}$ and $uWF_{mixing}$ are very small, and they were not calculated but they assumed a fixed value; for this reason, they were ignored in this study.

Lastly, the water footprint of a processed product is computed from the water footprint of the input product, corrected by two factors:

$$\mathrm{uWF}_{\mathrm{corr}} = \mathrm{uWF} \cdot \frac{f_v}{f_p} \qquad 3.10$$

- $f_p$ is the product factor and it is defined as the weight of a derived product obtained from a ton of input product;

- $f_v$ is the value factor and it is the market value of the derived product divided by the aggregated market value of all derived products resulting from a ton of input product.

As result, world averages of the water footprint of the most important animal products are reported:

*Table 3-7 World average of the water footprint of the main animal products*

| Product | WF [$m^3$/ton] |
|---|---|
| Cattle meat | 15400 |
| Sheep meat | 8700 |
| Pig meat | 5400 |
| Goat meat | 8700 |
| Chicken meat | 3900 |
| Egg | 2900 |
| Cow milk | 1020 |

This research is very important in view of this study because it allows you to make a first comparison with the data obtained; anyway, it is fundamental to remember that there are several differences between the two approaches, which will be explored in the Chapter 6.3.

# 4. EVALUATION OF THE WATER FOOTPRINT

This section deepens the methodology carried out to calculate the unit water footprint of animal products; in particular, it describes how the input data have been reworked, the assumptions that have been imposed, and above all the procedure that has been undertaken. Different scenarios on a national scale are been analyzed: at first results were obtained considering the scenario in which the uWF of farm animal products was calculated without considering the trade of the elements making up the diet; subsequently the trade was implemented. Both the models were created in such a way as to consider the temporal variability of the input data, obtaining a database with the unit water footprint of each product derived from the animals considered and variable from 1986 to 2016.

Substantially, there is no difference in the models of the two scenarios, since the only difference is the input data about feed. Nevertheless, an intermediate step was required because it was necessary to correct the water footprint of the feed to account the trade.

The results obtained make it possible to elaborate important observations on the evolution of the water efficiency over time, the percentage of blue water in comparison with the total and the volumes of water consumed worldwide for zootechnical purposes, as well as allowing the influence of the trade to be analyzed.

## 4.1. Animal product uWF without feed trade – Methodology

Below there is a detailed description of the procedure followed for the calculation of the unit water footprint of products of animal origin on a national scale, in the simplifying hypothesis of the absence of feed trade.

The following formula was used to calculate the unit water footprint of an animal in a specific livestock production system $\left[\frac{m^3}{ton_{Animal}}\right]$:

$$uWF_{Animal_i,ProdSystem_k} = \frac{\left[\sum_j \left(Feed_{j,k} * uWF_{Feed_j}\right)\right]}{conv_{head2ton}} * \frac{f_{v_{Animal_i}}}{f_{p_{Animal_i}}} \qquad 4.1$$

While in order to compute the unit water footprint of a derivative product $\left[\frac{m^3}{ton_{Product}}\right]$ this formula was used:

$$WF_{Product_i,ProdSystem_k} = \frac{\left[\sum_j \left(Feed_{j,k} * uWF_{Feed_j}\right)\right]}{Yield_{Product_i}} * \frac{f_{v_{Animal_i}}}{f_{p_{Animal_i}}} \quad 4.2$$

The procedure, therefore, requires that the quantities of the items of the diet are multiplied by their unit water footprints, and added together; subsequently, in order to respect the dimensional analysis and to obtain the uWF of animals, it was necessary to divide the value by a factor capable of converting the number of animals into tons. With this factor we try to consider the variability that animals age in their weights; moreover, it should be remembered that this factor does not present temporal variability and has therefore been kept constant throughout the study period. Finally, values were further multiplied by the value factor and divided by the production one, both described in 3.4. It is good to underline, however, that these factors, which are also constant over time, always take on a unit value, except for the hens that produce meat, for which the production value assumes a value equal to 10. The calculation of the water footprint of a derivative product is very similar to the one just described, but it is necessary to use the yield which takes the place of the conversion factor at the denominator, obtaining the uWF interpreted as water volume per unit of derived product. Please note that the yields vary over time.

The unit of measurement of consumed feed has been converted, passing from Kg to ton (dividing by 1000) and from tropical livestock units to animal heads, multiplying by the TLU conversion factor. This factor, described in 3.1.3, assumes different values, in relation to which animals you want to refer to; values used for the animals treated in this research are shown below:

*Table 4-1 Tropical livestock unit conversion factors*

| TLU conversion factors | |
|---|---|
| Cattle | 0.7 |
| Buffalo | 0.7 |
| Sheep | 0.02 |
| Goat | 0.02 |
| Pig | 0.2 |
| Poultry | 0.01 |

Subsequently, it is necessary to make some considerations regarding the unit water footprint of feeds. Unlike all crops, there is no database that defines the water footprint of grass considering the temporal variability on a country scale; however, high resolution data concerning uWF and production is available for the year 2000 only. Using this information, the national uWF of grass was calculated, carrying out a weighted average. This approximation was also justified by the fact that, of course, the grass uses only green water, while it does not have the blue component, and therefore the temporal variability of the water footprint is not high.

Concerning grains, the CWASI dataset provided information with temporal variability on a country scale; however, considerations had to be made to make them consistent with each other. The database about diet considers sorghum and millet in one item, whereas the uWF of both is provided; the same thing happens in the case of peas, for which in the database there is the unit water footprint of dry peas and green peas. To deal with these particularities, it was decided to consider, for both cases, a single water footprint calculated as the average of the two components, weighed with their production; in this way, the uWF of "Sorghum/Millet" and "Peas" items was obtained. Obviously, this consideration was made for both the blue and the green components. It was decided to consider the weighted average with the production in order to avoid that, with an arithmetic average, the water footprint of one of the two crops was given greater weight even if it is cultivated in smaller quantities.

Regarding the stover item, which as described in 3.1.3, includes residues and waste after harvest, it usually does not play a fundamental role in the diet of animals due to its low nutritional intake. Moreover, was not taken into consideration in this analysis, because they are produced using the water destined for crops: if you add the unit water footprint of this element to the calculation, you would risk committing double counting and consequently overestimate results.

Lastly, there is the occasional feed item: it includes elements from previous items, without distinctions and additional information. In order to consider this component of the diet and in the absence of further details, the average water footprint of grass and grains was simply calculated.

About yield, it represents the quantity of product that can be obtained from a single animal; depending on the type of product (meat, milk or eggs), data is provided in different units of measurements, in particular:

- [hg/head] in the case of chicken meat;
- [100mg/head] in the case of eggs;
- [0,1g/head] for all other cases.

Dividing by the correct corrective factor, all yields were expressed in $\left[\frac{ton}{head}\right]$. In the same way, the conversion factor refers to the same unit of measurement

Through this procedure the uWF of each product was calculated for all production systems present in every individual country; in order to obtain a reference value on a national scale, an average was calculated, by weighing the water footprints in the various production systems with their extension expressed in percentage terms.

$$uWF_{Animal_i} = \frac{\sum_k \left(uWF_{Animal_i,ProdSystem_k} * Perc_{ProdSystem_k}\right)}{100} \quad 4.3$$

In addition, some products, such as meat, can be obtained from both dairy and meat herds: in order to take this particularity into account, for these products a further average was made, weighed the uWF of these products with the percentage of animals belonging to the two flocks.

$$uWF_{Product_i} = \frac{\left(uWF_{Product_i,Dairy} * Perc_{Dairy}\right) + \left(uWF_{Product_i,Meat} * Perc_{Meat}\right)}{100} \quad 4.4$$

After performing all these operations, the unit water footprints of the major farm animal products were obtained, on a national scale and in the hypothesis of the absence of feed trade, from 1986 to 2016.

## 4.2. Animal product uWF with feed trade – Methodology

The next step was to implement the feed trade and to calculate the correct water footprint.

The methodology used is exactly the same described in 4.1, but there is a substantial difference between the two cases in the value of unit water footprint of crops. CWASI database, as described in 3.2, was created by calculating the water needed to produce a crop in each country; however, animals are bred by feeding them crops, but if the national production destined for zootechnical use is not sufficient to meet the request, the nation must import the goods from foreign nations. In this way, trade plays an important role because the same type of crop can be produced with a greater or lesser consumption of water depending on the production techniques adopted in the different countries, which influence its agricultural yield; moreover, depending on the climatic conditions and the degree of equipment with irrigation systems, even the component of blue water compared to the total can vary significantly.

As already mentioned previously, the grass is considered not to be traded, since in the case in which animals are not bred with pasture techniques but are fed in intensive systems, it is assumed that the grass component is taken from national territories; therefore, it is not necessary to correct its water footprint. As regards the water request of occasional feed, it is calculated, like in the previous scenario, as the average between the uWF of grain and grass, and his value changes as the uWF of crops changes. In the end, please remember that the water footprint of stover is not calculated and it is not considered in the calculations

The unit water footprint of the products can be different in the two scenarios, and this may be due to the concomitance of two factors:

- Presence of a significant component related to import, caused by a low national production or by an economy re-export based;
- Appreciable difference in terms of water demand between the locally produced feed and the imported one: this can happen if a poorly developed nation, in which the agricultural yields are not optimal, imports from a more advanced nation, in which the unit water footprint is lower, or otherwise, or vice versa.

The formula for correcting the uWF according to the trade is as follows:

$$\mathrm{uWF_i} = \frac{Prod_{Domestic_i} * uWF_i + \sum_j \left( Prod_{Imp_{j,i}} * uWF_j \right)}{\mathrm{Prod_{Naz_i}} + \sum_j \left( Prod_{Imp_{j,i}} \right)} \qquad 4.5$$

In this way an average of the water footprint of the i-th crop is calculated, weighing it with the quantities produced in the nation and those imported from other nations.

The peculiarity of this scenario was the need to derive the data relating to the production of each crop intended for national use ($Prod_{domestic_i}$) starting from the total production, which is reported on FAOSTAT website. The national production of crops has been calculated as the difference between the total production and the sum of the quantities exported to all over the world, for which it was necessary to use the bilateral trade matrix described in 3.2. It is precisely in this matrix that the reason why the time analysis starts from the year 1986 must be sought: even if the FAOSTAT website provides all the data that needed from 1961 onwards, the detailed matrix does not contain information relating to the first 25 years.

At first, it was hypothesized to fill the gap of the missing years by assuming that the trading partners have not changed from 1986 to 1996, and to consider an average of the quantities traded in this decade as a value for the years in which there is a lack of data. However, this hypothesis was subsequently discarded because it would be the cause of an approximation which is too large and difficult to control; furthermore, in this way two different methodologies would be used for two different time spans. Therefore, in the absence of other methods to critically consider the years up to 1985, it was decided to cut them out of the study period, focusing from 1986 to 2016

Even in this case, in considering the trade of items "Sorghum/Millet" and "Dry peas/Green peas" items, the trade of a fictitious item was considered, which it was calculated as the average of the trade of the components, weighed with their production. It is specified that, since the trade database does not provide information regarding pulses, no trade was considered about this item and its unit water footprint is considered unchanged in the two scenarios.

# 5. DATA PRE-PROCESSING

One of the first things that is very useful to do after collecting all the data, even before using them to perform the evaluation of the water footprint previously described, is to analyze them, in order to develop a critical knowledge and understanding, useful for interpreting subsequently results to the best of our capability.

The purpose we wanted to pursue in this chapter was to identify statistical information that could improve the knowledge on how data were derived and their robustness: specifically, the animal distribution obtained with the two proposed distribution models were compared on a country scale with FAOSTAT national data; the probability density function PDF of the animal density distributions were examined, and these allowed to quantify the spatial extension of the areas dedicated to the breeding of each class of animals.

Moreover, it is interesting to represent how livestock production systems are distributed among the world, and how they are widespread, both at a national resolution and at high spatial resolution. This point of view is fundamental to the aim of this work, because changing in production systems produce remarkable variation in composition of diets as well, and in consequence to this, the unit water footprint of farm animal products alters.

For the reason mentioned above, particular attention has been also given to the composition of the diet, pointing out how they vary according to the production system, and how different they are if the same system in different regions are evaluated.

## 5.1. Comparison between AW and DA models with FAOSTAT data (year 2010)

As said in 3.1.1, the FAOSTAT website provides two different animals distribution models, the Areal-Weighted and the Dasymetric model. In order to find out the differences between these two approaches with immediate effect, the numeric values are been aggregated at country scale, and they are been compared. It is important to keep in mind that the two models refer to the animal distributions in year 2010.

Moreover, the FAOSTAT website supplies also the data on a country scale, so a further comparison between the elaborated data and the registered ones was possible. This type of data is available from 1961 and 2016, and it come mainly from official census data and, in case they were absent, estimates have been made. In order to make a coherent comparison, data for the year 2010 were taken into consideration.

In a generic way, the two models do not differ substantially, with exceptions relating to countries where animal breeding is not very large. Comparing these results with FAOSTAT data, they both fit pretty good, in particular the DA model presents less disagreement: The reason for this result is the difference in the proceeding of the two models: the explanation of this peculiarity must be sought in the fact that the Dasymetric model tries to best represent reality by weighting the density data with land conditions.

This type of data analysis was done for each category of animal whose diet is available (cattle, buffaloes, chickens, sheep, goats and pigs); nevertheless, here only special cases are reported, related to buffalo and chicken livestock.

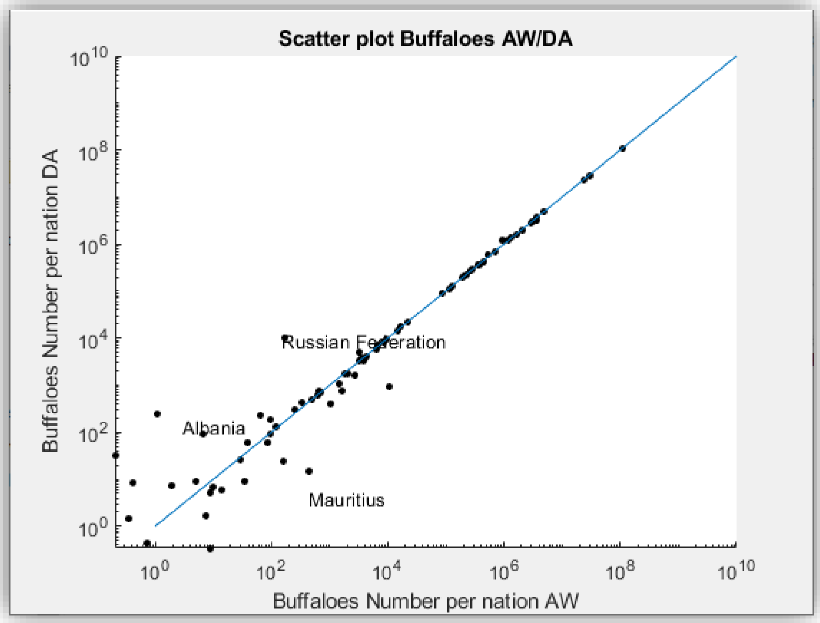



*Figure 5.1 – Comparison between national buffalo livestock estimated with AW and DA model*

The buffalo category is the one for which it is possible to observe the largest discordance between the two distribution models (Figure 5.1). Countries in which the livestock number is less than $10^4$, like, for example, Mauritius and Albania, are characterized by differences of one or two orders of magnitude; on the other hand, when considering countries where the presence of animals is more significant, the correlation is maximum. In a reasonable manner, it can be affirmed that the two models work substantially in the same way in case they deal with high values, but there are significant differences in the proceeding visible only with measures with an order of magnitude of $10^4$. However, this result does not represent a significant limitation in the two models, as errors are only made on small units; moreover, buffaloes are the class of animals that are least bred among those considered, therefore contextually it is the one for which the variations are more marked.

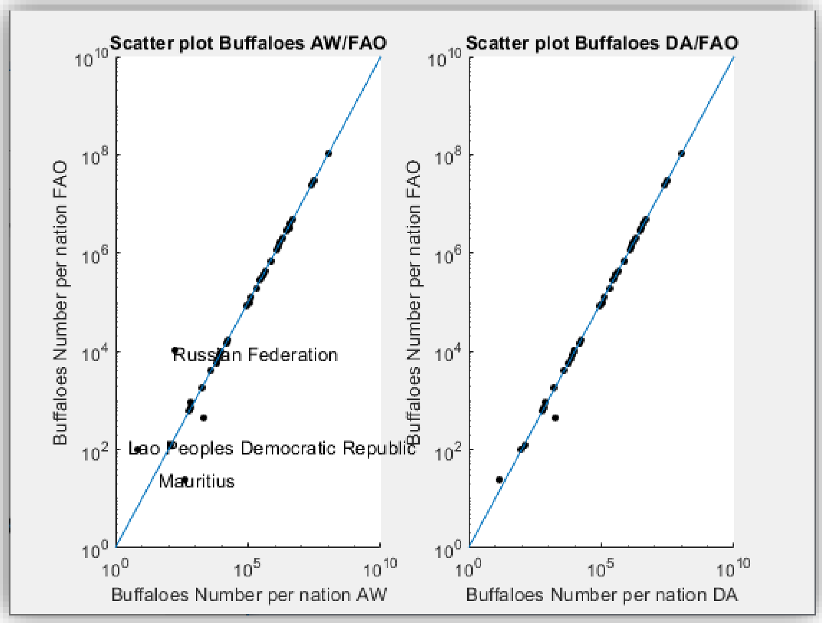



*Figure 5.2 Comparison between national buffalo livestock estimated with AW/DA model and FAOSTAT data*

The same observation can be made comparing the previous results with FAOSTAT data (Figure 5.2); moreover, like previously anticipated, it can be said that the DA model values have an almost perfect match with the census one, meanwhile the AW model results show the presence of some nations with different evaluations, like Mauritius, Lao Peoples Democratic Republic and Russian Federation. We also need to observe that the FAOSTAT database does not provides informations about all countries, since there is a lack of data related to countries with a very small number of buffaloes. The two main reason are the difficulties in the census of animal numbers under 100 units and the toughness in doing so in the least developed countries where a what to count animals is not completely systematized.

Regarding chickens, this is the other extreme case, in which both the two models practically represent the same chicken livestock number on a national scale (Figure 5.3). As opposed to buffaloes, this result is the consequence of a high poultry number for all nations, never lower than values of the order of $10^4$.

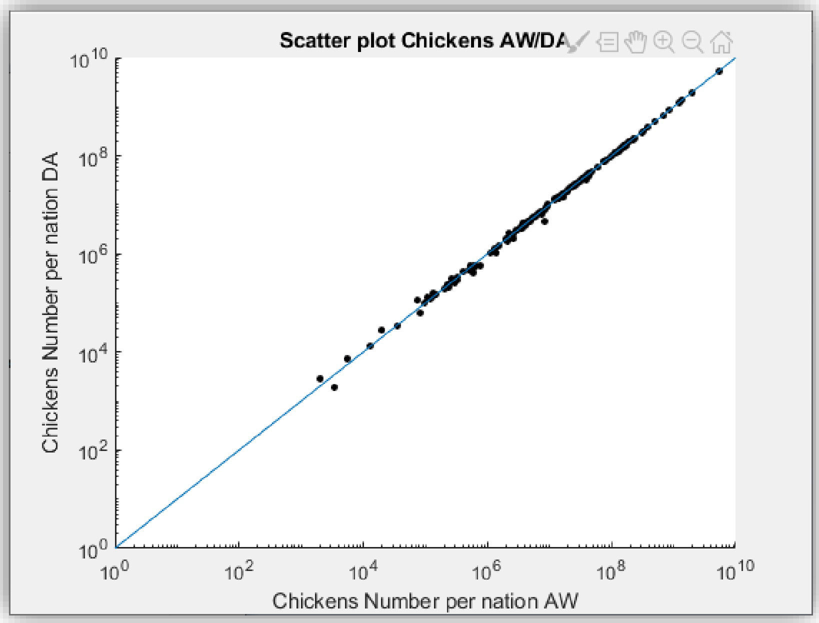



*Figure 5.3 - Comparison between national chicken livestock estimated with AW and DA model*

Both models also are in strong similarity with FAOSTAT data, with the only exception of Timor-Leste data: this singularity can be caused by the fact that census data could be affected by errors and uncertainties, representing in fact an outlier compared to the trend of all the other world nations (Figure 5.4).

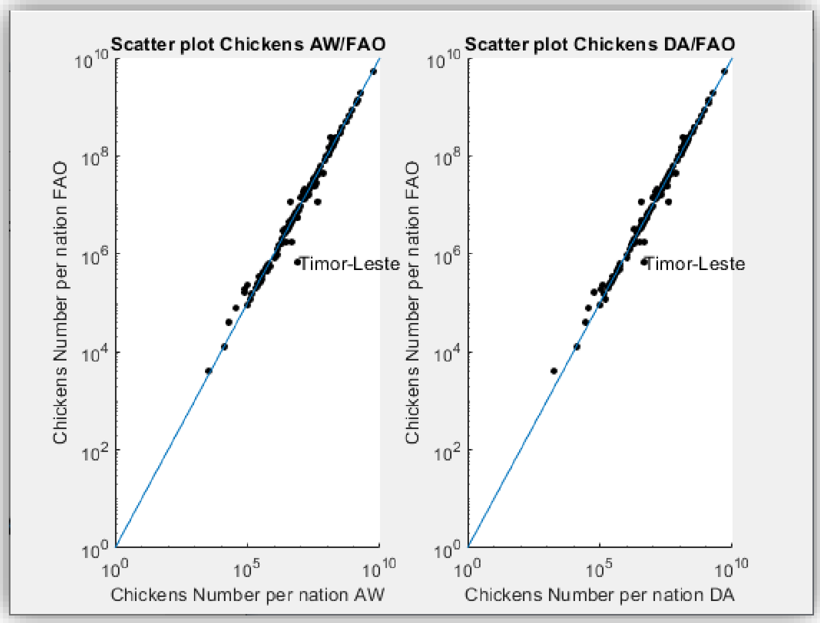



*Figure 5.4 - Comparison between national chicken livestock estimated with AW/DA model and FAOSTAT data*

Respecting the other categories of animals whose graphs have not been reported, although with their peculiarities, they can be considered a middle ground between the buffalo case and the chicken one, but for which the observations made so far are equally valid.

Referring to the FAOSTAT data about animal numbers, it is quite useful for this analysis to locate the most important producers of the different categories of animals in the world. The following pie charts show out the ten major world producers of buffaloes, cattle, chickens, pigs, sheep and goat, relating them to the rest of the world.

A clear result is that China is the most important country in chickens, pigs, sheep and goat production; Moreover, the productions of chickens and goat are mainly concentrated in a few countries; a similar trend is observed with buffaloes. A nation with a high animal production is the USA, which is the second most important country for chickens (10%) and pigs (7%), and the third for cattle (7%).

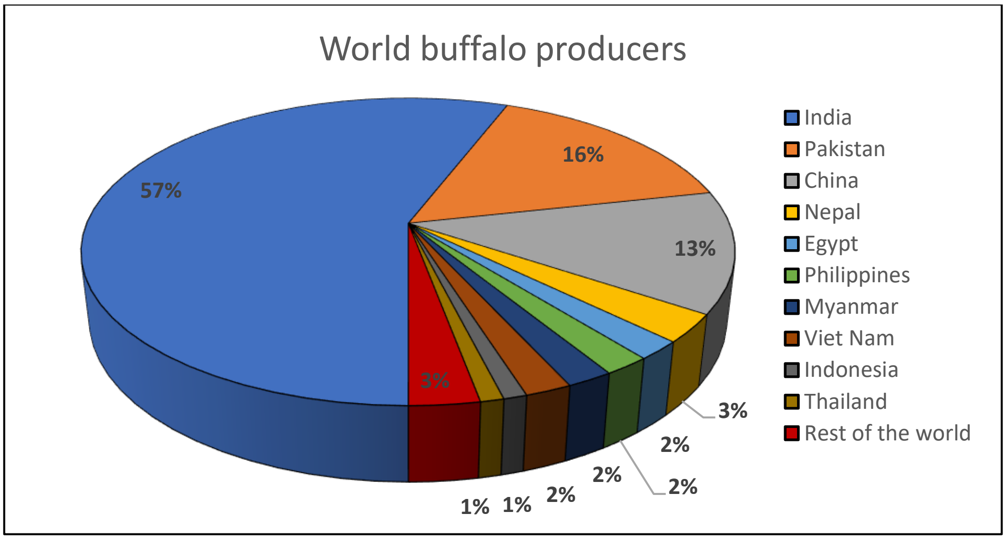



*Figure 5.5 Major buffalo producing countries*

Figure 5.5 clearly shows how buffalo breeding is predominantly concentrated in the Indian subcontinent and in Asia, in developing countries like India and China; this aspect is not to be ignored, as it significantly affects the unitary water footprint of the products derived from them. India has such a high production of buffalo also because of religious reasons. moreover, the high production of buffaloes in India is motivated for mainly religious reasons.

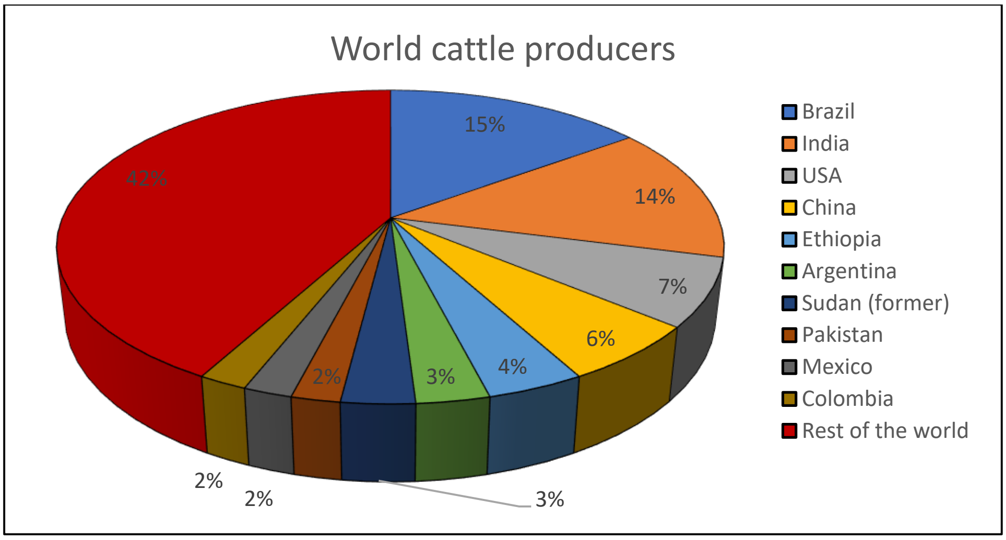



*Figure 5.6 Major cattle producing countries*

On the contrary, cattle are bred worldwide and in a more homogeneous way. Among the most important nations in this sense are Brazil (15%) and India (14%), which alone raise more than a third of the world cattle

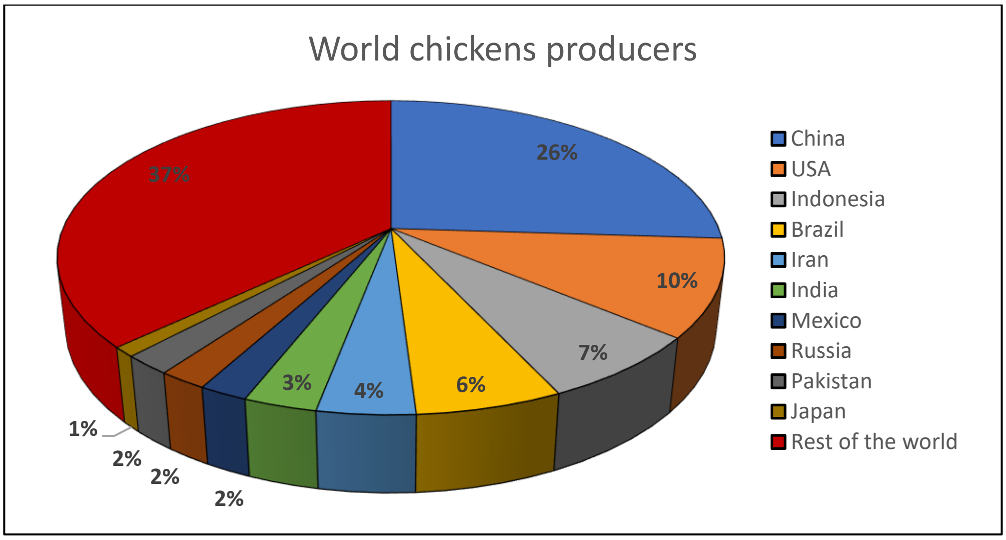



*Figure 5.7 Major chicken producing countries*

A quarter of the poultry comes from China (26%), while the United States only produces 10% of it. Half of the world demand is met by these nations, to which Indonesia and Brazil must be added.

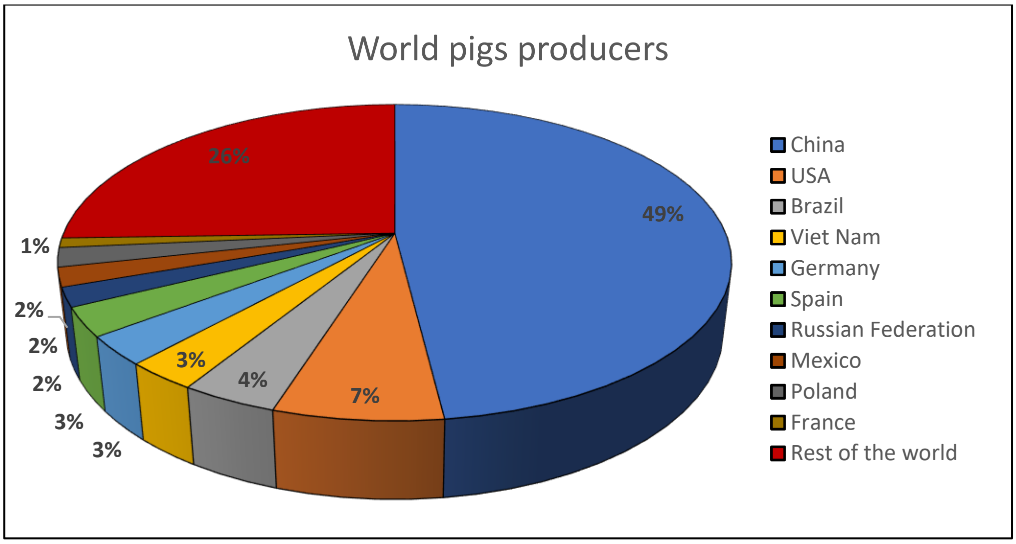



*Figure 5.8 Major pig producing countries*

Similarly to the case of buffalo, half of the world's pigs are raised in a single country, in this case China; although it is a developing country, it is characterized by good crop and animal yields and therefore not high unit water footprints. USA is in second place (7%) and Brazil is in third (4%).

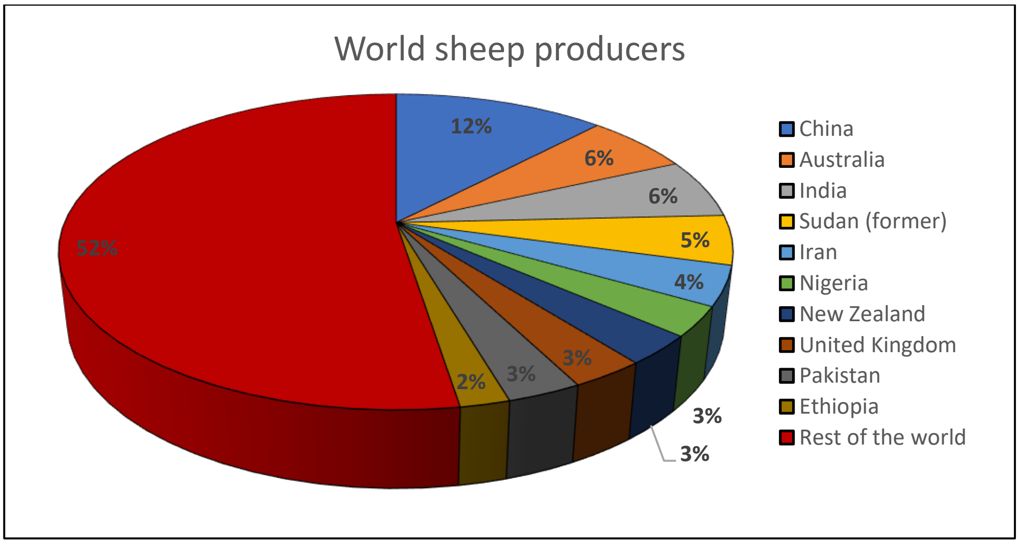



*Figure 5.9 Major sheep producing countries*

Sheep belong to the class of animals that is most heterogeneous among those analyzed: only China produces a percentage higher than 10%, while all other nations have percentages that do not exceed 6%. Considering this, there are countries like Australia and Sudan that which show higher percentages of more populated countries.

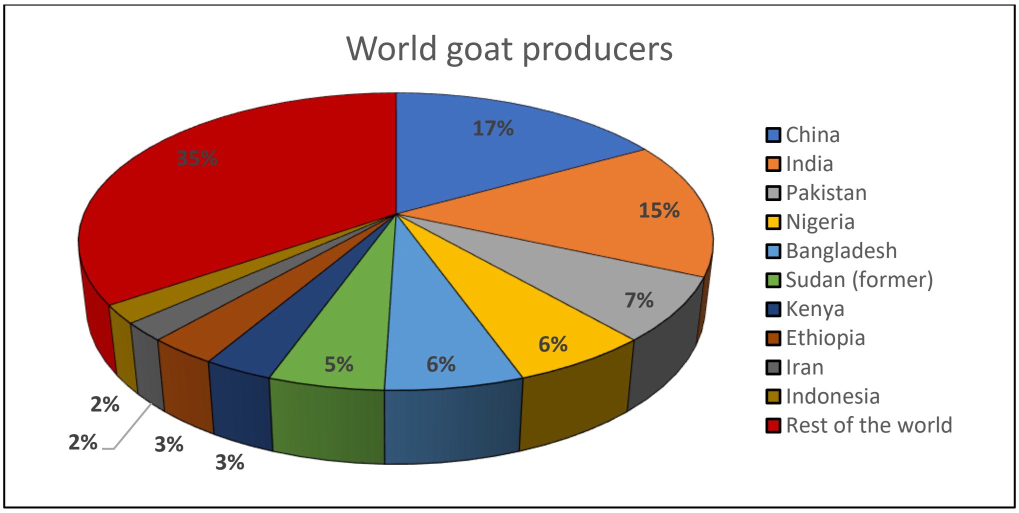



*Figure 5.10 Major goat producing countries*

China also records the highest concentration of animals raised also about goats (17%), but a similar percentage is also observed in India (15%); the third largest producer is Pakistan (7%). It is important to note that these three nations are also the three largest producers of buffalo, although in the case of goats their sum is less than 40%, while in that of buffalo it accounts for almost 90% of world production.

## 5.2. Probability Density Function and percentage of land used for farming

The probability density function describes the frequency with which, considered a sample interval, a range of numbers repeats. Applying the definition to the animal density, it is possible to make considerations about how the lands earmark for breeding are developed in extension, and the differences between the two predictive methods proposed and previously described.

The results show reasonably that the highest frequencies are obtained with the lowest values, emphasizing the fact that the extensive systems in which the animals are mainly bred through grazing cover a greater territorial extent than the intensive ones, in which the animals are bred within confined environments with considerably smaller extension. Furthermore, in almost all the cases, the AW model estimates a greater extension of extensive livestock production systems compared to DA model results; in the only cases of chickens and goat, the opposite case occurs.

The following graphs show the density distributions for each animal, calculated relative to the two spatial distributions:

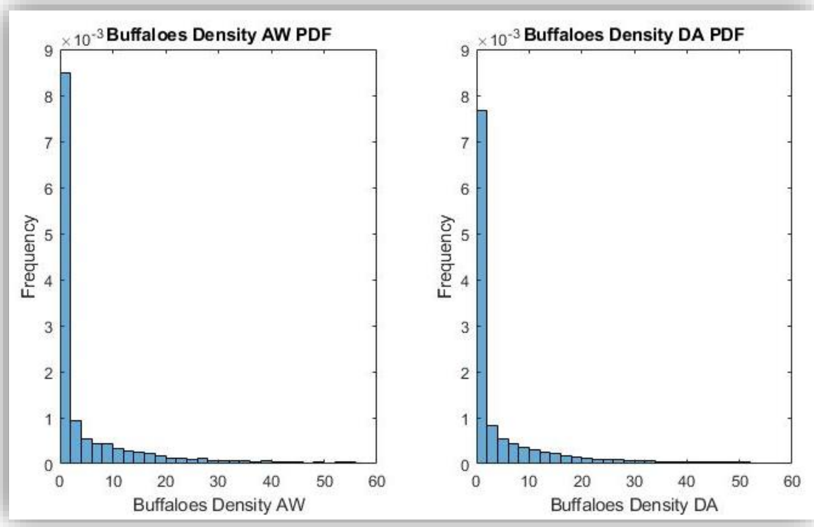



*Figure 5.11 Probability distribution of buffalo density*

In the case of buffaloes, the two models predict a very similar distribution (Figure 5.11); this reason must be sought mainly in the fact that these animals are bred only in a few regions, limiting the differences between the two models.

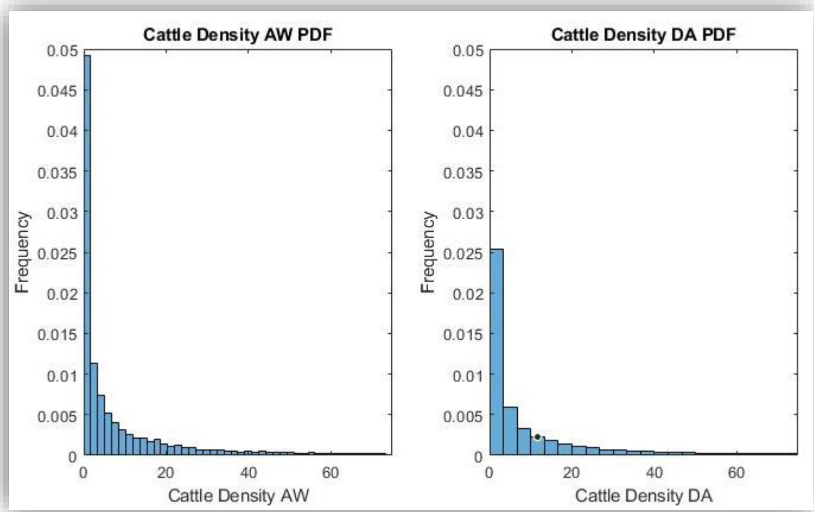



*Figure 5.12 Probability distribution of cattle density*

A completely antithetical reasoning can be carried out when considering cattle: since they are bred all over the world, the spatial extension is considerably greater than in the case of buffaloes, and therefore the two models have greater differences.

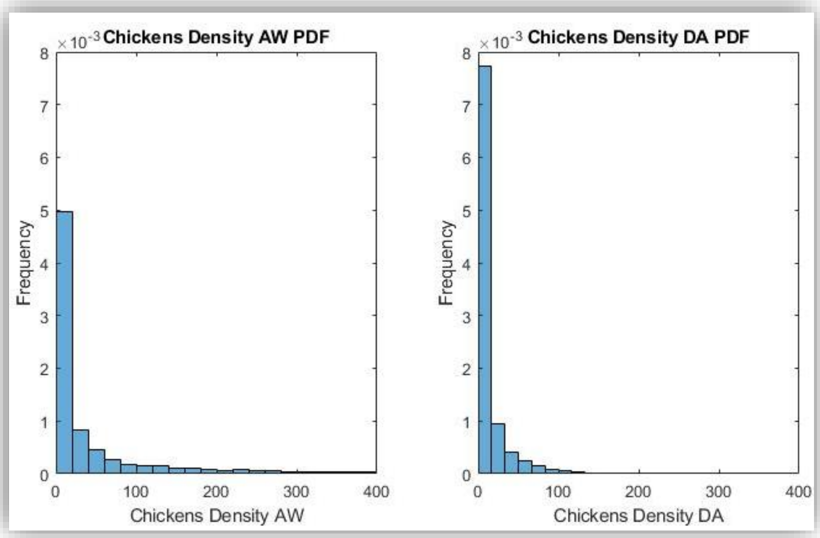



*Figure 5.13 Probability distribution of chicken density*

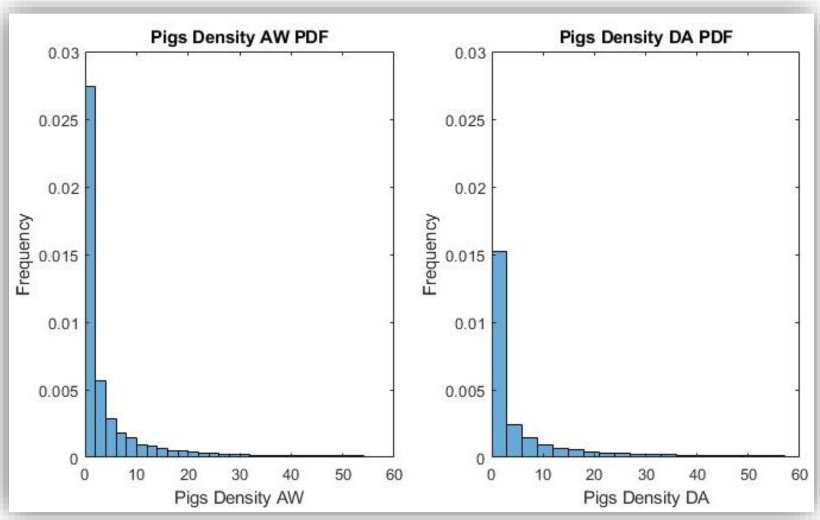



*Figure 5.14 Probability distribution of pig density*

For the same reason described in the case of cattle, differences in probability density distributions are observed also for pigs and poultry. However, if in the case of pigs the same tendency is observed in overestimating the extension of smallholder systems by AW model with respect to DA model, the opposite occurs in the case of poultry, for which the aw model provides for a greater extension of industrial and intensive systems.

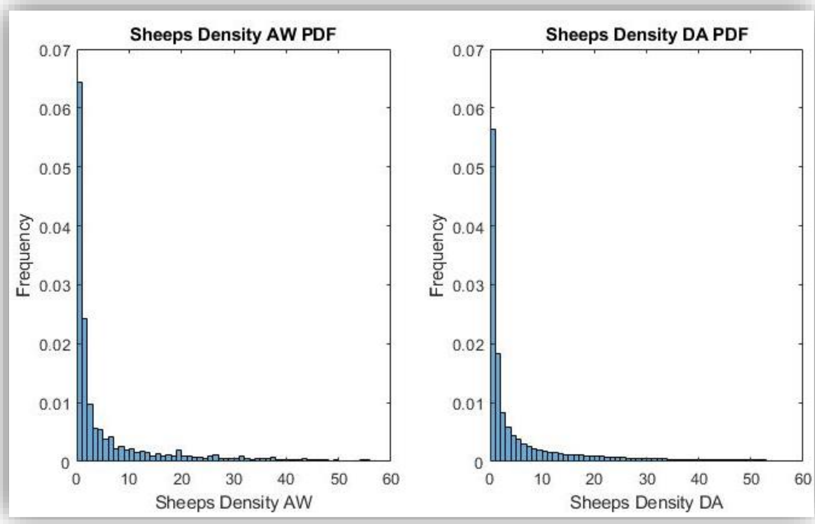



*Figure 5.15 Probability distribution of sheep density*

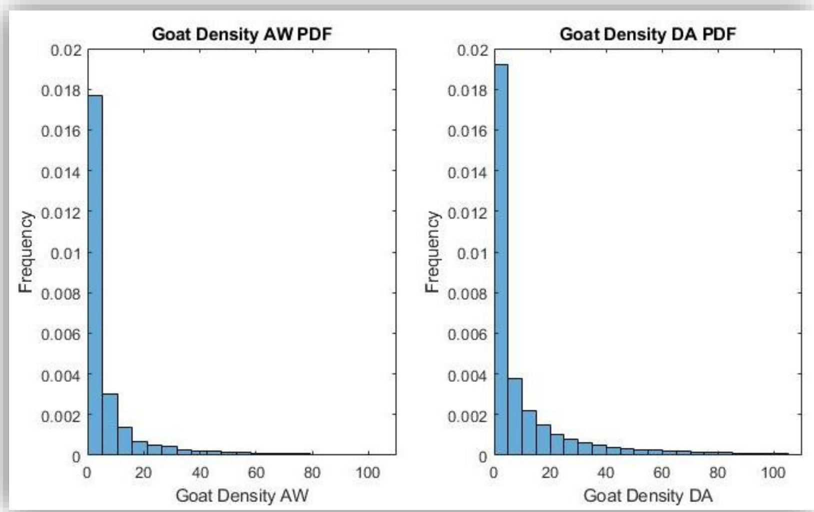



*Figure 5.16 Probability distribution of goat density*

Finally, observing the results related to sheep and goat, it is observed that in both cases the models work without substantial differences.

Consequently, the extention of the world land intended for farming has been calculated:

*Table 5-1 Percentage of land used for farming*

| Land use for farming | AW model | DA model |
|---|---|---|
| Buffaloes | 4.1% | 3.8% |
| Cattle | 40.9% | 36.4% |
| Chickens | 45.0% | 33.1% |
| Goat | 26.1% | 23.8% |
| Pigs | 19.2% | 15.6% |
| Sheeps | 33.5% | 29.3% |

It is intriguing to observe that the DA model, according to the boundary conditions implemented, always shows a less developed spatial resolution; it is also clear that the percentage difference is directly proportional to the animal class livestock number: the higher the number of animals, the greater the percentages but also the difference between the two models. The extreme case is represented by hens: the DA model foresees that intensive livestock production system is more widespread, reducing the worldwide extension of smallholder farms by about 12%.

## 5.3. Considerations on the main derivative products

The animals considered so far are bred for the purpose of producing goods that can be used by human being. As previously shown in Table 3-6, meat is obtained from all categories of animals; in addition, milk is obtained from mammals, and eggs from hens.

First, since we want to evaluate the temporal evolution of the unit water footprint and to correlate it with the consumption of volumes of water, it is useful to highlight how the production of these products has changed over time; furthermore, it is interesting to relate this variation with the population, calculating the per capita quantities.

To facilitate reading, as will be done in subsequent chapters, the results relating to the products most consumed by man are presented, and therefore produced in greater quantities: these goods are cattle meat, cow milk, pig meat and poultry meat.

The histograms in

Figure 5.17 show that the production of all the goods on which we have focused grows over time: this can be explained by the increase in the world population, and the trivial need to breed more animals and obtain more products from them to meet the needs of the world population. However, it is observed that the growth rates are different for the four products: the tons of cattle meat produced grow with the lowest rate, increasing by about 30%; in the other hand, chicken meat production in 2016 is almost four times larger than in 1986 and it shows an increase of 264%. Pork and cow milk production also show an increase, which in the first case is 96% while in the second it is 43%. It is interesting to note that cow's milk is a singular case because, contrary to what happens for other products for which a growing trend is observed throughout the span of time, production remains approximately constant during the first decade of analysis: the increase in production was registered only from 1996 onwards.

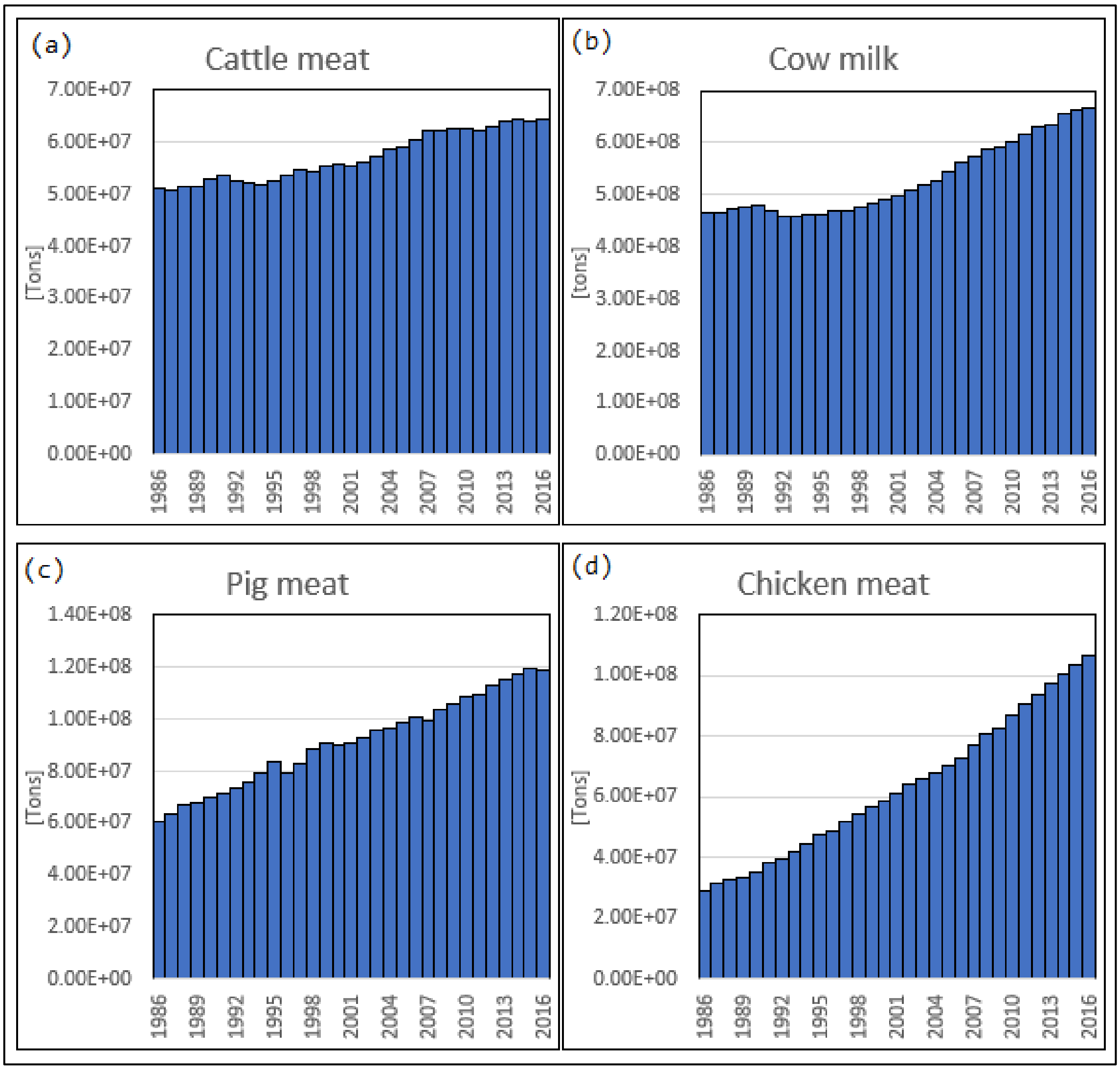



*Figure 5.17 Production of (a) cattle meat, (b) cow milk, (c) pig meat, (d) chicken meat from 1986 to 2016*

Interesting observations can be deduced from the values shown in Figure 5.18. The increase rate of meat production is lower than that of the population, which is why the quantities consumed by each person decrease over time. This figure could contrast the claim that the meat diet is spreading, but it is not: in fact, the countries affected by the greatest population increase are developing ones, in which diets are different from those of developed countries.

The same observation is valid for the first decade analyzed with regard to cow's milk: however, in the following years an increase was observed and in 2016 about 85 liters per capita are produced.

Finally, strictly increasing trends are observed in the per capita tons of pig meat and poultry meat, in particular in the second case the value has more than doubled and in 2016 it is around 14 $\frac{kg}{PerCapita}$.

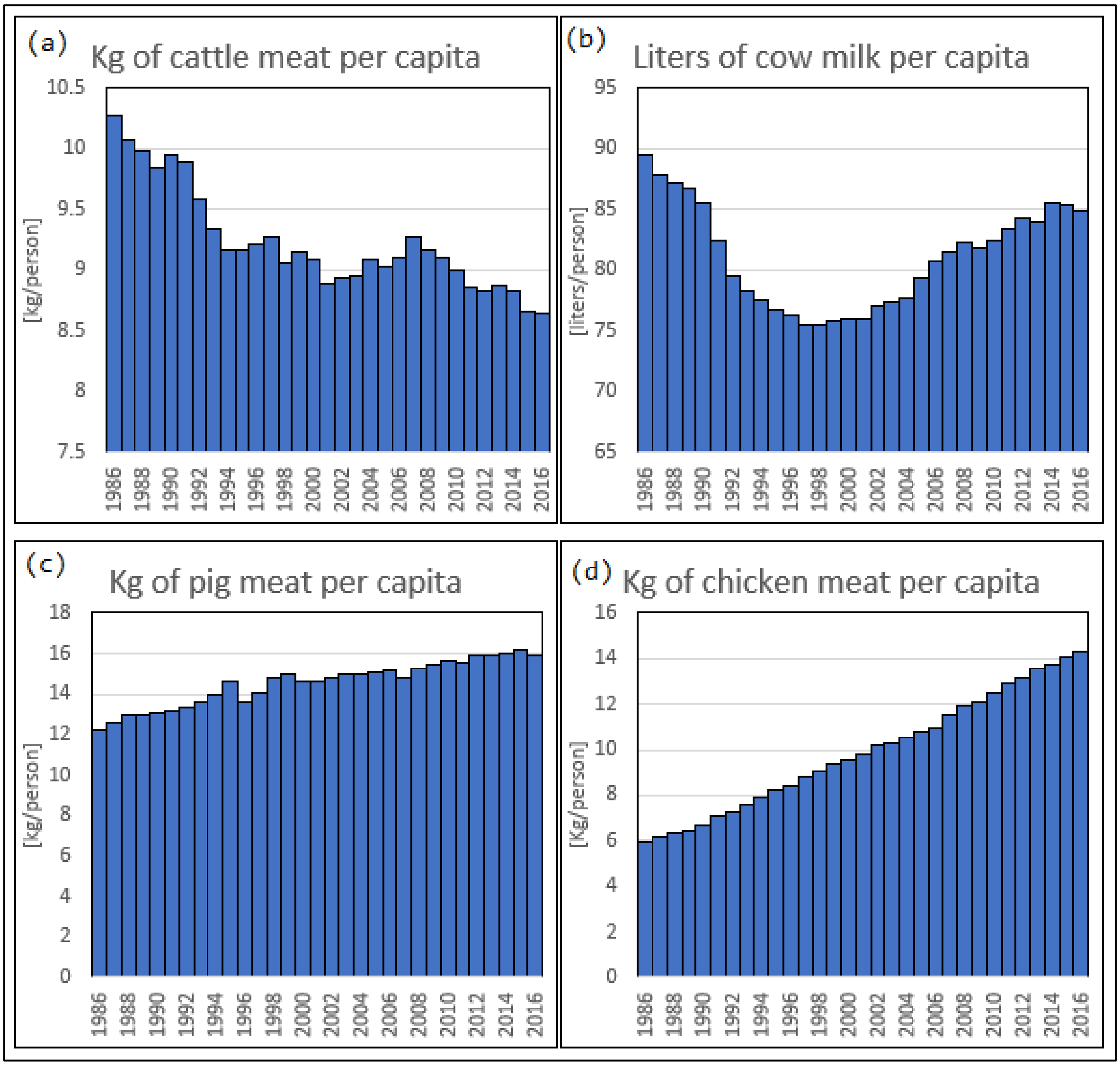



*Figure 5.18 Kilos (or liters) of (a) cattle meat, (b) pig meat, (c) pig meat, (d) chicken meat per capita from 1986 to 2016*

## 5.4. Livestock production systems

Livestock production systems described in 3.1.2 represent an important discriminating factor in the calculation of the unit water footprint. As a matter of fact, depending on the weather conditions and on the availability of some ingredients rather than others, the farmers adapt the diet which animal are bred.

It's an interesting point to deepen the knowledge about the extension of different production systems and particularly to outline how they are spread out within the world regions. Due to the difficulty of a complete understanding of histograms concerning 8 production systems associated with 29 world regions defined in (Herrero *et al.*, 2013b), in Figure 5.19 and Figure 5.20 solely livestock systems and mixed crop-livestock systems are not subdivided in turn in arid, humid and temperate climatic conditions.

Figure 5.19 and Figure 5.20 draw attention to the most extensive regions with lands suitable for breeding: Former USSR region is the biggest one, with predominantly solely livestock and other systems; after there is Canada, with an extension less than half that one of the previous region, but with a comparable subdivision; then there are USA, MENA region (Middle East and North Africa), China, RSAM and Brazil, with a significant extend; in the end, all the other regions exhibit measures too small and not comparable. It is important to highlight that urban and intensive category, are mainly present in European regions, but they are characterized by a high density that refers to a low territorial extension.

In percentage terms, EU North, Pacific Island, Japan and Congo Basin regions are the ones where high density farms are most developed with an extension greater than 60%, whereas values less than 10% are recorded mainly in Africa and Oceania; in these regions, as also occurs in ROWE, Canada, and RSEA PAC area, a prevalence of the solely livestock system can be observed compared to the mixed one, while in European, Asian and India regions the opposite occurs.

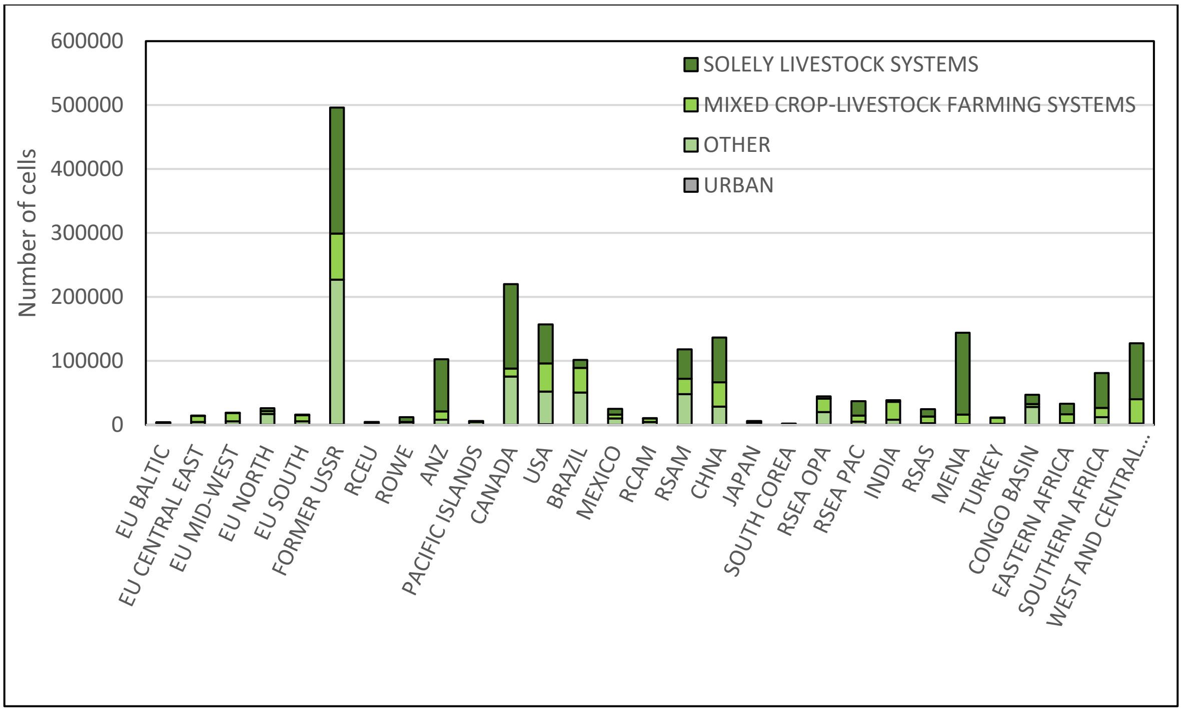



*Figure 5.19 Extensions of livestock production systems for 29 world regions*

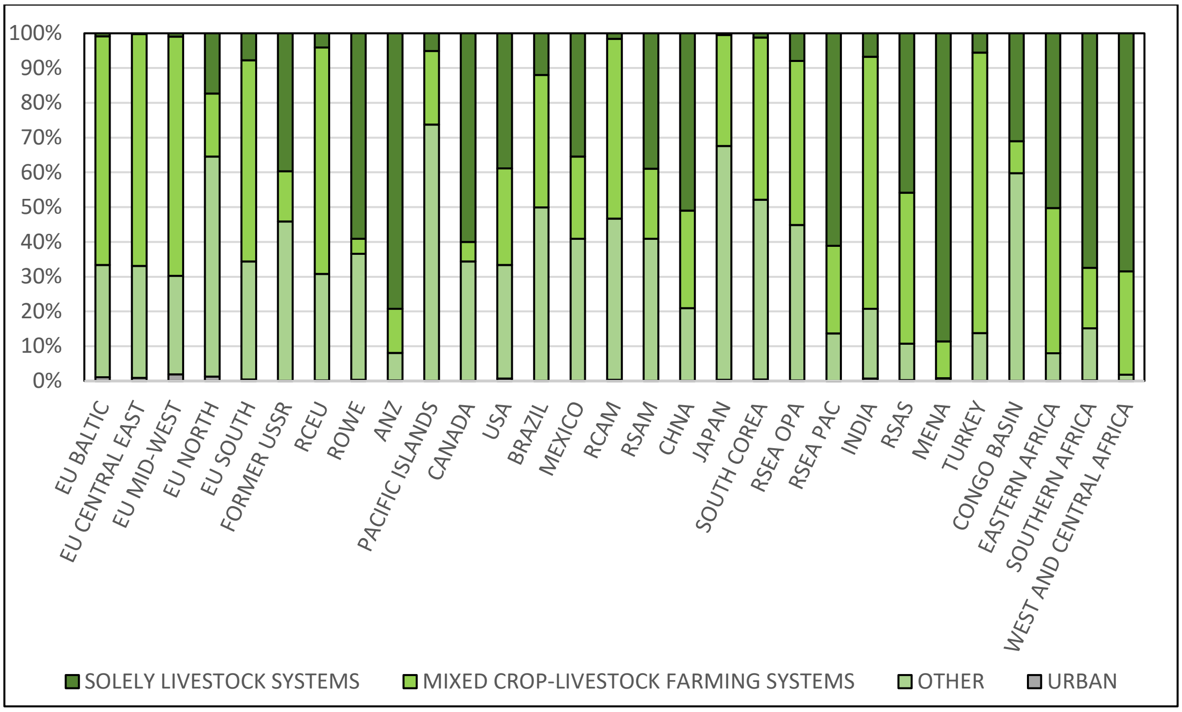



*Figure 5.20 Percentage of livestock production systems for 29 world regions*

Nevertheless, for a better comprehension, it is quite useful to further gather data in 9 world macro regions.

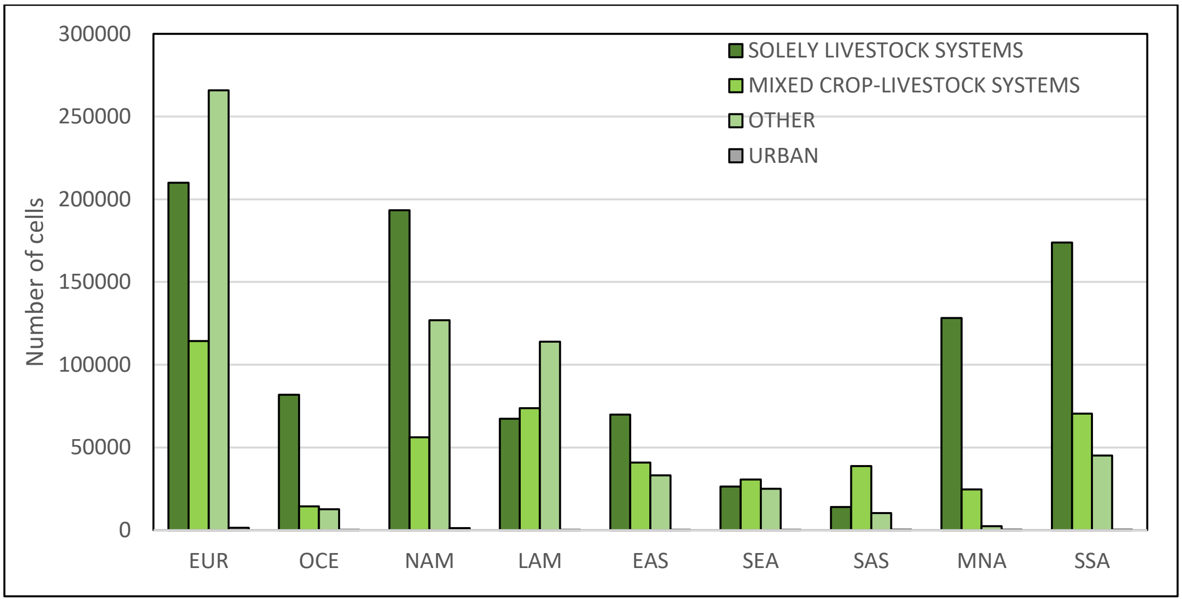



*Figure 5.21 Extensions of livestock production systems for 9 world macro regions*

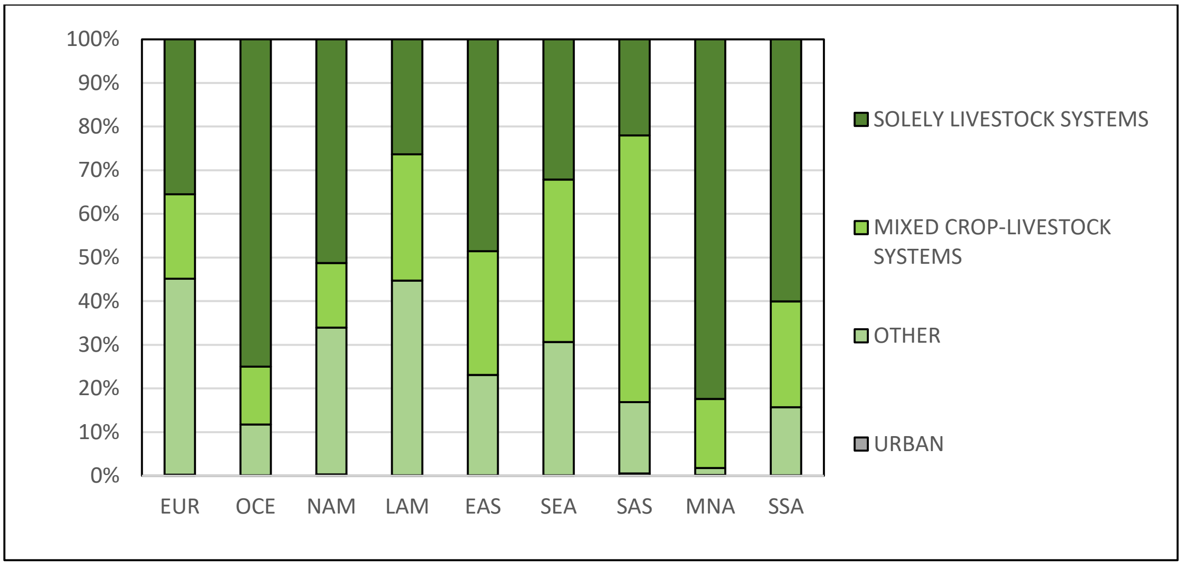



*Figure 5.22 Percentage of livestock production systems for 9 world macro regions*

As shown in Figure 5.21 and Figure 5.22, Europe is the region with the largest extension of land intended for animal production (mainly Former USSR countries), which about 45% is extensive but unspecified, while 35% are equipped for animal production only and 20% it is used for both breeding and harvesting purpose. MNA and Oceania regions are distinguished because of the highest percentage of solely livestock production system, with values respectively 80% and 75%; quite the opposite, LAM and SAS show the lowest percentage of this system (25% and 20%). In addition, SAS macro region reveals the biggest mixed-crop livestock production system, approximately 60%; instead, as for all the other regions, the percentage is constant around a 25% average value. In the end, extensive but not crop or rangeland-based production system has a variable percentage between regions: Europe and LAM show the highest percentage (both 55%); the lowest are in SAS and Oceania (approximately 15% and 10%).

On a macro region scale it makes sense to explore also the distinction according agro-climatology aspects.

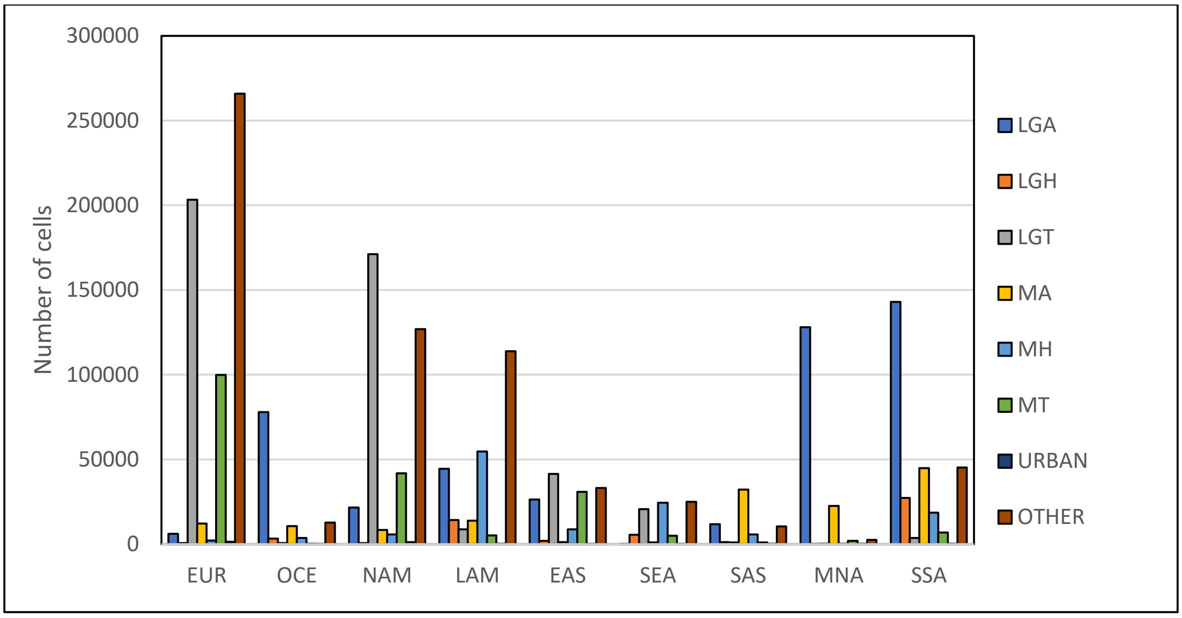



*Figure 5.23 Extensions of livestock production systems for 9 world macro regions with agro-climatology distinction*

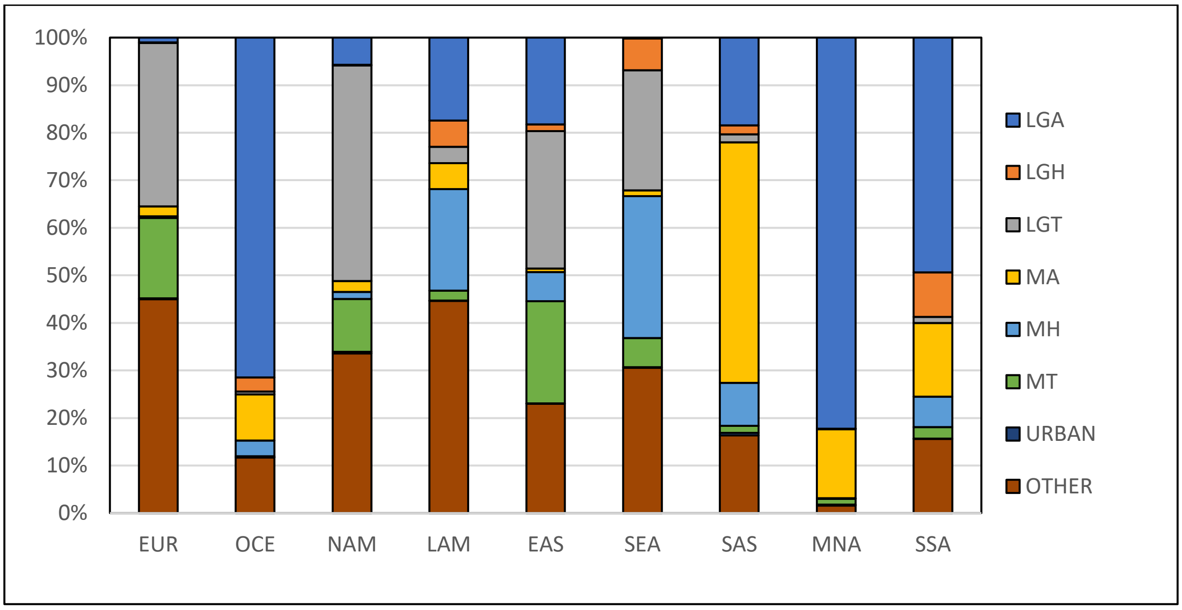



*Figure 5.24 Percentage of livestock production systems for 9 world macro regions with agro-climatology distinction*

How highlighted in Figure 5.23 and Figure 5.24, arid conditions are prevalent in Oceania, MNA and SSA macro-regions; tropical and temperate areas (please note that in this study these are considered in a single class and characterized by the same diet) strongly characterize Europe and NAM; in the end, LAM, SEA are the regions where larger humid weather conditions can be found. Because of this, in Oceania, MNA SSA regions, the solely livestock system is mainly made in arid conditions; at the same time, the mixed-crop system is used in SAS, MNA and SSA mainly in arid conditions.

## 5.5. Composition of the diets

Like previously said in 3.1.3, in this work data relating to diets presented in (Herrero *et al.*, 2013b) were used. Given the multitude of combinations between the 29 world regions and the 8 livestock production systems, the database contains a huge amount of information, and it is difficult to analyze it concisely and clearly at the same time. Nevertheless, it can be interesting to analyze how the diet changes as a function of the livestock production systems. To accomplish this, arithmetic averages have been done, and the results are proposed below, remembering that no distinction has been made between production systems according to the climatic conditions. In order to facilitate reading, averaged composition of the diet about solely, mixed crop-livestock and urban production systems were considered, excluding the "other" production system from this kind of analysis. It is needed to keep in mind that considering an average you can't appreciate singularities, which in some cases can be also relevant: this is because a production system can be utilized in completely different parts of the world. Besides, it is considered a single diet for both sheep and goat, and the same happened in the case of buffaloes and cattle (bovines); in addiction, regarding these animals, a further distinction between the diet of dairy and beef herds has been done.

Bovine's diet is mainly composed by grazing, which constitutes a variable percentage between 67% and 88%; the greatest consumption of grass is associated to solely livestock production systems. The component related to stover and occasional feed is usually low, and only in the case of meat bovine, breed with urban livestock production system, the occasional feed exceeds 10%. Concerning grains, this is used mainly in dairy bovine's diet, with a percentage between 10% and 18%; lower values are observed in the case of meat bovine's diet. However, the quantity of crops that make up that item is similar in all the cases analyzed: maize is the most used crop, immediately after there is the soya; other crops that show a significant percentage are barley, wheat and other cereals.

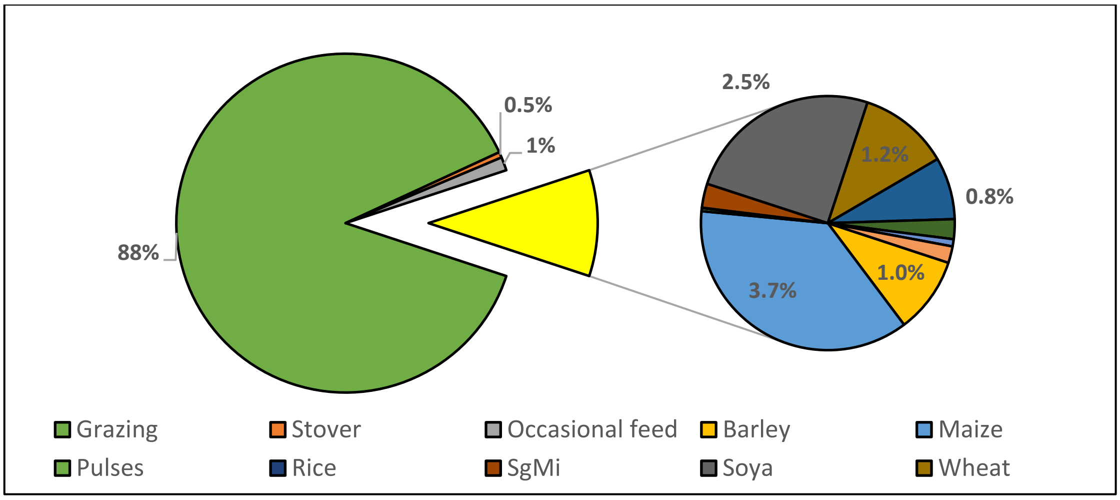



*Figure 5.25 Diet in solely livestock production systems – Dairy bovine*

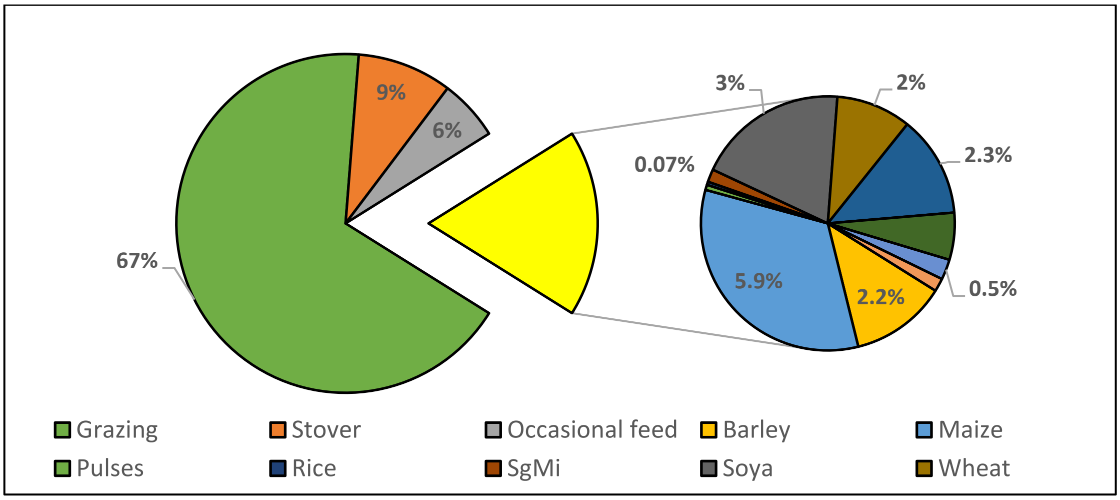



*Figure 5.26 Diet in mixed crop-livestock production systems – Dairy bovine*

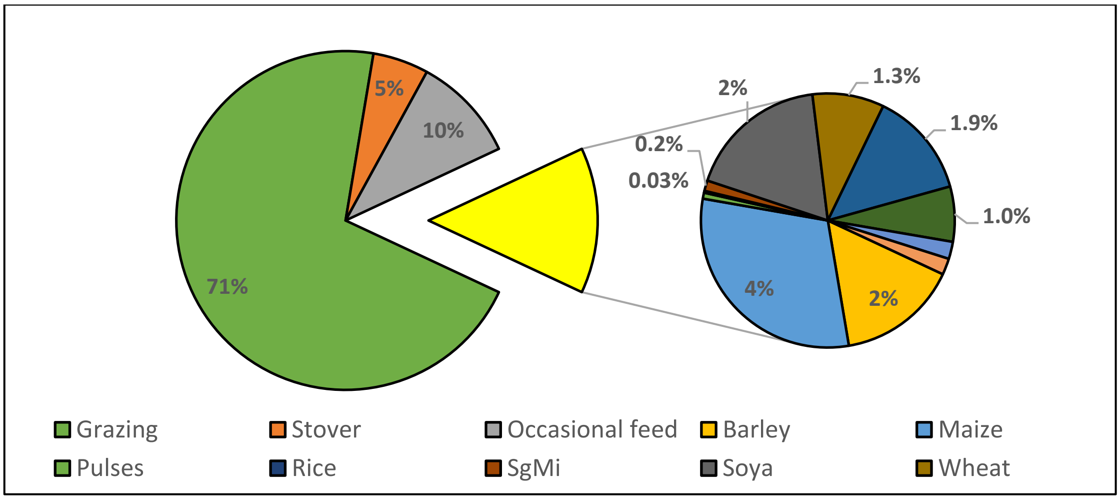



*Figure 5.27 Diet in urban livestock production system -Dairy bovine*

On average, the dairy cattle diet is very similar between the intensive and the extensive systems, especially when considering the mixed case, while in the case of animal breeding only, these are raised with a percentage of grass higher than about 20% at the expense of the stover and occasional feed.

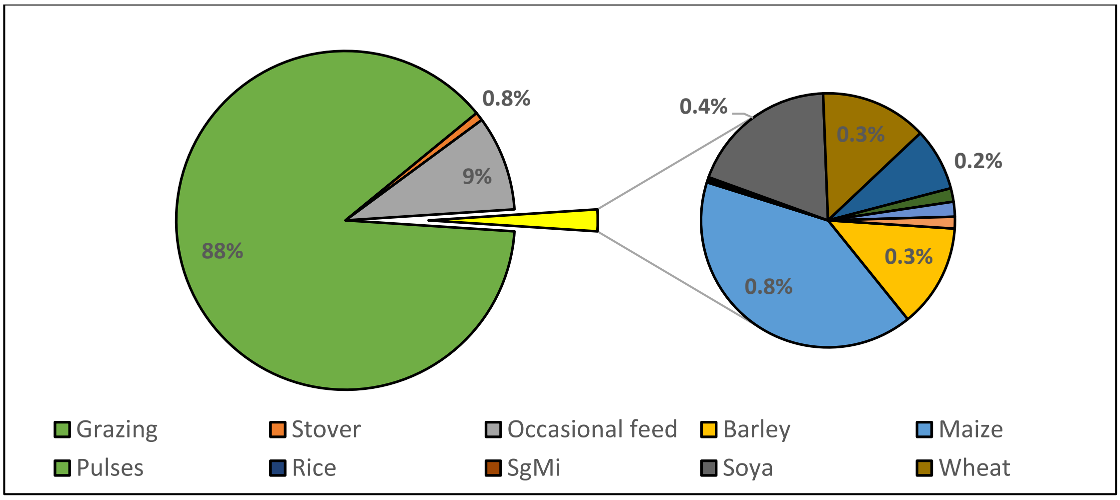



*Figure 5.28 Diet in solely livestock production systems – Meat bovine*

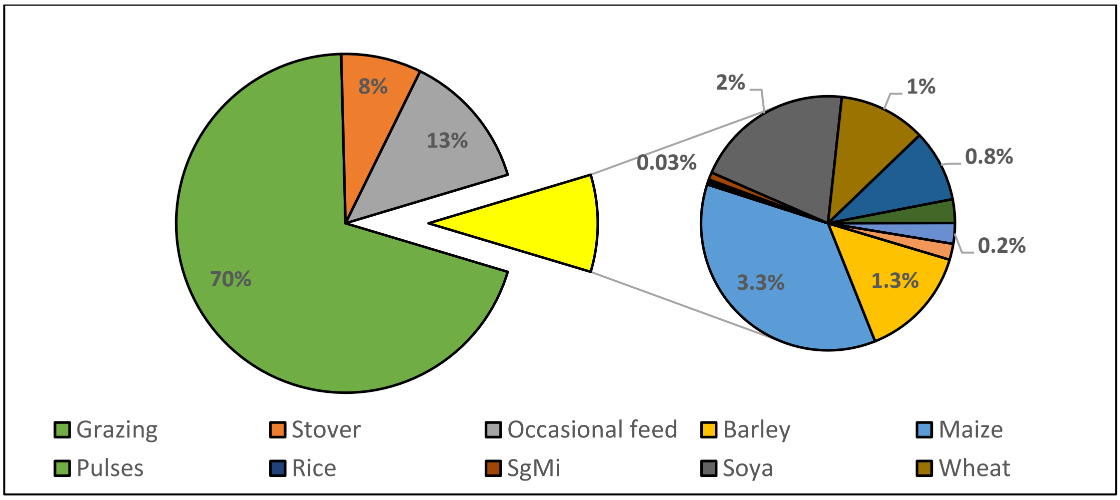



*Figure 5.29 Diet in mixed crop-livestock production systems – Meat bovine*

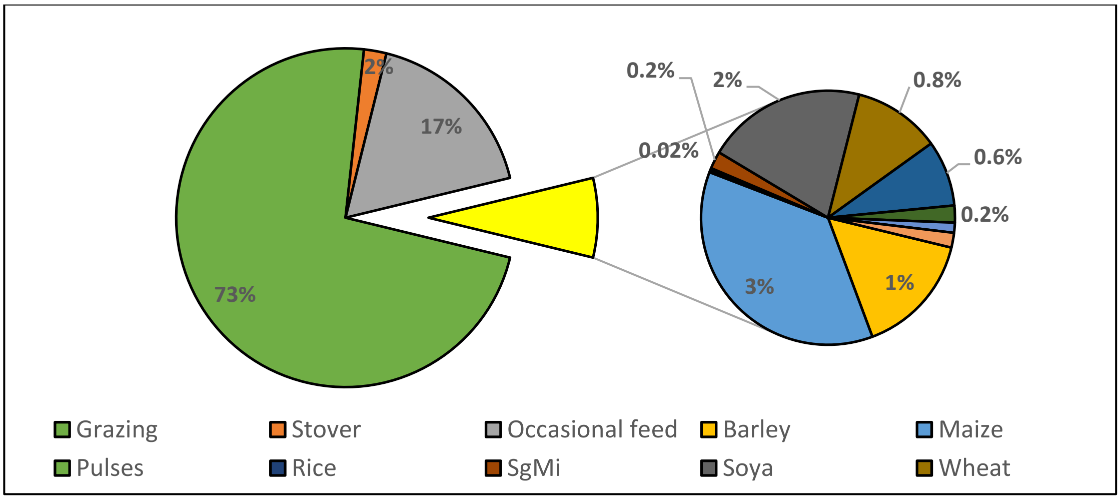



*Figure 5.30 Diet in urban livestock production system – Meat Bovine*

the same observation made in the case also applies here; however, there is an increase in the consumption of occasional feed, which is between 9% and 17%; the composition of the feed, however, does not vary markedly.

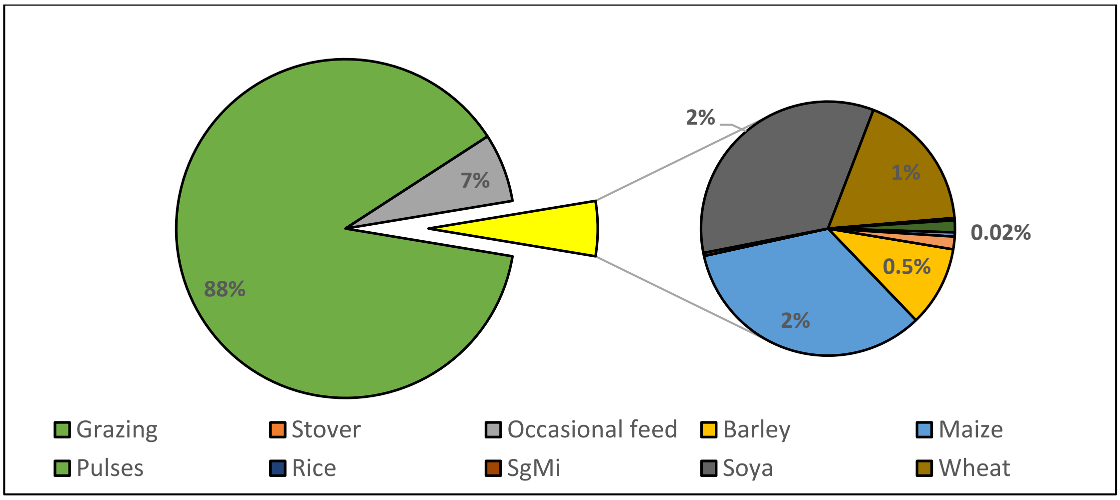



*Figure 5.31 Diet in solely livestock production systems – Dairy sheep and goat*

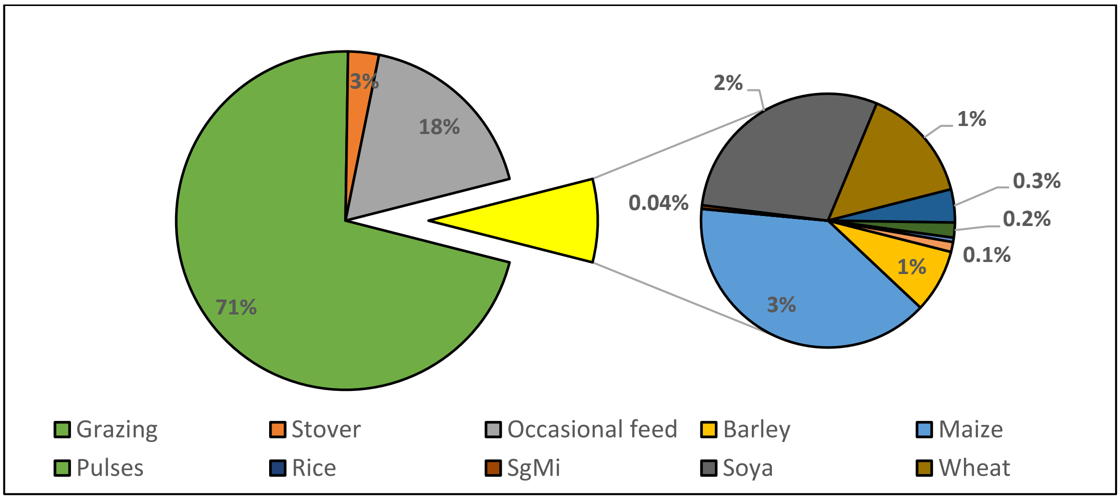



*Figure 5.32 Diet in mixed crop-livestock production systems – Dairy sheep and goat*

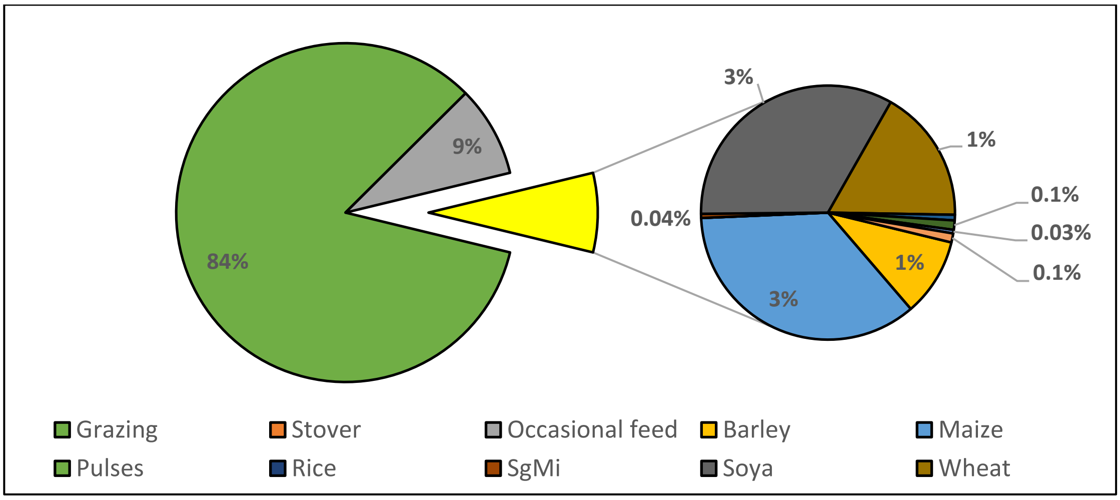



*Figure 5.33 Diet in urban livestock production system – Dairy sheep and goat*

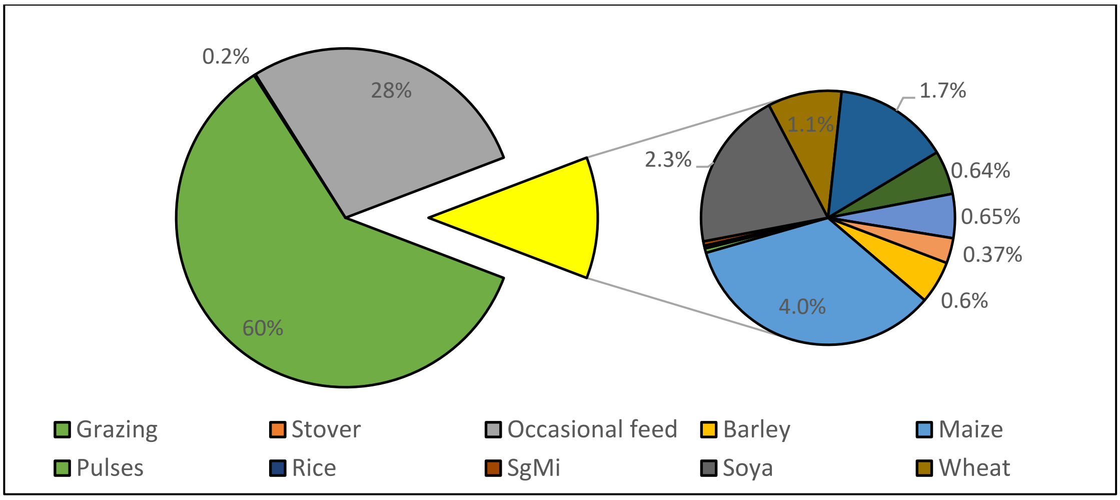



*Figure 5.34 Diet in solely livestock production systems – Meat sheep and goat*

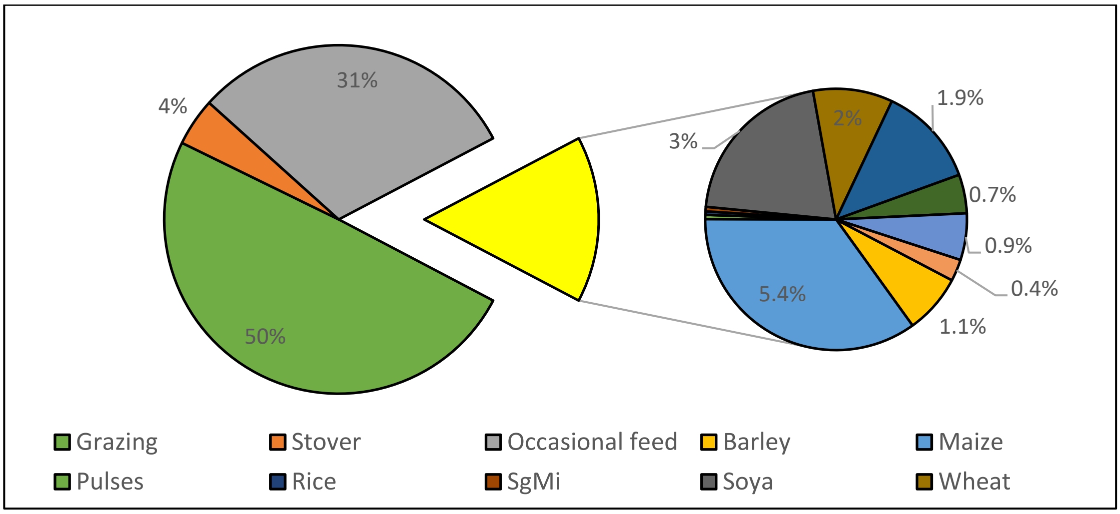



*Figure 5.35 Diet in mixed crop-livestock production systems – Meat sheep and goat*

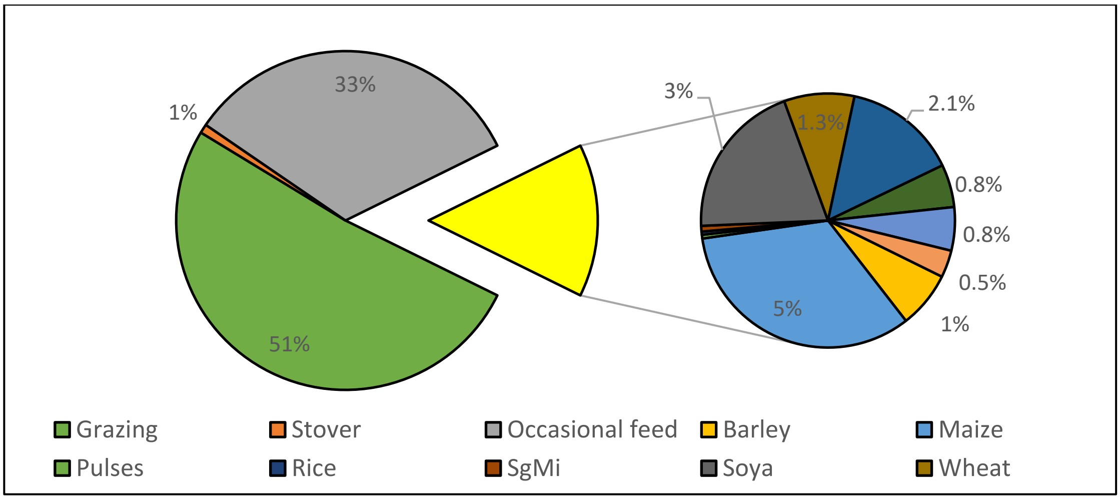



*Figure 5.36 Diet in urban livestock production system – Meat sheep and goat*

The diet of sheep and goat shows a greater variability and major differences between meat and dairy animals; a common aspect is the low utilize of stover. Dairy and sheep goat are fed mainly with grazing (up to 88%) and with a percentage of occasional feed which not exceed 18%. Grains only cover a small part of the total feed, less than 10%, mainly soya, maize, wheat and barley.

Regarding sheep and goat bred for the purpose of producing meat, the grass is used less, at most 60%, due to an important increasing of the percentage of occasional feed (up to 33%) and to a slightly greater use of grains which reaches 15%. Grain, in this case, is composed in a more heterogeneous way, in which the most common crops are wheat and soya, but almost all the other crops are used more significantly.

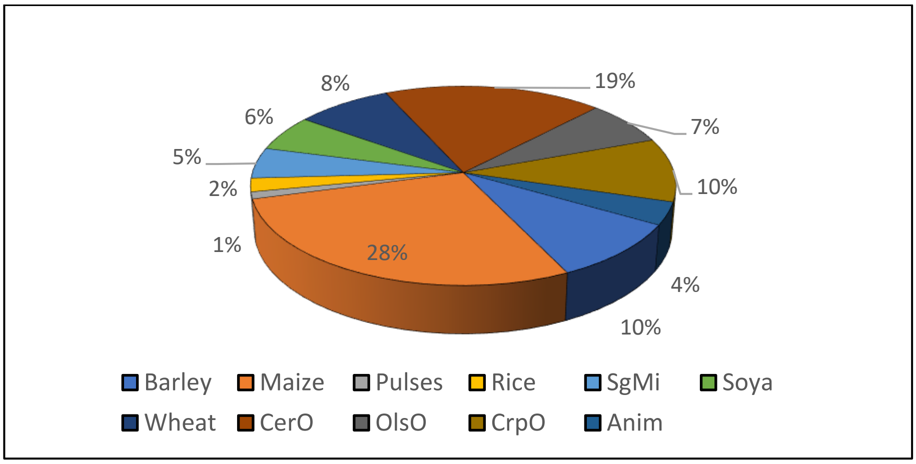



*Figure 5.37 Pig diet*

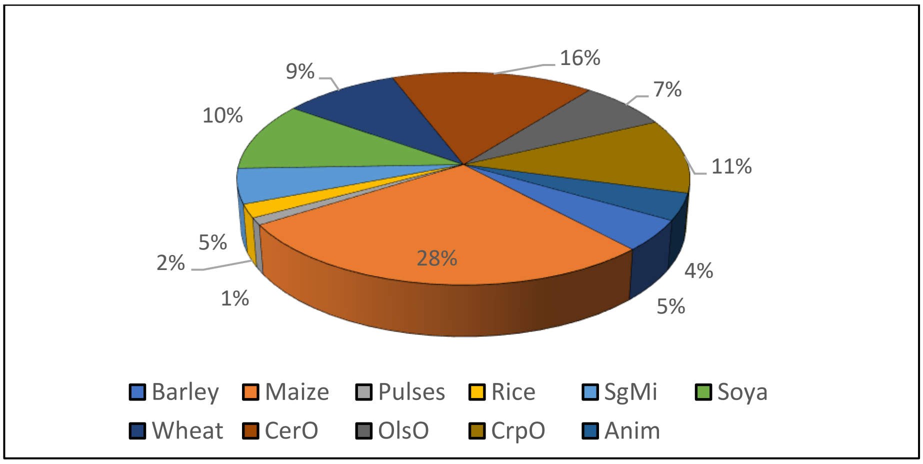



*Figure 5.38 Poultry diet*

Pig and poultry are raised in a very similar way; furthermore, there are no significant alterations between two production systems (smallholders and industrial), which is why only two graphs are shown. These animals, unlike all the others, are raised only with grains; in particular, maize is the most utilized crop, followed by other cereals, barley and other crops.

# 6. RESULTS

Unit water footprint values of farm animal products calculated through the methods described in the previous chapter are reported in this section. The temporal variability and the consideration of different scenarios made it possible to carry out further analyzes, highlighting similarities and differences.

Firstly, the global the unit water footprint of all the products of animal origin considered has been assessed, and consequently the percentage of the blue component compared to the total value has been evaluated, highlighting the evolution that they have undergone over time from 1986 to 2016. In general, the water footprint of almost all products has decreased over time, in some cases more linearly than others. By relating these values to the quantities of animal produced, it was also possible to quantify the volumes of water consumed, for which a general increase in time was observed; however, the volumes of blue water do not undergo substantial changes.

Subsequently, uWF results are shown and critically commented on a national scale through world maps. We focus on four main products, that are highly consumed by the world population (i.e., cattle meat, cow milk, pig meat and poultry meat). The uWF of all products on a country scale can be found in Appendices. For the same products, maps showing how the water footprint changed between 1986 and 2016 have been created with the same resolution. Furthermore, for the three major producers of each of these products, another type of analysis was carried out, also providing information regarding the volumes of water used in the years 1986 and 2016, in order to relate the unit water footprint to the quantities produced, and so that an order of magnitude on the $m^3$ of blue water used was provided.

Finally, an analysis was carried out in order to analyze the effect of the feed trade. To accomplish this aim, a hypothetical scenario in which all the feed comes from national productions was considered. Time series (built starting from values averaged worldwide) have been created to understand the influence of the trade over the three decades investigated by this research. Moreover, as done previously, information on the four most consumed products is deepened, creating scatter plots that, on a national scale, emphasize the consequences of the trade on water efficiency. Here a focus on the three major world producers has been done, and to the nations which have a considerably different unit water footprint between the case without trade and that with it, but which still are characterized by appreciable productions. Additionally, the averages of water footprints were calculated on a regional scale (always considering the two cases), to understand if there is a zoning of the water footprint and to relate this figure to those relating to the national and world scale.

## 6.1. World average results

### *6.1.1. Time series - uWF*

In order to give a first order of magnitude of the unit water footprint necessary to produce all the goods of animal origin that have been taken into consideration, the world averages have been calculated. In order to produce significant global estimates, world averages have been calculated through a weighted average using the production of each nation as a weight. In this way greater importance is given to the water footprint of the most productive nations, minimizing that relating to countries with low quantities produced.

Having available all the data necessary to calculate the water footprint from 1986 to 2016, a temporal analysis of these world average values was carried out, to analyze whether the factors that come into play have changed over time and if they have therefore led nowadays to require a smaller quantity of water to produce the same good compared to past years. These factors can be identified in the following:

- grain unit water footprint variable over time (depending on their production yields);
- quantity of product obtained from each animal, according to the yield of the animal;
- crop trade effect.

The animal diet is not among these factors, as it is worthy to note that this does not have a temporal variability because it is only available for year 2000.

The results obtained are then presented, in which the products deriving from the same animal were grouped. The first observation that can be made from these graphs and which confirms all previous studies conducted on this subject is that producing meat requires the greatest quantity of water; it is for this reason therefore that carnivorous diets are more expensive from the water point of view than vegetarian ones.

Analyzing the graphs proposed, it can be observed that over the three decades in question the unit water footprint of all products has decreased (with the exception of sheep milk); it is also noted that the temporal trend of the water footprint is quite linear in the case of buffalo, cattle, sheep goat and the respective derivative products (Figure 6.1, Figure 6.2, Figure 6.3, Figure 6.4)Figure 6.2; on the other hand, pigs and chickens (Figure 6.5 and Figure 6.6) show a less regular trend with more singularities and peaks in value, for example in 1988, 1995, 2003, 2007 and 2012. This phenomenon can be explained by the fact that these two categories of animals are bred entirely with crops, which are traded: it is therefore possible that the commercial network has caused the major producers to import crops which in these years required a greater water footprint than in others, or they have changed partners. Quite the opposite, in the case of the other categories of animals, they also present the grass component in the diet, which is not traded: since this often represents an important portion of all the feed eaten by animals, the direct consequence is that there are fewer singularities, and possibly that these affect the general trend less. Furthermore, a notable contribution is given by the improvement of production techniques, which can be quantified in the increase in the values relating to the yields of the products.

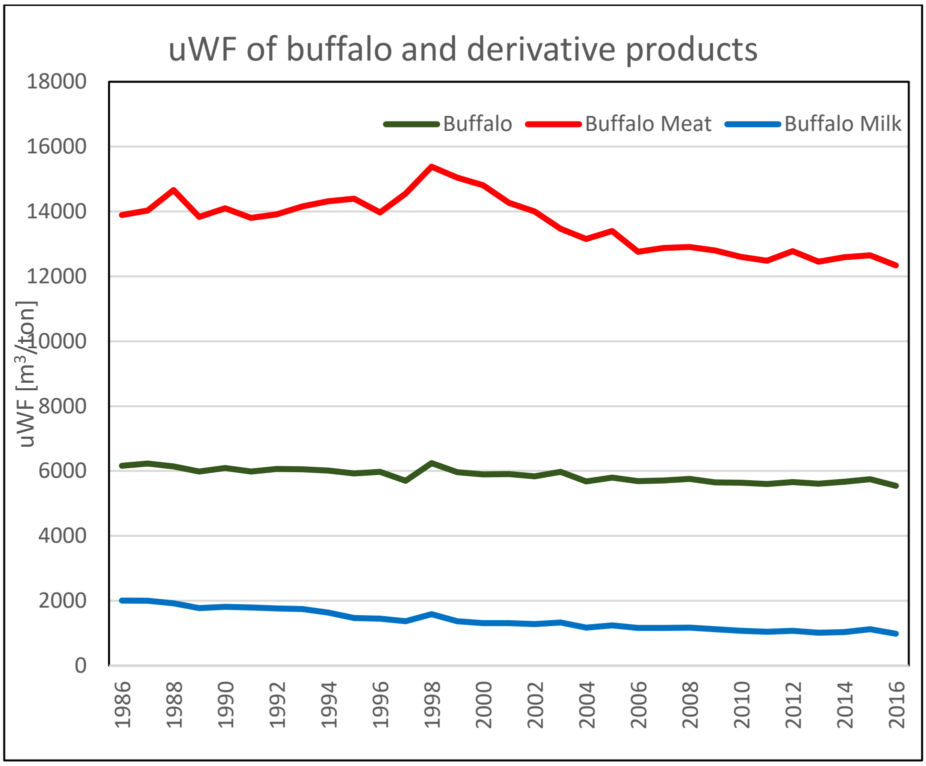



*Figure 6.1 uWF of buffalo and derivative products*

Products related to buffalo breeding have undergone an increase in water efficiency in a linear manner (Figure 6.1); only in the case of the last years of the twentieth century there was a peak in water demand. In percentage terms, the water footprint of buffalo and its meat fell by about 10%, while that of milk has gone from 2000 $m^3$/ton to 980 $m^3$/ton (reduction of 51%, buffalo milk is the product that undergoes the greatest decrease of all those analyzed in detail). It is important to specify that it is normal to observe different variations in products derived from the same animal: they are primarily characterized by different yields, and it is possible that the breeding techniques of meat production have evolved more quickly than those of milk and vice versa. Moreover, it must be remembered that meat can be obtained from both dairy and beef buffalo, while milk is obtained only from the first type of herd, but they are characterized by different diets.

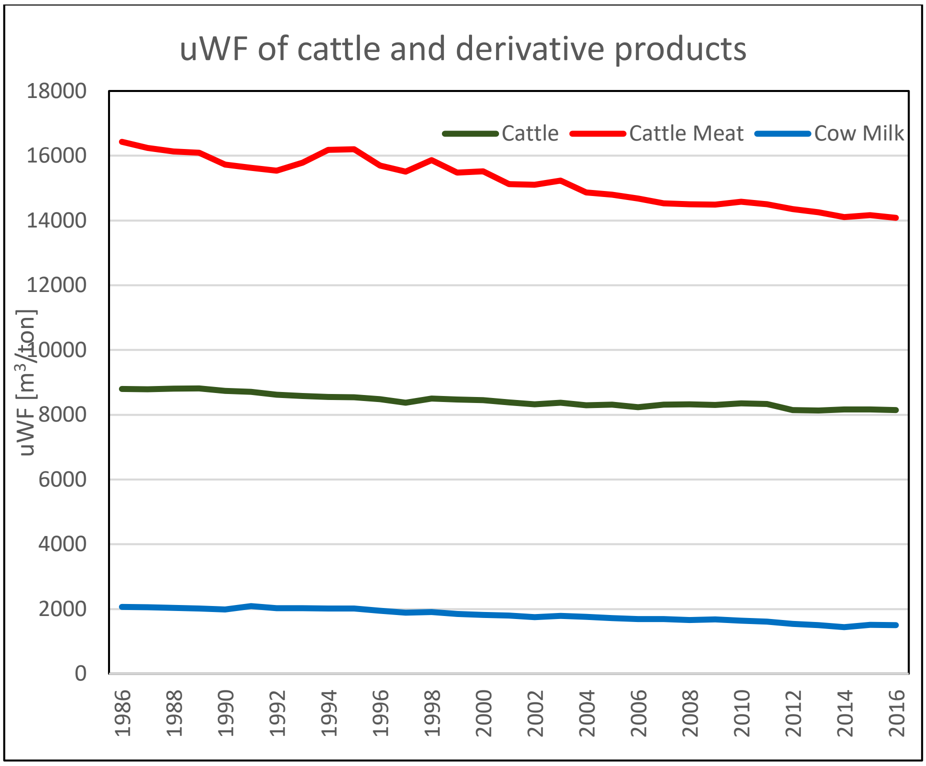



*Figure 6.2 uWF of cattle and derivative products over time*

Cattle shows the same decreasing trend observed in the case of buffaloes, and the same applies to its meat, for which 14000 $m^3$/ton are needed to produce it in 2016; on the other hand, the uWF of milk, although it has decreased over time, has done so with less incidence, reducing by about 30% compared to the initial value of 2000 $m^3$/ton.

The case of sheep (Figure 6.3) is singular, since it is observed that its uWF has remained roughly constant over time, while the efficiency relative to meat has increased by 20% due to a significant improvement in production yield. Moreover, as regards milk, it is the only case in which the unit water footprint increases between 1986 and 2016, in particular by 13%: this phenomenon can be explained by an increase in the production of this good in less developed countries characterized by higher yields.

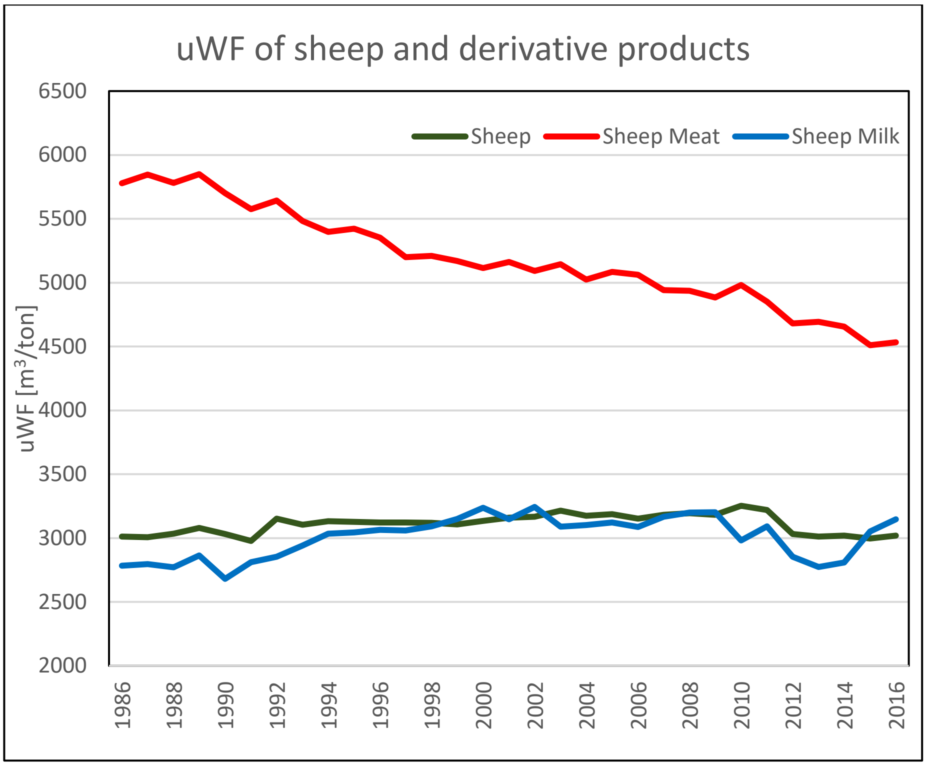



*Figure 6.3 uWF of sheep and derivative products over time*

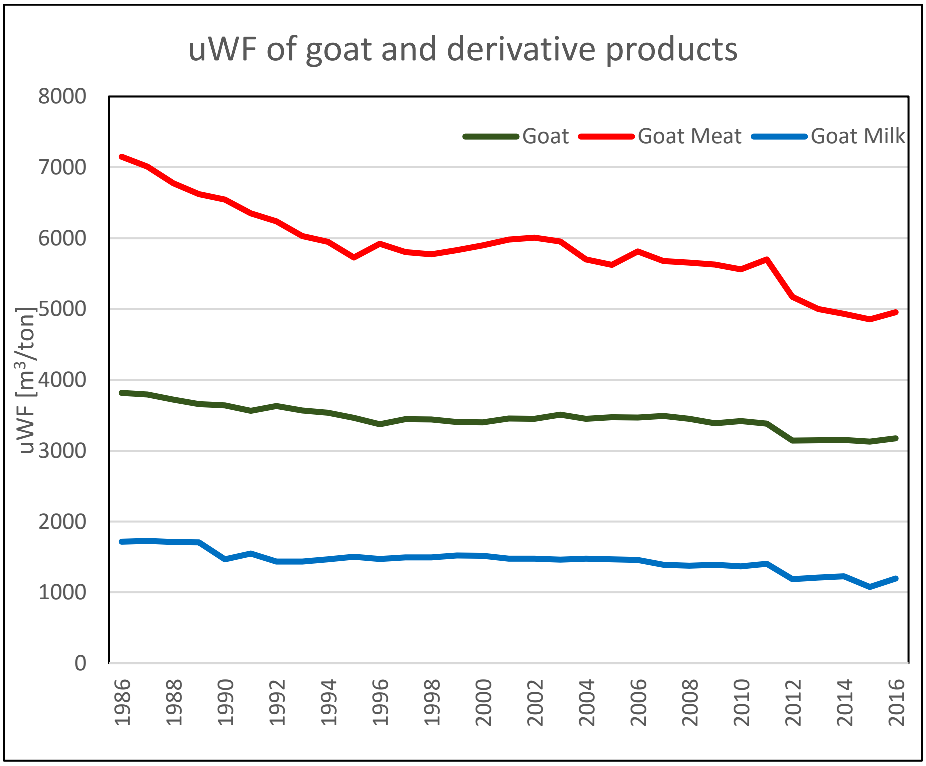



*Figure 6.4 uWF of goat and derivative products over time*

The reduction of the water footprint of goats and of the meat and milk derived from them is similar to each other, and is approximately 30% in the case of the animal and 20% in the case of products: in 2016 it takes 5000 $m^3$/ton to bred goat and 4950 $m^3$/ton and 1200 $m^3$/ton to produce meat and milk respectively. Analyzing the time series, it can be said that a significant improvement occurred in the 1980s and 1990s as regards meat water efficiency, while milk uWF remained constant during the same period of time and showed a more gradual decrease over the following years.

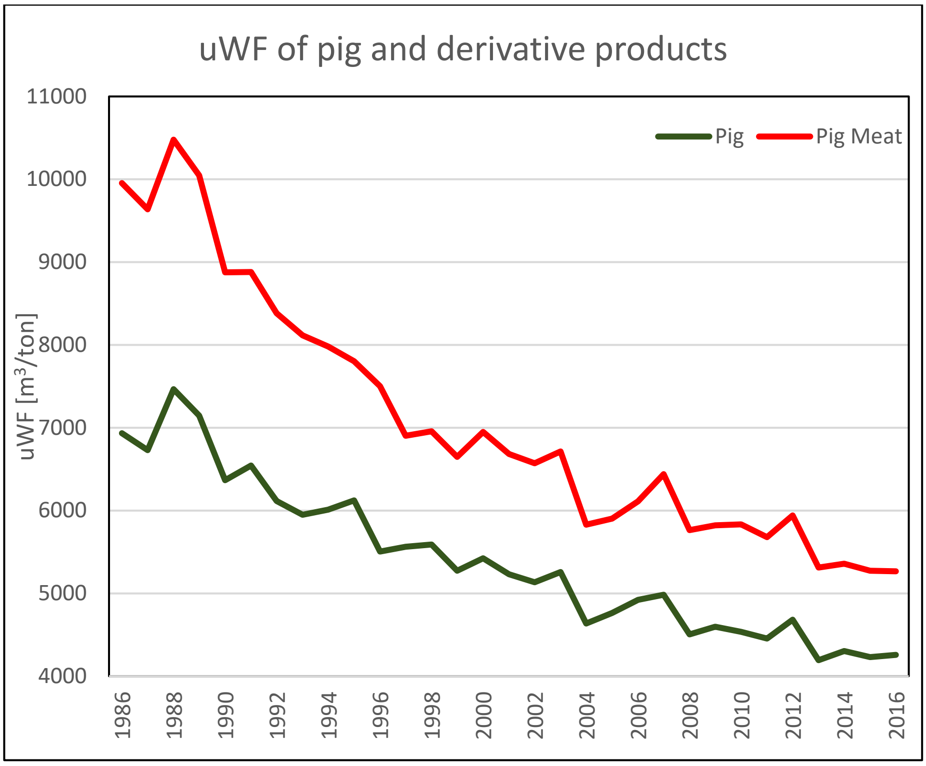



*Figure 6.5 uWF of pig and derivative products over time*

As mentioned above, the case of pigs (as well as that of poultry) is not linked to the water footprint of grass but only to that of crops and their trade: for this reason, the time trend is not as linear as the previous cases. Pigs show a significant increase in terms of water efficiency, in fact the uWF of meat has decreased by 47% in thirty years and stands at the value of 5270 $m^3$/ton in year 2016. The decrease linked to the production of cattle was slightly slower, decreasing by 39% compared to 7000 $m^3$/ton needed in 1986.

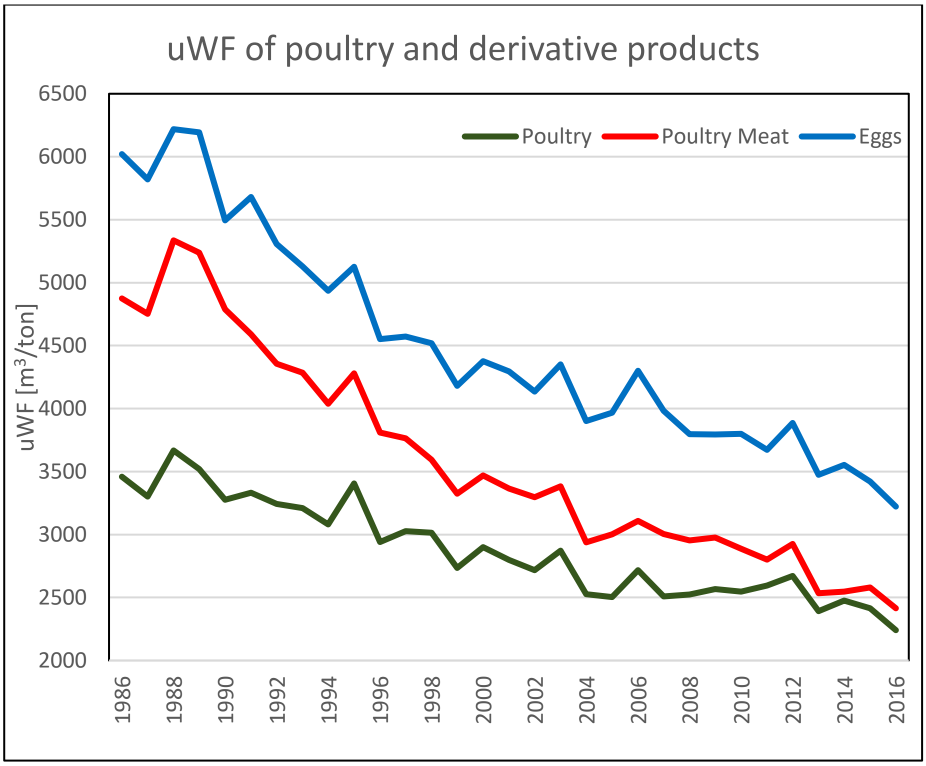



*Figure 6.6 uWF of poultry and derivative products over time*

Poultry is the category of animals that has most showed a decrease in the water necessary to obtain the products: in the case of meat, there is a lower value of 50%, while for eggs it is about 46%. Moreover, Figure 6.6 clearly shows how the meat yield has significantly increased over time, so much so that the gap between the water footprints of chickens and its meat has decreased significantly. In 2016, 3220 $m^3$/ton are needed to produce eggs, and 2410 $m^3$/ton to obtain meat.

### *6.1.2. Blue water use - uWF*

Using the same procedure, the blue water footprint was calculated as a percentage of the total one; the results are shown below.

The graphs show first of all that the percentage of unitary blue water footprint, compared to the total one, has always been less than 20% for all the products analyzed; The percentages of blue water do not all show a decreasing trend over time: for example, in the case of pigs, a tendency to increase can be observed, albeit in small entities; in 1986, to produce cow's milk 3.5% of blue water was required, while in 2016 this percentage rose to 4.5%. It can also be observed that appreciable peaks in blue water use occur in the same years for all the products, for example 1992, 1998 and 2003. This result can be related to the rainfall in these years: to make the crops grow in these years drought in the fields of nations with suitable equipment, it was necessary to resort to a greater quantity of irrigation water.

Since milk and meat are derived from animals raised with different diets, it is possible to observe a different use of blue water; it should also be remembered that the values in graphs are obtained as a world average weighted with production, which is why the percentages are not exactly the same also for pigs and hens (defined by a single diet).

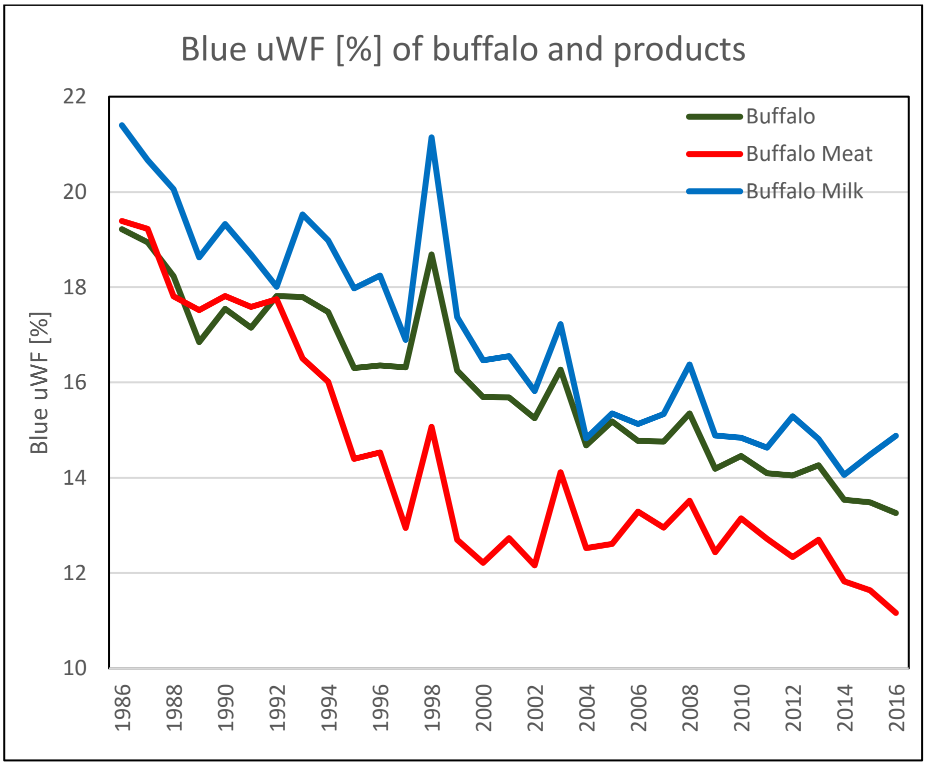



*Figure 6.7 Blue uWF [%] of buffalo and products*

Buffaloes is the class of animals that require the highest percentages of blue water; the highest percentage was recorded for milk production (22%) in 1986 and 1998. The reason for this peculiarity may be the distribution of the major buffalo producers: they are concentrated in countries like India, Pakistan and China. In particular, the first two nations satisfy the production of 73% of the buffaloes, and they can be characterized by a low optimization of rainwater and require a greater quantity of blue water. However, over the course of thirty years, the percentage of blue water used has decreased by 30% for animal and its milk and 40% for meat; in 2016, 12% of the unit water footprint of meat is satisfied by water from irrigation systems.

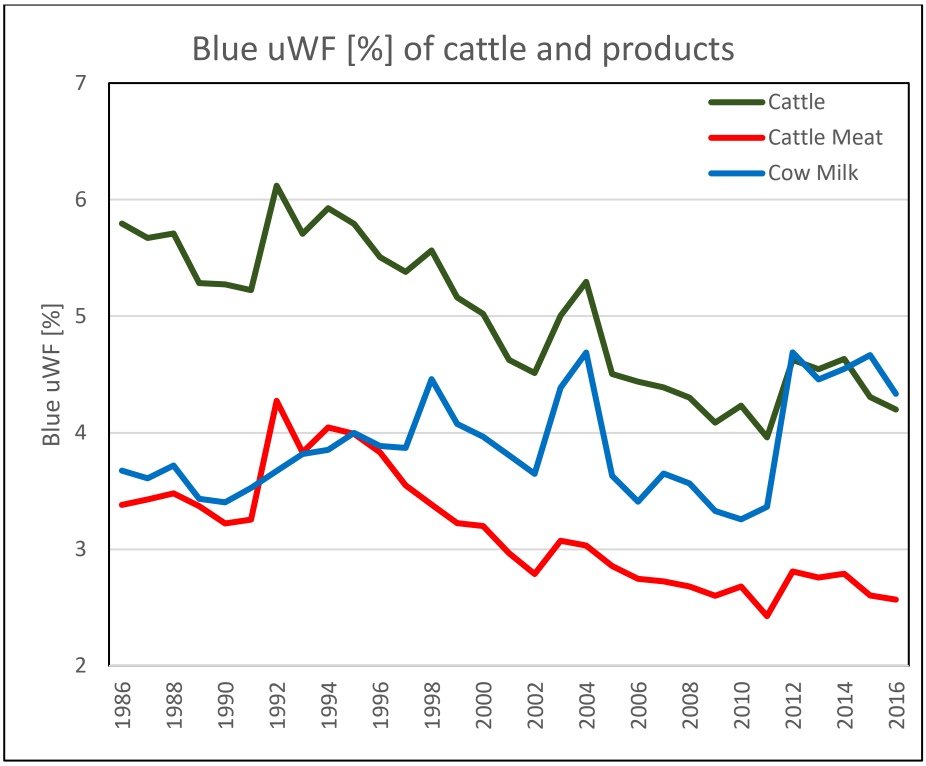



*Figure 6.8 Blue uWF [%] of cattle and products*

Figure 6.8 shows an irregular trend in the blue water component referring to the water footprint of milk: an increase of one percentage point has been observed in recent years. On the contrary, the meat trend is decreasing and, in 2016, 3% of the water used to produce it is blue.

A particular case is represented by pigs (Figure 6.9): in fact, to raise pigs and to obtain meat, the same blue water percentage is needed, due to the fact that meat is the only product derived from this category of animals, for which a single diet is defined. In addition, meat is mainly produced in countries where pigs are bred. Moreover, it is observed that values remain constant throughout the analysis time with a slight positive trend, showing variations less than one percentage point.

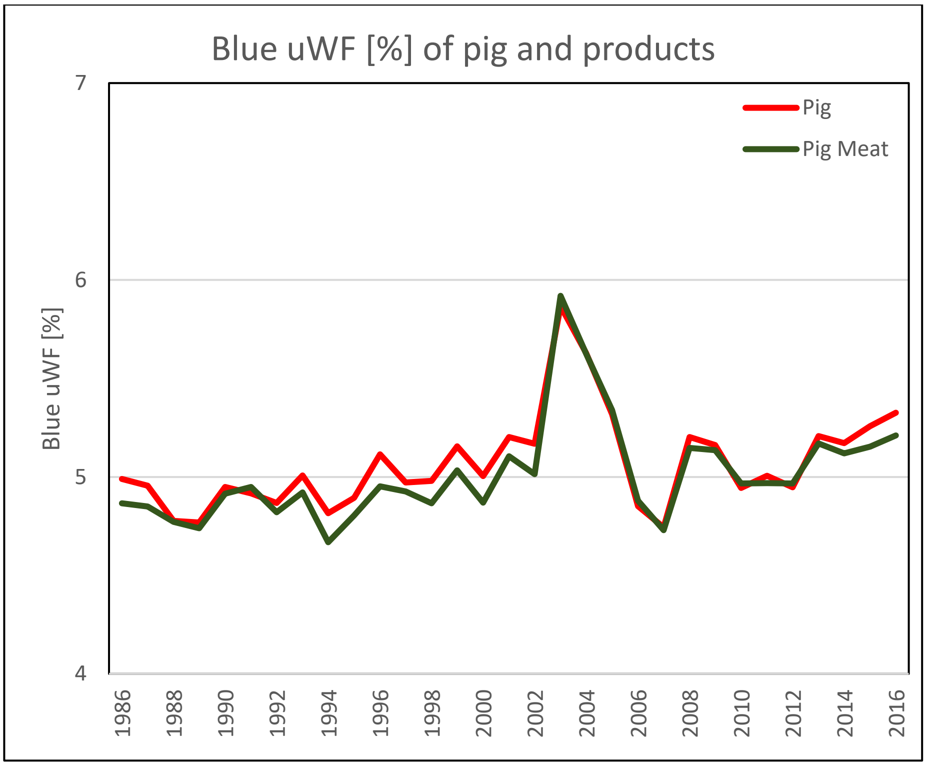



*Figure 6.9 Blue uWF [%] of pig and products*

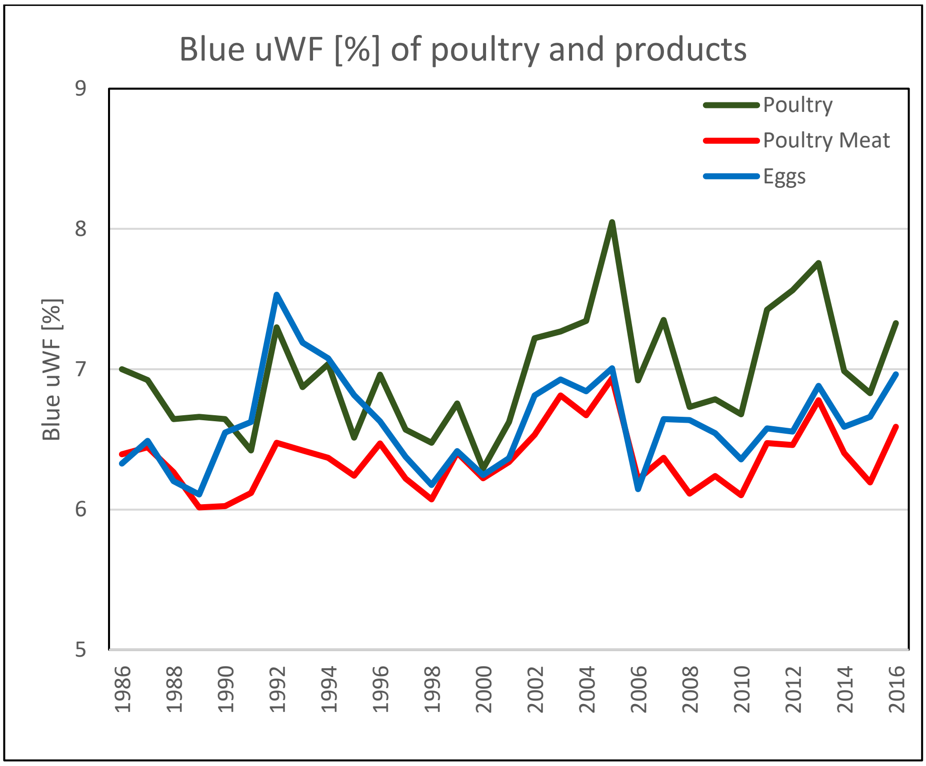



*Figure 6.10 Blue uWF [%] of poultry and products*

The case of hens is more irregular and there are variations of about 2 percentage points around the average value of 7%; less irregular is the variation of blue water as regards meat and eggs; also in this case, however, a positive trend can be observed, which has allowed an increase of 0.5% in thirty years.

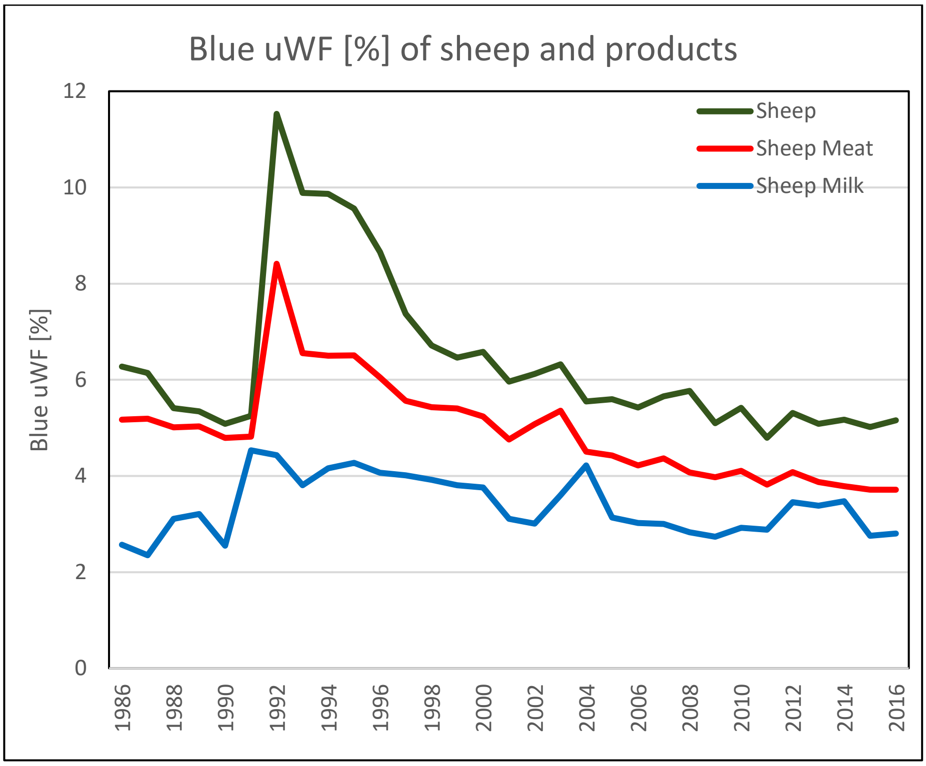



*Figure 6.11 Blue uWF [%] of sheep and products*

the blue unit water footprint of sheep derivative products show two opposite trends: in the case of meat there is a decrease of one percent, while for milk an increase of the same amount is recorded; this increase occurred mainly in 1991, while in the following years the average remained constant. particular attention must be paid to the peak recorded in the same year for sheep and its meat: the percentage of irrigation water doubled, and then decreased just as quickly in the following years. The motivation must be sought in the presence of a crop in the diet, which has undergone a significant increase in the use of blue water for its growth, probably due to climatic conditions.

Goats have developed a remarkable efficiency in terms of blue water, almost halving its percentage compared to the total one (Figure 6.12); however, a significant increase is observed between 1990 and 1992, like in the case of sheep (sheep and goats have the same diet composition). In 2016, about 7% of the total uWF to produce both meat and milk is blue.

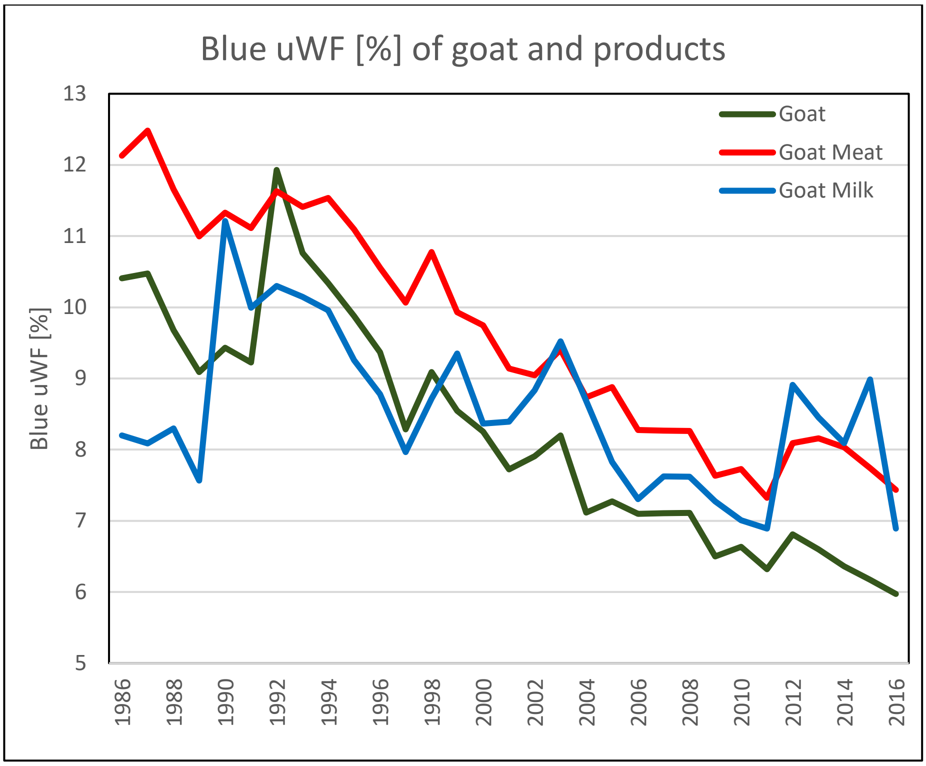



*Figure 6.12 Blue uWF [%] of goat and products*

### *6.1.3. Time series and blue use – WF*

A further result of considerable impact and very useful for understanding the evolution regarding the use of water in the food sector, are the volumes of water used, divided into blue and green water. Data, as done previously, are presented on a global scale: it was therefore calculated by multiplying the world average of the water footprint weighed with the production (previously proposed) by the world production itself. Therefore, although it is an average value, it has a considerable value and is very useful for starting to have an order of magnitude also relative to the volumes.

With the exception of pigs, for the production of which the total volume of water has decreased by about 20% over time, all the other products show an increasing or at most constant trend in water consumed. This result shows how, although the unit water footprint has decreased, at the same time there has been a considerable increase in production, which in turn causes an increase in the water consumed in absolute terms; the increase in production is certainly linked to the improvement of animal yields, to the increase in the world population, and last but not least, to the increase in the consumption of animal meat in human diets.

It is also observed that the volumes of blue water undergo little appreciable variations, since these are only in the order of a few percentage points (the same percentages shown in 6.1.2).

Time series obtained are reported:

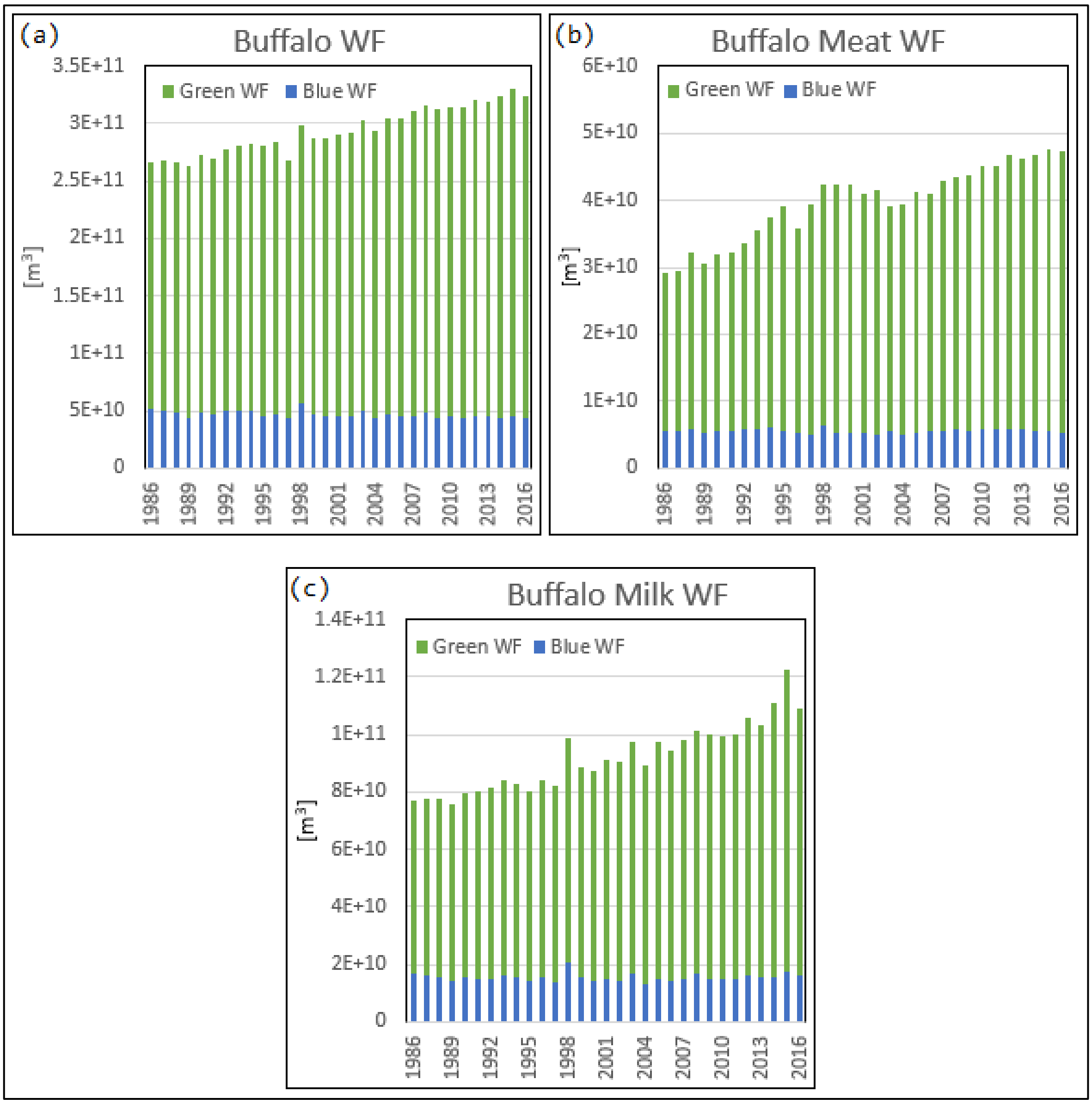



*Figure 6.13 Water footprint of (a) buffalo, (b) buffalo meat and (c) buffalo milk*

The increase in buffalo breeding and in the production of meat and milk occurred faster than their reduction in the unit water footprint, and a 60% increase in the volumes of water needed to produce meat was obtained. Moreover, the volumes of blue water have a minor variation compared to rainwater.

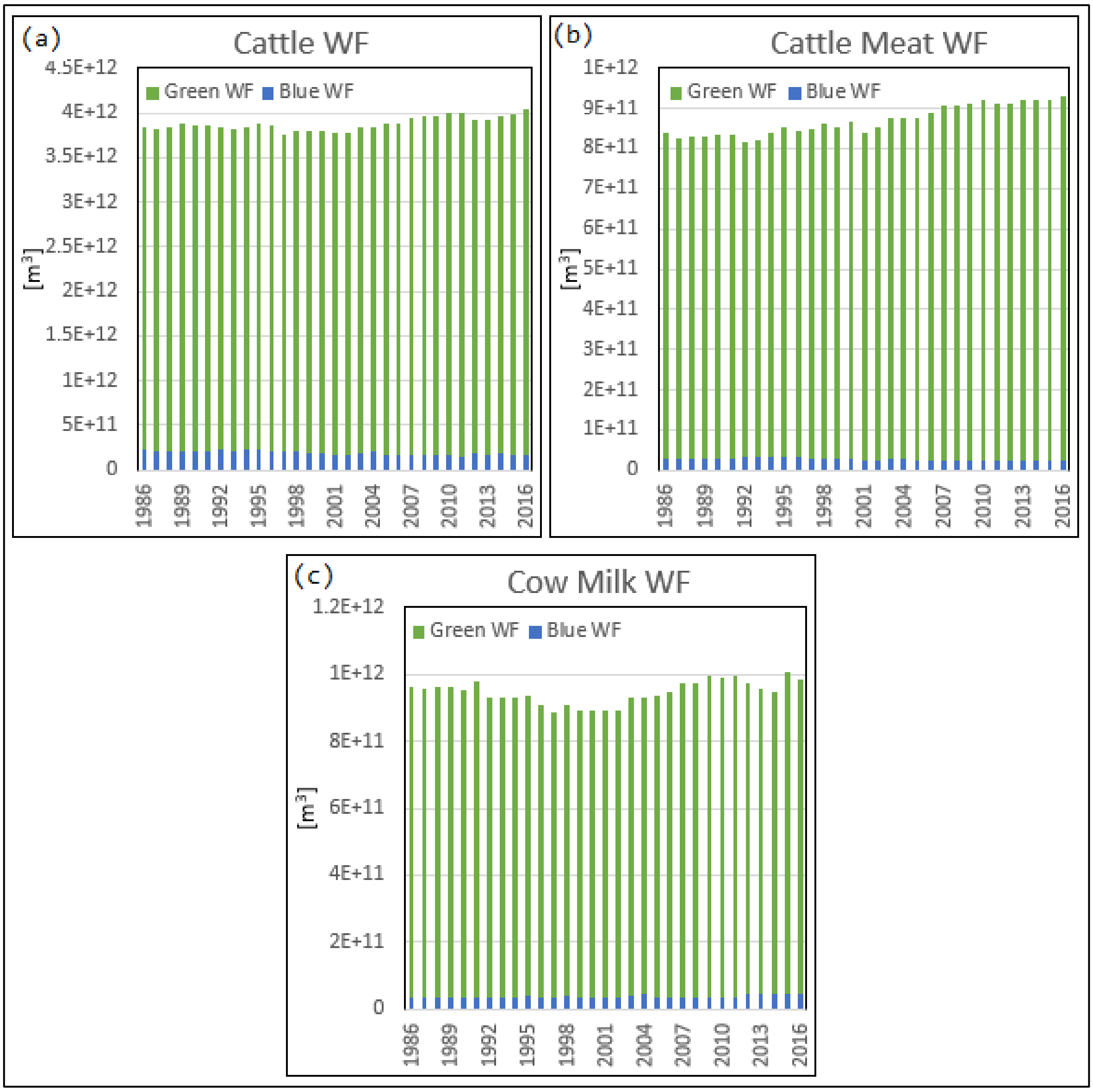



*Figure 6.14 Water footprint of (a) cattle, (b) cattle meat and (c) cow milk*

The production of cattle did not change annually on the world volumes of water used, which underwent variations of less than 6%; meat, on the other hand, showed a 10% increase, and in 2016 more than nine trillion cubic meters were needed.

Pig production grew over the thirty-year period, but the significant reduction in the unit water footprint meant that 30% less than the volume of water used in 1986 was used in 2016. However, together with the improvement in meat yield, the volumes linked to its production remained constant at a value of approximately six trillion cubic meters.

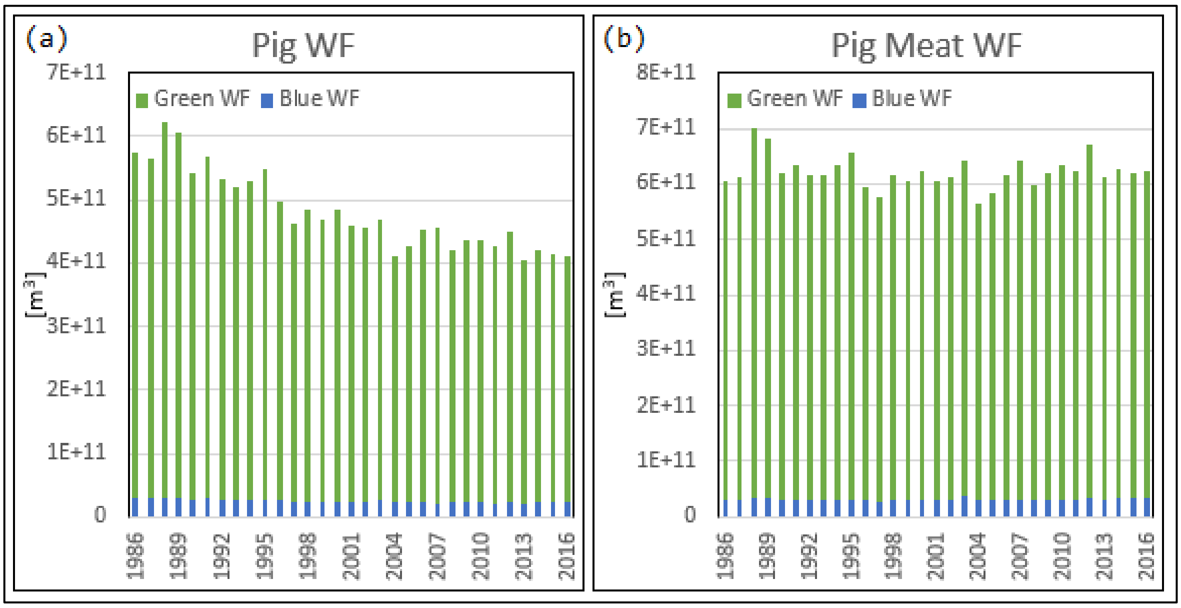



*Figure 6.15 Water footprint of (a) pig and (b) pig meat*

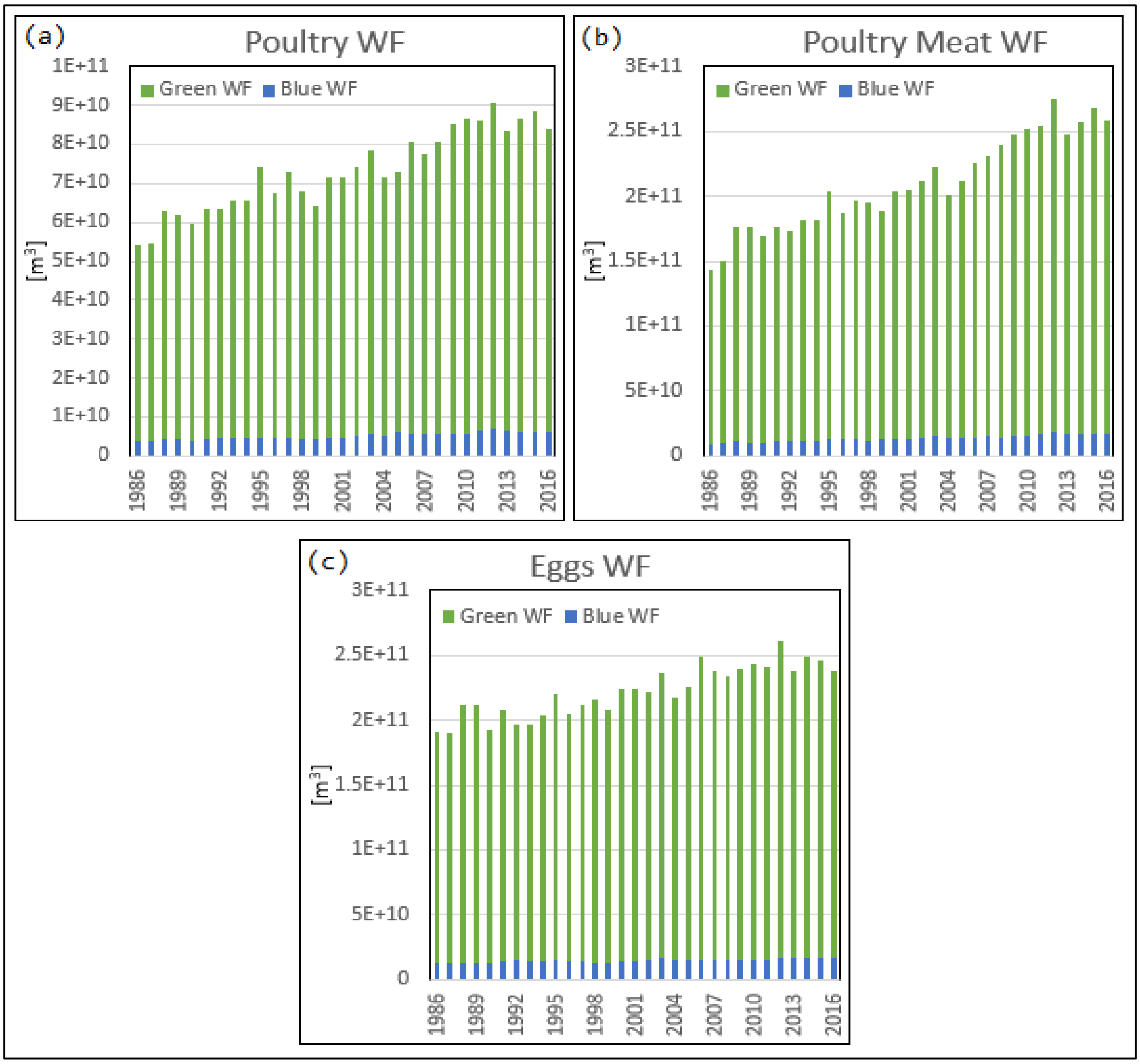



*Figure 6.16 Water footprint of (a) poultry, (b) poultry meat and (c) eggs*

Volumes of water linked to the production of hens and derived products has also increased over time; due to a substantial increase in demand and although the water footprint halved in 2016 compared to 1986, the volumes of water increased by 80 percent, and in 2016 2.5 trillion $m^3$ were consumed. On the other hand, eggs required a lower increase in terms of volume (25%).

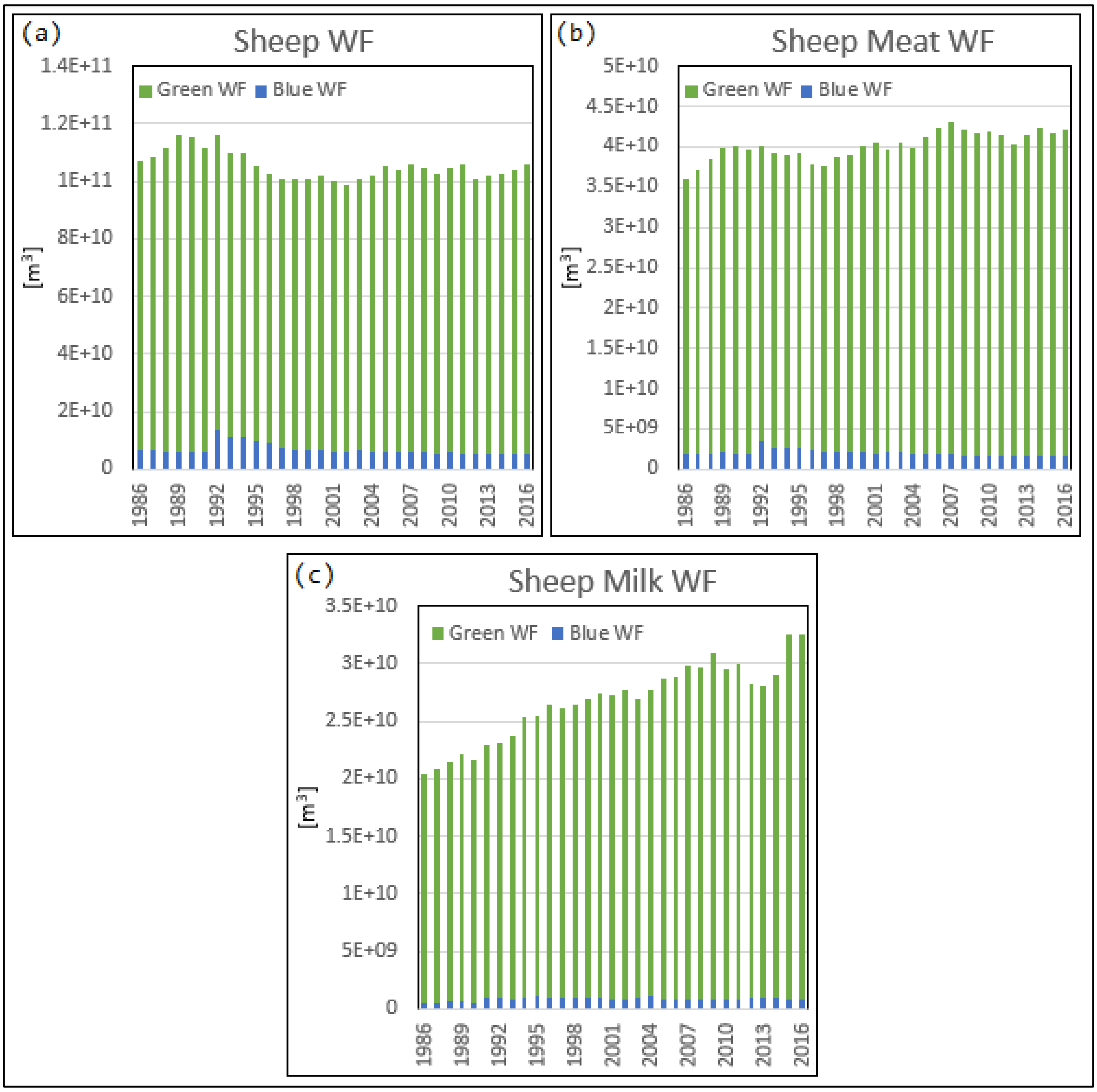



*Figure 6.17 Water footprint of (a) sheep, (b) sheep meat and (c) sheep milk*

Sheep and sheep meat, as in the case of cattle, consume a quantity of water (1 trillion and 0.4 trillion of $m^3$) that undergoes fluctuations, but remains on average constant; instead milk production raised substantially, and the water consumed increased by 60%. There is a slight decrease in the first years of the second decade of 2000, although there has been a further increase in the last two years. The same particularity is observed for products derived from goats, although in general there is an uptrend in water consumption: for meat, the percentage difference between 1986 and 2016 is 84% with an increase from 0.15 to 0.27 trillion cubic meters; concerning milk, the increase was a quarter of the water used in 1986.

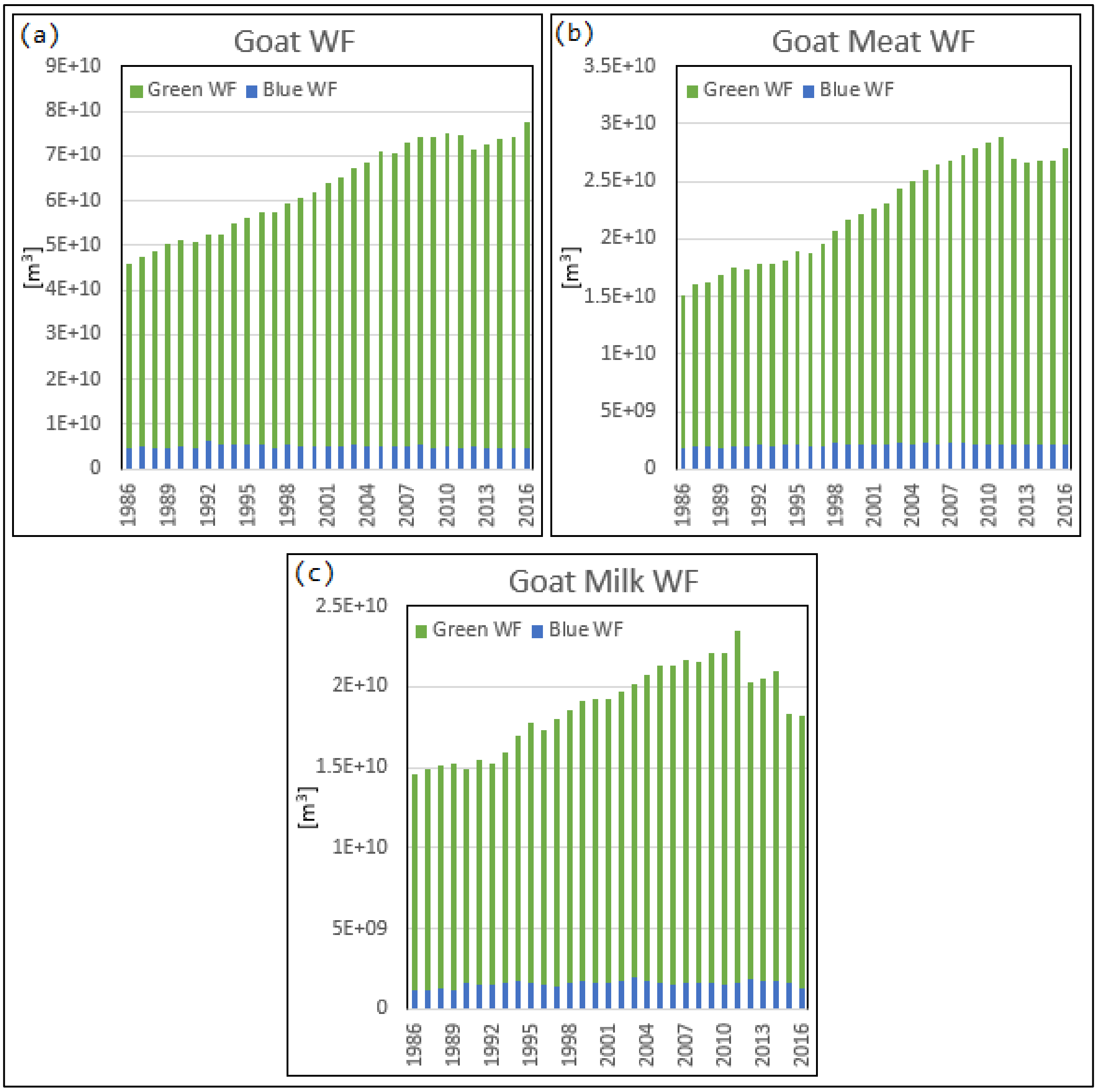



*Figure 6.18 Water footprint of (a) goat, (b) goat meat and (c) goat milk*

## 6.2. Results on a country scale

### *6.2.1. uWF world maps*

By increasing the precision scale, the world maps relating to the unitary water footprint for various products are shown below. As mentioned previously, for the sake of brevity, in this chapter the maps for the most consumed products in the world are shown (cattle meat, cow milk, pig meat, poultry meat).

In order to make a comparison between the first and last year of the period taken into consideration, the maps for 1986 and 2016 were made.

It should be remembered that due to the geopolitical evolution that has taken place in this period of time, the nations and their borders vary between the two proposed maps: for example, in 1986 it is possible to see the USSR characterized by a single water footprint; in 2016, however, the difference in values for each constituent nation is observed. There are other similar cases, but hardly observable due to the small extension of the countries involved, among which we remember the disintegration of Czechoslovakia, Sudan and Serbia and Montenegro State Union.

In these cases, the comparison is always possible, but it is useful to remember that the information about a smaller state should be more precise than that of the state from which it fell apart, since they are averaged on an obviously lower number of samples. This reasoning is more valid in the case of USSR, due to its considerable territorial extension, and which by disintegrating has given rise to various nations; their different techniques of breeding and harvesting and the different degrees of equipment for irrigation can affect the national average yield and the percentage of blue water used.

Generally speaking, it can be observed that the nations that require a greater quantity of water to produce animal products are those in Africa, the Middle East and the Indian subcontinent; this observation is of considerable importance, as developing nations are concentrated in the aforementioned regions, for which the population is destined to increase in the coming years. If in the next few years it is not possible to reverse this trend, we would find ourselves in need of ever greater quantities of water to meet the demand of the population.

In addition to these maps, others were created, in which the relative difference, in percentage terms, of the unitary water footprint between 1986 and 2000 was calculated; in this way it is possible to identify the nations that have improved water efficiency over time, and distinguish them from those that have not undergone substantial changes or that even produce goods of animal origin that require more unit water than in the past.

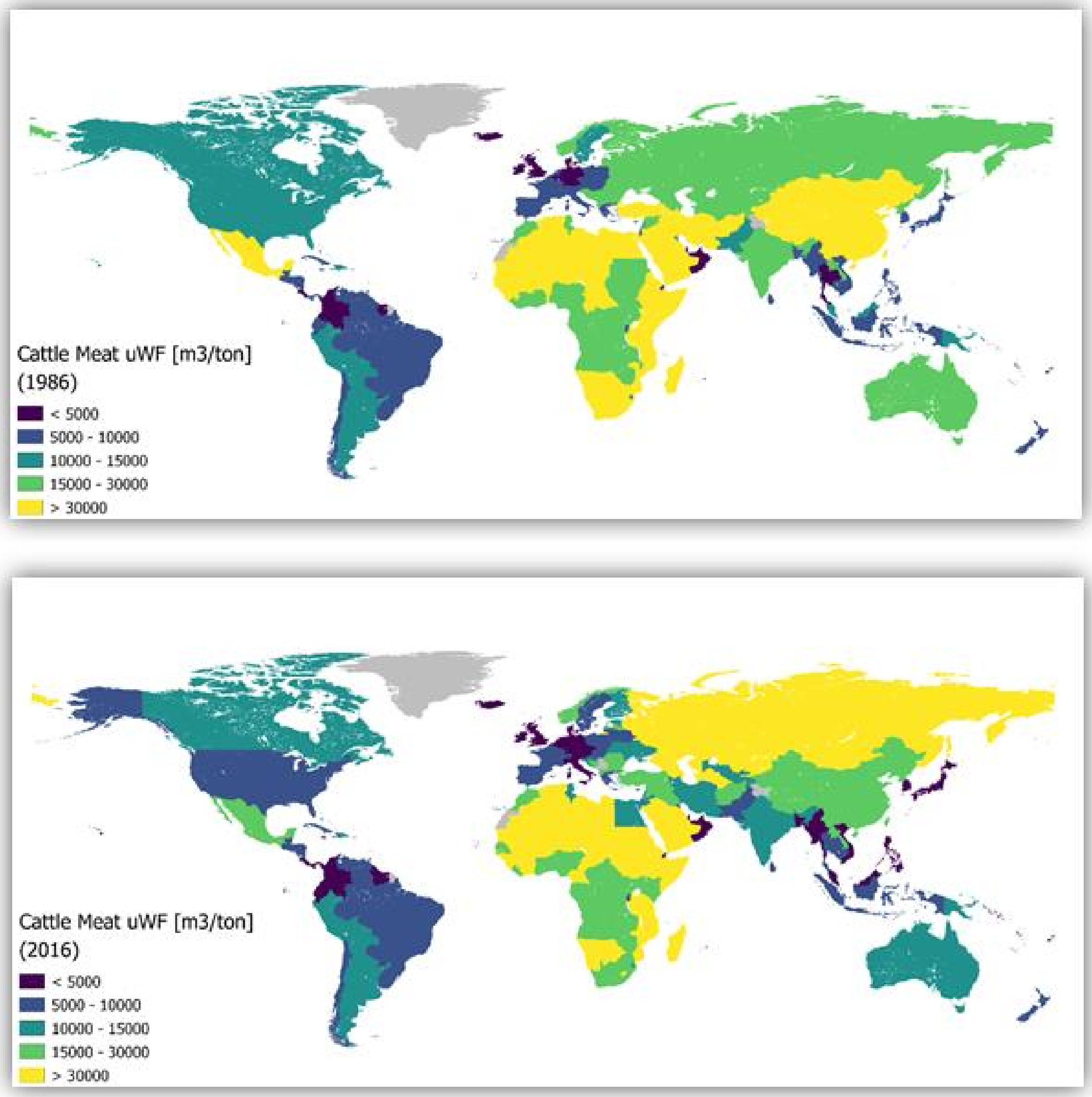



*Figure 6.19 Cattle meat uWF (1986 and 2016)*

Studying the national water footprints, for the reason previously described, it is observed that the unitary water footprint of cattle meat in 2016 is greater than that of the USSR in 1986, while it is lower in the other new nations.

Furthermore, reductions can be observed in many countries, especially in the United States, Mexico and China; in the first two countries the uwF is still higher than the world average, while the opposite happens in USA. In contrast to the high values recorded in Africa, lower unitary water footprints are result in Europe (mainly Italy, Germany and United Kingdom), America and several Asian nations like, for example, Thailand and Japan.

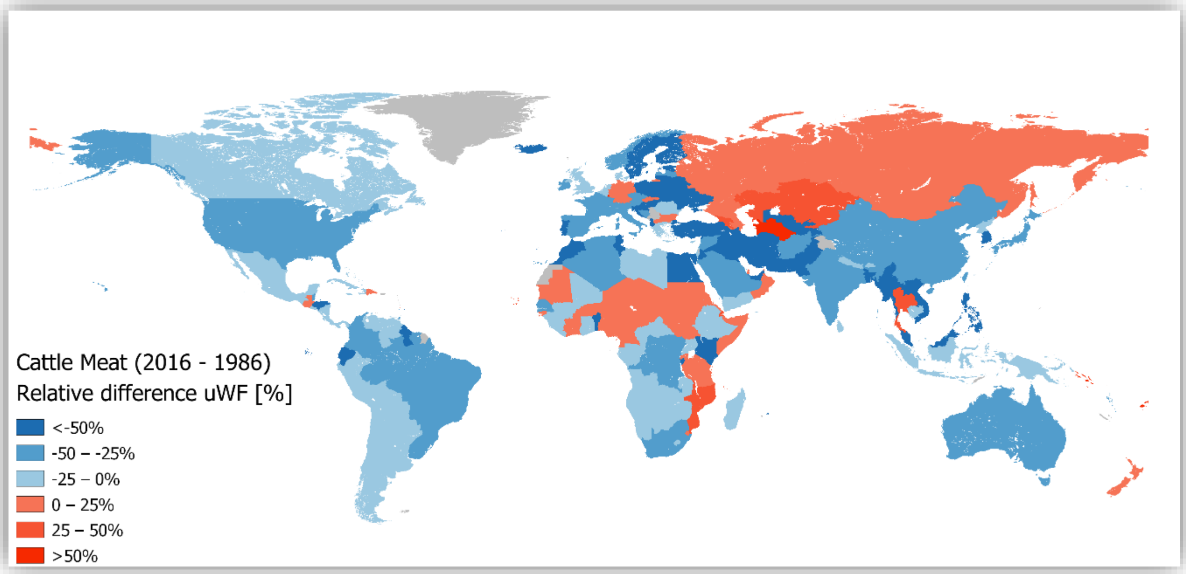



*Figure 6.20 Percentage reduction in the uWF of cattle meat between 1986 and 2016*

The previous map is very useful and allows us to understand that efficiency has improved almost all over the world, in greater terms in the United States, in Brazil in the countries of Eastern Europe (due to the break-up from the USSR) and in Asia; on the contrary, countries in which an opposite trend is observed are concentrated mainly in central Africa and Russian Federation.

As far as cow milk is concerned, on the other hand, the results are more homogeneous in the different continents (Figure 6.21): almost all African countries are characterized by a high and above the world average water footprint, both in 1986 and 2016. In the Middle East and Asian countries, the decreases in uWF are more evident; Moreover, in the Middle East, Oman has a very low uWF compared to the surrounding countries. Furthermore, in Europe almost all countries have excellent water efficiency, as well as countries such as New Zealand and Japan.

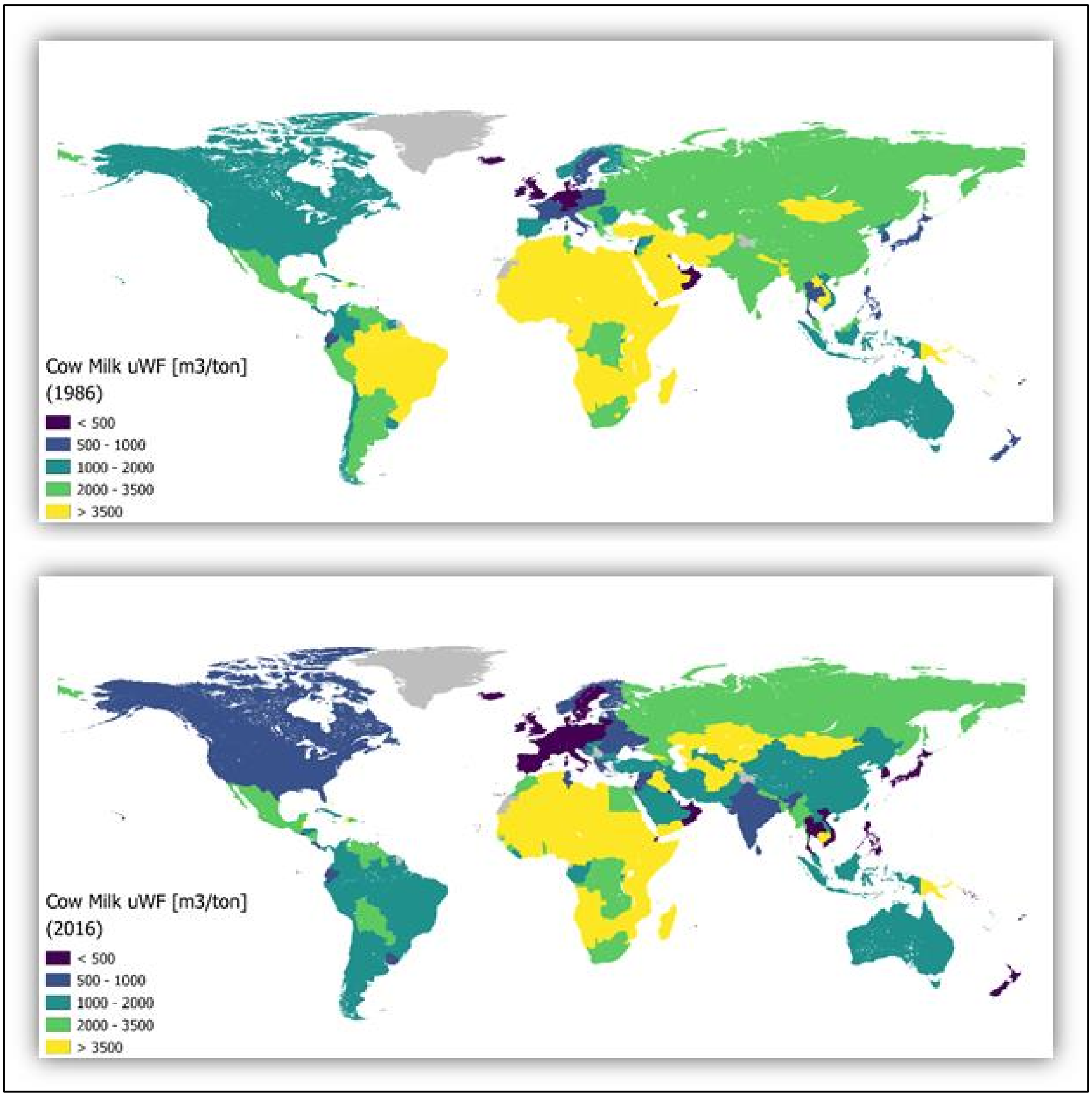



*Figure 6.21 Cow milk uWF (1986 and 2016)*

Figure 6.22 shows there are few countries where the water footprint of milk has increased over time, among which there are mainly African nations (Republic of Chad of all), central Asia and central-southern America nations. The other nations show an improvement and the uWF is less than 25% in the case of most of the remaining African countries, and even less than 50% for European and Southeastern Asia and Australia and New Zealand.

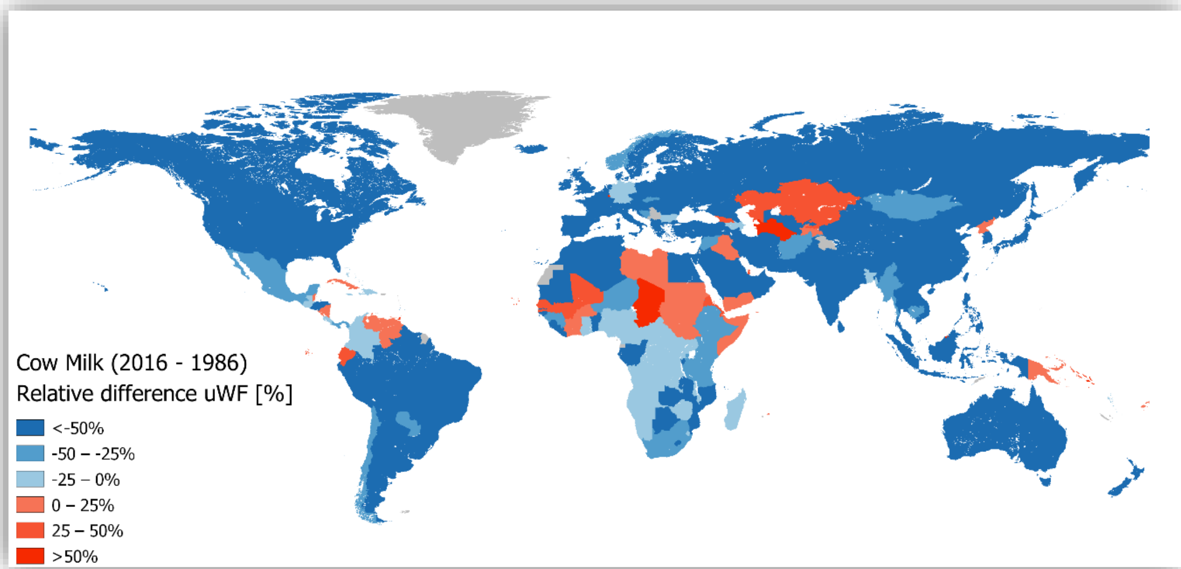



*Figure 6.22 Percentage reduction in the uWF of cow milk between 1986 and 2016*

The case of pigs is singular, because due to religious reasons, pork is not consumed, and therefore very often not even produced, in Islamic nations; they are concentrated in central-northern Africa and the Middle East.

Reductions are recorded throughout America, particularly in Brazil and, in general, in the northernmost part of South America; the lowest values are concentrated in Asian countries, such as China, Mongolia and Vietnam. A singular and interesting case is that of Australia, in which the uWF is significantly above the world average, also in 2016. results are shown in Figure 6.23.

As in the case of other products, also concerning pork, many African states have lost efficiency over time; to these are added countries such as Mongolia and Indonesia. Across America there is a noticeable improvement in efficiency, while as far as Europe is concerned, the improvements are not so marked; indeed, it occurs that in a developed country like Germany the unit water footprint has increased.

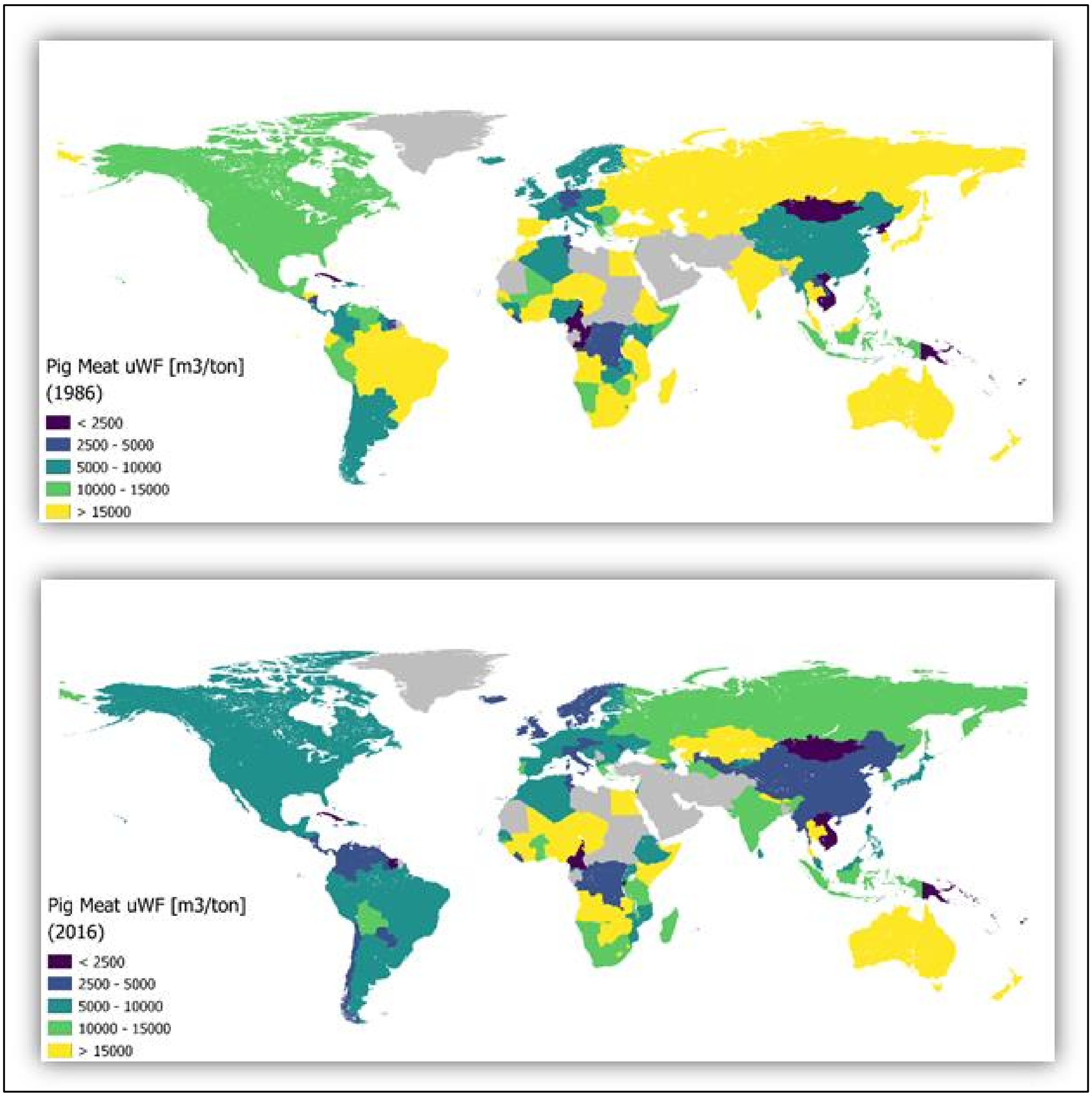



*Figure 6.23 Pig meat uWF (1986 and 2016)*

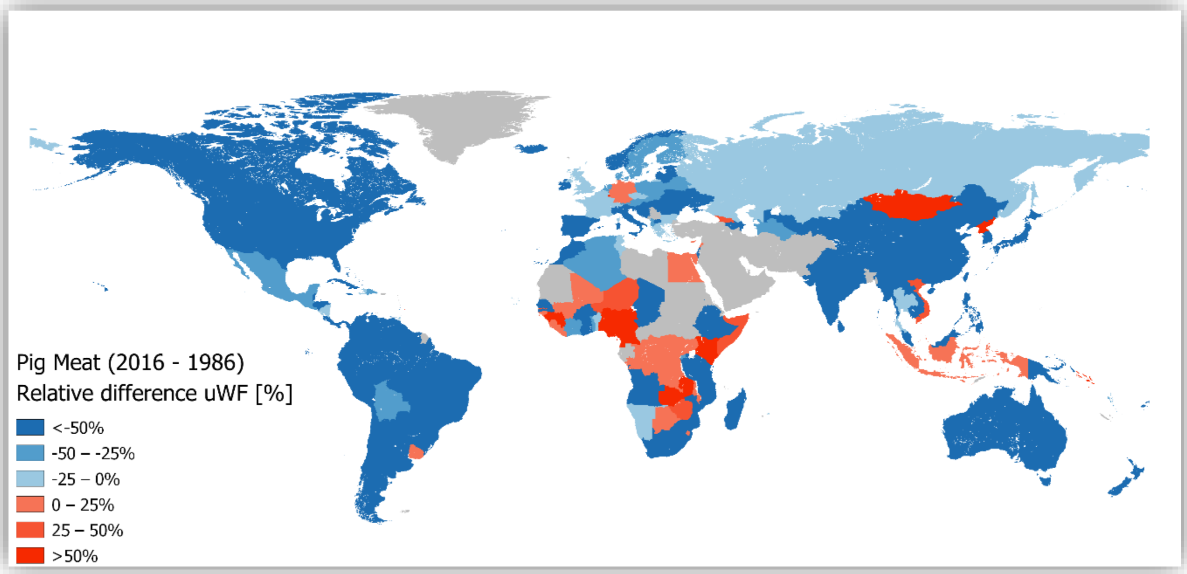



*Figure 6.24 Percentage reduction in the uWF of pig meat between 1986 and 2016 (nations without production in grey)*

The significant difference between the water footprints of poultry meat from 1986 and 2016 for almost all the world nations is consistent with the fact that the world average uWF undergoes a reduction of about 50%, as previously highlighted in 6.1.1.

In Latin American countries, such as Brazil, the greatest improvements can be observed, but also in the United States and Canada. In 2016, Europe is all characterized by a low uWF, and the lowest values were calculated the United Kingdom, Germany, Sweden, Austria and Hungary. Finally, in China and Asia there is an additional macro area with excellent water efficiency.

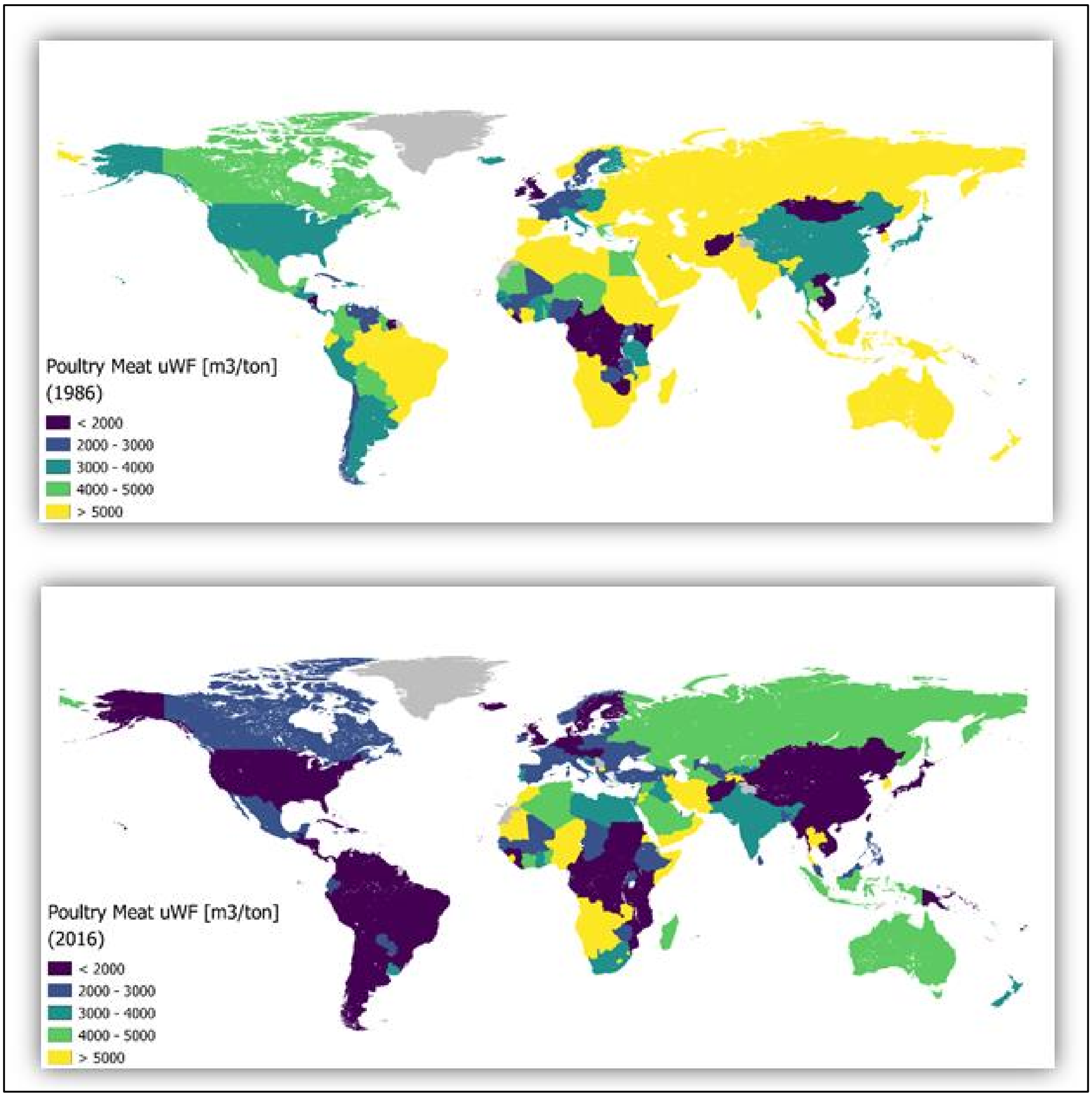



*Figure 6.25 Poultry meat uWF (1986 and 2016)*

The latter map shows that the United Kingdom, although characterized by a low unit water footprint to produce poultry meat, has slightly increased its value compared to the past. The same trend is observed for the usual African countries, with percentages in some cases greater than 25%; a significant increase is also observed in Mongolia.

In contrast, all of America, as well as Asia, Oceania and Eastern Europe, showed a greater increase of 50%.

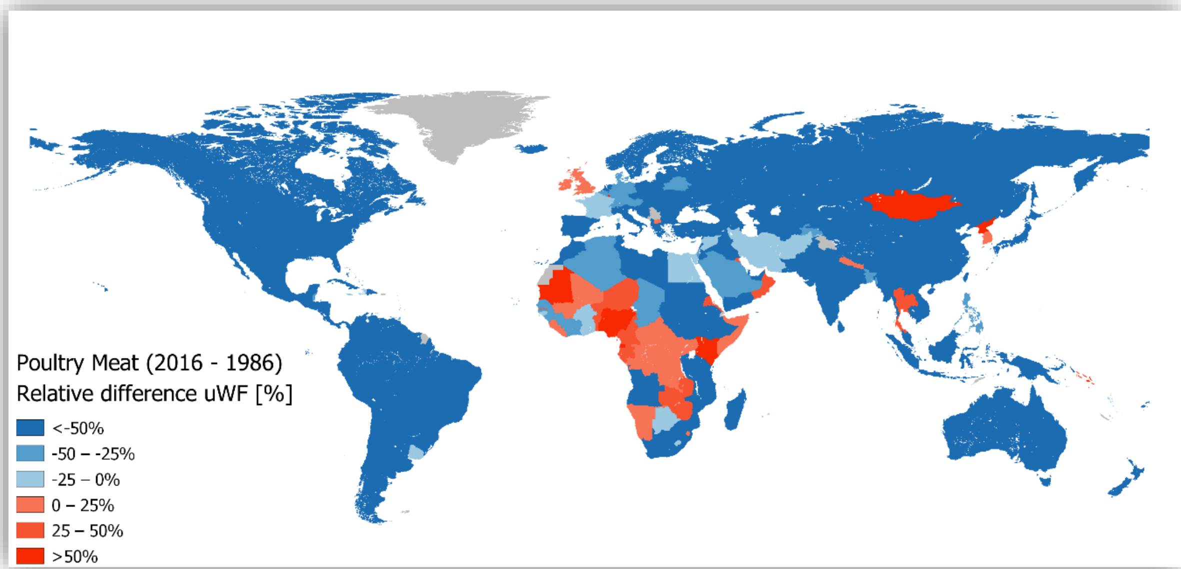



*Figure 6.26 Percentage reduction in the uWF of poultry meat between 1986 and 2016*

### *6.2.2. Focus on the major world producers*

Once the unitary water footprint of animal products for each country has been calculated, it is necessary to relate it to the production of the individual nations. As already mentioned, the uWF is a value that in turn is used to calculate a quantity that is more useful from an environmental and economic point of view, namely the volumes of water that are consumed, with focus on those coming from irrigation systems.

It could happen not hardly that, although the water efficiency is remarkably high, the volumes of water required are very high due to the large production demand (as proved by results shown in Chapter 6.1.3): this phenomenon occurs mainly in the case of advanced countries which have developed good production techniques. In order to investigate this aspect with a more detailed scale, the volumes of water necessary to produce the main products of animal origin for the three major world producers were calculated; the values were computed for the year 1986 and 2016, to highlight the temporal variation and the evolution of the blue component.

It should also be noted that over time production has changed, and that countries that appeared as major producers in 1986 are not in 2016 and vice versa. In this sense, geopolitical evolution takes on a central role: in fact, in 1986 the USSR was one of the major producers of all products, but obviously in 2016 its production was broken up among all the countries founded by its disintegration.

moreover, the unitary water footprints on a regional scale are shown, which allow us to understand which large producer is more water efficient.

*Table 6-1 Results for the three largest cattle meat producers (1986-2016)*

| Cattle Meat | 1986 | | | | | |
|---|---|---|---|---|---|---|
| | Production [ton] | uWF [$m^3$/ton] | World average uWF [$m^3$/ton] | WF [$m^3$] | Blue WF | |
| | | | | | [%] | [$m^3$] |
| USA | 1.13E+07 | 13438 | 16430 | 1.52E+11 | 0.87% | 1.31E+09 |
| USSR | 7.84E+06 | 28535 | | 2.24E+11 | 2.19% | 4.90E+09 |
| Brazil | 3.60E+06 | 7773 | | 2.80E+10 | 9.30% | 2.60E+09 |

| Cattle Meat | 2016 | | | | | |
|---|---|---|---|---|---|---|
| | Production [ton] | uWF [$m^3$/ton] | World average uWF [$m^3$/ton] | WF [$m^3$] | Blue WF | |
| | | | | | [%] | [$m^3$] |
| USA | 1.15E+07 | 9648 | 14082 | 1.11E+11 | 0.60% | 6.60E+08 |
| Brazil | 9.28E+06 | 5446 | | 5.06E+10 | 5.07% | 2.56E+09 |
| China | 7.00E+06 | 25856 | | 1.81E+11 | 0.12% | 2.12E+08 |

*Table 6-2 Percentage change in volumes consumed for cattle meat between 1986 and 2016*

| Cattle Meat WF % difference (1986-2016) | |
|---|---|
| USA | -27% |
| Brazil | 81% |

United States is the nation with the highest production of cattle meat in the whole period considered (Table 6-1Figure 6.1), for which it requires a uWF lower than the world average; the tons produced are approximately constant, but the volumes of water consumed decrease by 27% (Table 6-2) according to the same percentage reduction of the uWF. The portion of blue water is less than one percentage point and has decreased over time. In 1986, USSR was the second largest producer, but needed a water footprint more than double that of USA, consuming 0.2 trillion cubic meters, of which 2% from irrigation. Brazil is the nation that has experienced the greatest increase in cattle meat production which has almost tripled in thirty years; although the uWF is less than half the world average, the volumes of water are not negligible and have undergone an 80% increase; it is also noted that, thanks to the improvement of production techniques, the percentage of blue water halved and in 2016 it was 5% of the total (however high compared to developed countries).

*Table 6-3 Results for the three largest cow milk producers (1986-2016)*

| Cow Milk | 1986 | | | | Blue WF | |
|---|---|---|---|---|---|---|
| | Production [ton] | uWF [m³/ton] | World average uWF [m³/ton] | WF [m³] | [%] | [m³] |
| USSR | 1.02E+08 | 3270 | 2061 | 3.33E+11 | 0.26% | 8.54E+08 |
| USA | 6.49E+07 | 1128 | | 7.33E+10 | 1.91% | 1.40E+09 |
| Germany | 3.45E+07 | 285 | | 9.85E+09 | 0.05% | 5.41E+06 |

| Cow Milk | 2016 | | | | Blue WF | |
|---|---|---|---|---|---|---|
| | Production [ton] | uWF [m³/ton] | World average uWF [m³/ton] | WF [m³] | [%] | [m³] |
| USA | 9.64E+07 | 598 | 1497 | 5.76E+10 | 1.38% | 7.97E+08 |
| India | 7.74E+07 | 840 | | 6.51E+10 | 29.28% | 1.91E+10 |
| China | 3.68E+07 | 1520 | | 5.59E+10 | 0.15% | 8.64E+07 |

*Table 6-4 Percentage change in volumes consumed for cow milk between 1986 and 2016*

| Cow Meat WF % difference (1986-2016) | |
|---|---|
| USA | -21% |

The only nation that is among the three major producers of milk in both 1986 and 2016 are the United States, which after the break-up of the USSR go into first position; water efficiency is quite high, and improves over time, so as to allow the production of 30% more milk with a water consumption of less than 21%.

In 2016, India is the second largest producer of milk, for which it requires a water footprint of 840 $m^3$/ton. It is very important to highlight that 30% of the volume of water used (19 billion cubic meters) derives from irrigation: India is a developing country, in which production systems have not undergone improvement and for which the use of rainwater has not been optimized yet.

Finally, although China produces about a third of the milk compared to United States, it uses the same quantities of water as the unit water footprint is considerably higher (but in line with the world average).

*Table 6-5 Results for the three largest pig meat producers (1986-2016)*

| Pig Meat | 1986 | | | | | |
|---|---|---|---|---|---|---|
| | Production [ton] | uWF [m³/ton] | World average uWF [m³/ton] | WF [m³] | Blue WF | |
| | | | | | [%] | [m³] |
| China | 1.72E+07 | 6468 | 9954 | 1.11E+11 | 7.90% | 8.77E+09 |
| USA | 6.38E+06 | 11751 | | 7.50E+10 | 6.98% | 5.24E+09 |
| USSR | 6.05E+06 | 17781 | | 1.08E+11 | 2.95% | 3.18E+09 |

| Pig Meat | 2016 | | | | | |
|---|---|---|---|---|---|---|
| | Production [ton] | uWF [m³/ton] | World average uWF [m³/ton] | WF [m³] | Blue WF | |
| | | | | | [%] | [m³] |
| China | 5.41E+07 | 3142 | 5266 | 1.70E+11 | 8.34% | 1.42E+10 |
| USA | 1.13E+07 | 6855 | | 7.76E+10 | 6.83% | 5.30E+09 |
| Germany | 5.59E+06 | 5085 | | 2.84E+10 | 0.91% | 2.60E+08 |

*Table 6-6 Percentage change in volumes consumed for pig meat between 1986 and 2016*

| Pig Meat WF % difference (1986-2016) | |
|---|---|
| China | 53% |
| USA | 4% |

As regards pig, China has always been the largest meat producer linked to the high percentage of animals bred; in 2016, production even quadrupled. Breeding techniques, trade and diet composition positively affect the water footprint, which is lower than the world average and halves in 30 years; in this way, the volume used increases by only 53% over time. As the pig diet only includes crops, the percentage of blue water is higher than cattle meat and cow milk and it is on average 8%. Moreover, compared to 1986, this percentage increased by half a percentage point: this is a singular case, and can be explained by the variation of the commercial partners.

*Table 6-7 Results for the three largest poultry meat producers (1986-2016)*

| Poultry Meat | 1986 | | | | | |
|---|---|---|---|---|---|---|
| | Production [ton] | uWF [$m^3$/ton] | World average uWF [$m^3$/ton] | WF [$m^3$] | Blue WF | |
| | | | | | [%] | [$m^3$] |
| USA | 6.73E+06 | 3415 | 4875 | 2.30E+10 | 6.97% | 1.60E+09 |
| USSR | 2.99E+06 | 6917 | | 2.07E+10 | 4.22% | 8.71E+08 |
| Brazil | 1.62E+06 | 6810 | | 1.10E+10 | 0.74% | 8.17E+07 |

| Poultry Meat | 2016 | | | | | |
|---|---|---|---|---|---|---|
| | Production [ton] | uWF [$m^3$/ton] | World average uWF [$m^3$/ton] | WF [$m^3$] | Blue WF | |
| | | | | | [%] | [$m^3$] |
| USA | 1.87E+07 | 1654 | 2415 | 3.09E+10 | 6.87% | 2.12E+09 |
| Brazil | 1.39E+07 | 1846 | | 2.56E+10 | 0.97% | 2.49E+08 |
| China | 1.27E+07 | 1416 | | 1.80E+10 | 5.63% | 1.01E+09 |

*Table 6-8 Percentage change in volumes consumed for poultry meat between 1986 and 2016*

| Poultry Meat WF % difference (1986-2016) | |
|---|---|
| USA | 35% |
| Brazil | 132% |

Finally, United States are the most important producer of chicken meat, followed by Brazil and China (the second producer was USSR in 1986). The unit water footprint in the USA was 3415 $m^3$/ton (the world average was 4875 $m^3$/ton), and halved in 2016; however countries like Brazil have undergone a marked improvement in efficiency and in 2016 the water footprint was 1846 $m^3$/ton, only 200 $m^3$/ton greater than that in the United States; the uWF of poultry meat in China stands at the same values as well.

Also considering the significant growth in meat production, there is an increase of 34% of water used in the United States and 132% in Brazil. It is also specified that the percentage of blue water used does not vary substantially over time, and that it assumes a more consistent value in the United States (about 7%), while in Brazil 0.25 billion cubic meters are consumed (compared to 2.1 billion cubic meters in the USA). Finally, also in 2016, China uses irrigation water for 6% of the total.

### *6.2.3. Analysis of the factor driving uWF patterns*

Considering the results shown in the previous sections, we analyze here the most important factors driving spatial and temporal heterogeneities of the animal water footprint. To do this, the singular cases were analyzed relating to Brazil, China, USA, and USSR. These countries were chosen as they are the major producers of the four products studied in detail so far.

The factors that are expected to influence the differences between water footprints are the following:

- type of livestock production systems;
- composition of the diet;
- yields of animal derivative products;
- uWF of crops (that means to account for crop yield);
- international trade of crops.

The first two factors are closely related to each other because, as described in 3.1.3, diets are defined, for each region, according to production systems.

The territorial extensions of the production systems (described in 3.1.2), expressed in percentage terms and on a country scale, are shown in Table 6-9 for the study countries.

*Table 6-9 Livestock production systems – Percentages*

| [%] | Cattle, buffalo, sheep and goat | | | | | | | Pig | | Poultry | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGA | LGH | LGT | MA | MH | MT | URBAN | Extensive | Intensive | Extensive | Intensive |
| Brazil | 5 | 7 | 0 | 6 | 32 | 0 | 50 | 35 | 65 | 5 | 95 |
| China | 19 | 1 | 30 | 1 | 6 | 21 | 21 | 43 | 57 | 15 | 85 |
| USA | 13 | 0 | 25 | 5 | 4 | 19 | 33 | 1 | 99 | 1 | 99 |
| USSR | 1 | 0 | 38 | 0 | 0 | 15 | 46 | 24 | 81 | 13 | 87 |

As regards mammals, intensive systems cover a large percentage of the total, reaching 50% in Brazil; on the contrary, China, although having a high percentage, it is equal to 21%, and is the only case among those considered in which the intensive systems are the predominant.

China, USA and USSR are nations with predominantly temperate climate; in China and USA arid lands with a percentage cover bigger than 10% can also be found; Brazil, on the other hand, is mainly humid: these aspects are found in the type of extensive livestock systems.

As regards pigs and chickens, they are mainly bred in intensive and industrial conditions especially in the case of chickens; only in China and USSR they are bred by smallholders for more than 10% (15% in China and 13% in USSR). The United States breed pigs only intensively, while in China both methods are used almost equally.

Strictly speaking, different diets for the same nation must be considered according to all the production systems used; however, to make a rough consideration, a diet was calculated by mediating each diet with the percentage of the production systems. Since, as already mentioned in 3.1.3, there are different diets for beef and dairy cattle, and considering that beef can be produced from both herds, a further average was made: this was weighed with the number of animals each of the two flocks compared to the total, for each production system and nation.

Table 6-10 and Table 6-11 show the results obtained.

| [kgDM/TLU] | Cattle Meat | | | | Cow milk | | | |
|---|---|---|---|---|---|---|---|---|
| | BRAZIL | CHINA | USSR | USA | BRAZIL | CHINA | USSR | USA |
| Grazing | 1483.0 | 2761.0 | 4220.3 | 2723.0 | 3423.3 | 2759.2 | 4720.9 | 3124.0 |
| Stover | 0.0 | 60.5 | 0.0 | 0.0 | 0.0 | 60.6 | 0.0 | 0.0 |
| Occasional | 1531.2 | 0.0 | 130.7 | 0.0 | 771.9 | 0.0 | 0.0 | 0.0 |
| Grains | 22.3 | 125.2 | 386.8 | 1594.3 | 159.6 | 128.1 | 435.5 | 2142.1 |
| Barley | 0.0 | 0.0 | 76.6 | 0.0 | 0.0 | 0.0 | 88.8 | 0.0 |
| Maize | 14.3 | 68.6 | 20.8 | 989.4 | 101.9 | 70.2 | 17.6 | 1325.1 |
| Pulses | 0.0 | 0.0 | 4.3 | 0.0 | 0.0 | 0.0 | 5.0 | 0.0 |
| Rice | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 |
| Sg/Mi | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Soya | 6.5 | 24.9 | 0.3 | 491.3 | 46.5 | 25.5 | 0.0 | 662.7 |
| Wheat | 0.9 | 6.2 | 137.2 | 113.6 | 6.3 | 6.4 | 155.2 | 154.3 |
| CerO | 0.0 | 5.9 | 85.0 | 0.0 | 0.0 | 6.3 | 96.6 | 0.0 |
| OlsO | 0.0 | 6.3 | 21.3 | 0.0 | 0.0 | 6.5 | 24.0 | 0.0 |
| CrpO | 0.7 | 12.7 | 29.0 | 0.0 | 4.9 | 12.9 | 33.3 | 0.0 |
| Animal | 0.0 | 0.2 | 12.4 | 0.0 | 0.0 | 0.0 | 15.1 | 0.0 |

*Table 6-10 Average diets to produce cattle meat and cow milk*

USSR was the country where more feed is needed to raise cattle to produce meat and milk, mostly grass, but with a good percentage of grains, in particular wheat, barley and other cereals. In Brazil the diet is made up of grass and occasional feed; in the United States, on the other hand, the prevailing grains are maize, soya and wheat. Very similar diets are needed to produce milk in percentage terms, but in absolute terms cattle need larger quantities of food to produce meat.

*Table 6-11 Average diets to produce pig meat and poultry meat*

| [kgDM/TLU] | Pig Meat – Poultry Meat | | | |
|---|---|---|---|---|
| | BRAZIL | CHINA | USSR | USA |
| Grazing | 0.0 | 0.0 | 0.0 | 0.0 |
| Stover | 0.0 | 0.0 | 0.0 | 0.0 |
| Occasional | 0.0 | 0.0 | 0.0 | 0.0 |
| Grains | 1819.0 | 1322.8 | 3596.6 | 3192.2 |
| Barley | 8.3 | 2.2 | 52.4 | 1131.0 |
| Maize | 1093.3 | 526.1 | 2490.9 | 0.0 |
| Pulses | 0.0 | 22.1 | 0.4 | 63.9 |
| Rice | 0.0 | 211.2 | 0.0 | 0.0 |
| Sg/Mi | 66.9 | 26.4 | 129.7 | 0.0 |
| Soya | 219.9 | 89.9 | 106.9 | 0.0 |
| Wheat | 16.2 | 35.2 | 161.7 | 791.2 |
| CerO | 76.5 | 37.0 | 418.4 | 876.8 |
| OlsO | 68.5 | 114.6 | 187.3 | 187.9 |
| CrpO | 258.4 | 225.7 | 0.0 | 85.3 |
| Animal | 11.0 | 32.5 | 48.8 | 56.2 |

In the case of pig meat and poultry meat, the diets are the same; moreover, they are composed only of grains. As in the previous case, USA and USSR consume more feeds, in this case more than double, compared to Brazil and China. However, the composition is different: in USSR, maize and other cereals were mainly used, in USA barley, other cereals and wheat, and in the end maize, other crops and soya in Brazil and China.

In order to carry out a critical analysis of the proposed results, it is necessary to analyze them considering the water footprints of each ingredient. These results are proposed in the following table:

*Table 6-12 uWF of the ingredients of the diet*

| [m3/ton] | Barley uWF | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 2339 | 1003 |
| China | 816 | 968 |
| USA | 1345 | 877 |
| USSR | 1994 | |

| [m3/ton] | CerO uWF | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 5153 | 2787 |
| China | 2049 | 997 |
| USA | 2966 | 2189 |
| USSR | 2139 | |

| [m3/ton] | CrpO | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 578.56 | 1405.15 |
| China | 1857.77 | 554.493 |
| USA | 541.57 | 1004.53 |
| USSR | 2383.15 | |

| [m3/ton] | Maize | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 2769.87 | 1121.34 |
| China | 1152.38 | 715.266 |
| USA | 676.43 | 462.58 |
| USSR | 1243.77 | |

| [m3/ton] | Occasional feed | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 125.29 | 64.48 |
| China | 173.026 | 96.111 |
| USA | 221.75 | 163.40 |
| USSR | 311.83 | |

| [m3/ton] | OlsO | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 10986.3 | 5317.30 |
| China | 3317.52 | 2432.18 |
| USA | 5187.01 | 3565.67 |
| USSR | 5165.44 | |

| [m3/ton] | Pulses | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 2820.28 | 2472.38 |
| China | 2820.28 | 1165.74 |
| USA | 2820.28 | 2472.38 |
| USSR | 3183.46 | |

| [m3/ton] | Rice | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 3530.20 | 1286.62 |
| China | 936.237 | 736.87 |
| USA | 1481.02 | 1226.69 |
| USSR | 2288.12 | |

| [m3/ton] | Sorghum/Millet | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 2224.85 | 2012.80 |
| China | 1660.77 | 1013.79 |
| USA | 1078.24 | 962.06 |
| USSR | 3573.77 | |

| [m3/ton] | Soy | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 3615.18 | 1831.03 |
| China | 3457.99 | 1728.02 |
| USA | 1920.01 | 1232.91 |
| USSR | 2645.07 | |

| [m3/ton] | Wheat | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 2404.00 | 1291.31 |
| China | 1677.72 | 948.507 |
| USA | 2316.26 | 1488.89 |
| USSR | 2084.69 | |

| [m3/ton] | Grass | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 1206.09 | |
| China | 1856.865 | |
| USA | 2279.90 | |
| USSR | 2145.69 | |

It can be observed that the unit water footprint of grass is very high in USA and in USSR, where it has an almost double value compared to that in Brazil (remember that the uWF of grass is the only one that has been kept constant).

In USSR, in 1986, as the diet is on average composed of 90% grass, the uWF of cattle meat is strongly influenced by its water efficiency; a completely similar reasoning applies to China, but the unit water footprint in 2016 is lower than that of the USSR by about 3000 $\frac{m^3}{ton}$ (25856 $\frac{m^3}{ton}$ ) as the quantities consumed are lower, while there is no big difference in terms of water footprint of grain. In Brazil, on the other hand, the diet is composed of grass and occasional feed, whose water footprint is linked to that of grass: since this one is small, Brazil is one of the most efficient countries.

As regards cow's milk, it is observed that the USSR and China are the countries with the worst unit water footprint, and, also in this case, this can be explained on the basis that the diet is mainly composed of grass. Singular is the case of USA, for which the water footprint is 3 times smaller than that of the USSR, in 1986: although the United States was the nation that needed more water to grow grass, in the diet there is a great contribution of grains as well, including mainly, as mentioned, maize and soy. Since the water footprint of maize is 676 $\frac{m^3}{ton}$ in 1986 (in Brazil it is 2770 $\frac{m^3}{ton}$ and in China it is 1152 $\frac{m^3}{ton}$) while that of soybean is 1920 $\frac{m^3}{ton}$ (about half of that in Brazil and China), the water footprint of cow's milk in the USA is equal to 1128 $\frac{m^3}{ton}$ in year 1986 and 598 $\frac{m^3}{ton}$ in 2016.

The diet of pigs and hens is the same, and is composed only of grains; however, the different composition of the feed significantly affects the water footprint of the derived products.

In 1986, USSR produced pork by raising animals in quantities more than double compared to China and Brazil and approximately comparable with those in the USA; in addition, in USSR maize and other cereals were mainly used, while in the USA they needed barley, other cereals and wheat, and in the end maize, rice and other crops are the ingredients of the diet in China.

This heterogeneity, depending on the uWF of the grain in each country and the quantities used, means that the pig meat produced in China is defined by an unit water footprint (6458 $\frac{m^3}{ton}$) 3 times smaller than that of the USSR and 2 times that of the USA.

Finally, as regards chicken meat, although there are variations in the composition of the diet, in 2016 the uWF in the different countries is comparable.

In the end, the effect of animal yields (Table 6-13) should not be overlooked: the first observation is that thanks to the improvement of breeding techniques, the yields increase over time, in some cases to double. It is also evident that in some cases the variations between nations are far from negligible: there are no substantial variations in pork production, but the opposite happens for cow's milk, whose efficiency in the United States is eight times greater than that of Brazil in 1986 (in 2016 the ratio drops to six).

*Table 6-13 Yields of derivative products*

| [hg/head] | Cattle meat yield | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 1846 | 2469 |
| China | 1023 | 1433 |
| USA | 2751 | 2495 |
| USSR | 1950 | |

| [0,1g/head] | Poultry meat yield | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 12000 | 22584 |
| China | 10273 | 13453 |
| USA | 14578 | 21000 |
| USSR | 13000 | |

| [hg/head] | Pig meat yield | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 664 | 877 |
| China | 667 | 774 |
| USA | 798 | 957 |
| USSR | 805 | |

| [hg/head] | Cow milk yield | |
|---|---|---|
| | 1986 | 2016 |
| Brazil | 7325 | 17113 |
| China | 15360 | 24210 |
| USA | 59129 | 103482 |
| USSR | 22569 | |

As for the trade, its effect will be analyzed in Chapter 7, but it is anticipated that this is not significantly influential.

In conclusion it can be said that due to the multiple variables involved, the variations in the uWF of farm animal products between nations cannot be explained systematically since it varies according to the country, product and year considered. However, it is possible to identify the main factors in the diet and water footprint of its components, while the animal yield intervenes significantly only in reference to particular products. The case of pork is analyzed below.

In 2016, in order to produce pork, 3142 $\frac{m^3}{ton}$ were necessary in China, 6855 $\frac{m^3}{ton}$ in USA and 6232 $\frac{m^3}{ton}$ in Brazil, with a reduction compared to thirty years before by 51%, 41% and 50% respectively.

As regards Brazil, the most determining factor is the yield, which over time has decreased by 32%. In this country the pig diet is mainly composed of maize (more than 50%), soya and other crops. Meanwhile the uWF of maize and soybeans decreased by 60% and 47% respectively, there was a strong increase in the water needed to produce other cereals (140%). For this reason, the general reduction of the water footprint of the feed takes on less importance.

On the contrary, in China, the innovation of breeding techniques was not as rapid, so yield only underwent a 16% increase. However, the uWF of crops has decreased significantly, on average by 35% (it reaches 72% in the case of other crops). It is mainly for this reason that China shows the fastest reduction of the water footprint of pork among the three countries analyzed, as it goes from 6468 $\frac{m^3}{ton}$ to 3142 $\frac{m^3}{ton}$ (savings of 51%).

Finally, USA is the nation with the highest water footprint among those considered: this peculiarity is explained by the fact that the composition of the diet in the United States requires pigs to eat greater quantities of food (3192 $\frac{kgDM}{TLU*y}$, which is more than double that with which pigs are fed in China). Anyway, the 41% reduction between 1986 and 2016 made it possible to produce pig meat by requiring 6855 $\frac{m^3}{ton}$ (about the quantity needed in China in 1986). The reduction is due to a contemporary and almost equal effect of the increase in the yield (20%) and the decrease of water used to cultivate crops. In USA, pigs are bred mainly with barley, wheat and other cereals, whose water footprint decreases by an average of 20-25%.

## 6.3. Comparison with previous studies

The study and the results proposed by (Mekonnen and Hoekstra, 2010) and previously described in Chapter 3.4 were used to make a comparison with the results obtained in this work in order to verify the procedure used. Remember that the uWFs shown in the database are calculated with data averaged over the decade 1996-2005. In order to make the comparison, therefore, it was decided to do it considering the virtual water of products relating to the year 2000, the central year of the time span.

If we consider the averages of the unit water footprints weighed with the production of the corresponding animals or derivative products, calculated with both methods, the following results are obtained:

| $[m^3/ton]$ | 2000 | | |
|---|---|---|---|
| | Mekonnen and Hoekstra, 2010 | Mekonnen and Hoekstra, 2010 (paper data) | This research |
| Buffalo | 7645 | | 5891 |
| Cattle | 7088 | | 8455 |
| Eggs | 2826 | 2900 | 4377 |
| Goat | 3528 | | 3402 |
| Buffalo Meat | 12908 | 15400 | 14812 |
| Cattle Meat | 10481 | 15000 | 15516 |
| Goat Meat | 5523 | 8700 | 5897 |
| Pig Meat | 3908 | 5400 | 6951 |
| Sheep Meat | 8308 | 8700 | 5115 |
| Buffalo Milk | 1111 | | 1309 |
| Cow Milk | 981 | 1020 | 1820 |
| Goat Milk | 1487 | | 1515 |
| Sheep Milk | 1604 | | 3237 |
| Pig | 3455 | | 5424 |
| Poultry | 3177 | | 2900 |
| Poultry Meat | 3624 | 3900 | 3468 |
| Sheep | 4973 | | 3134 |

*Table 6-14 Comparison of the uWF world averages (*

Firstly there is a discrepancy between the values calculated using the WaterStat database and those reported in (Mekonnen and Hoekstra, 2010), in particular when considering cattle meat: the uWF reported in the paper is approximately 15000 $\frac{m^3}{ton}$, very similar to that calculated with the data obtained with this analysis, but one third larger than that calculated from the data in the database.

The virtual water content of the eggs calculated here is about double that of WaterStat (4377 $\frac{m^3}{ton}$); a similar result is also observed in the case of sheep's and cow's milk. Higher average values (with an increase between 16 and 50% depending on the product considered) are also observed in the case of cattle and cattle meat, buffalo meat and milk, goat meat and pig meat.

Finally, considering goat and its products (meat and milk), poultry, poultry meat, and goat milk, the relative world average water footprints are approximately equal if calculated with the two different methods.

As done so far, nationwide results are shown concerning four products:

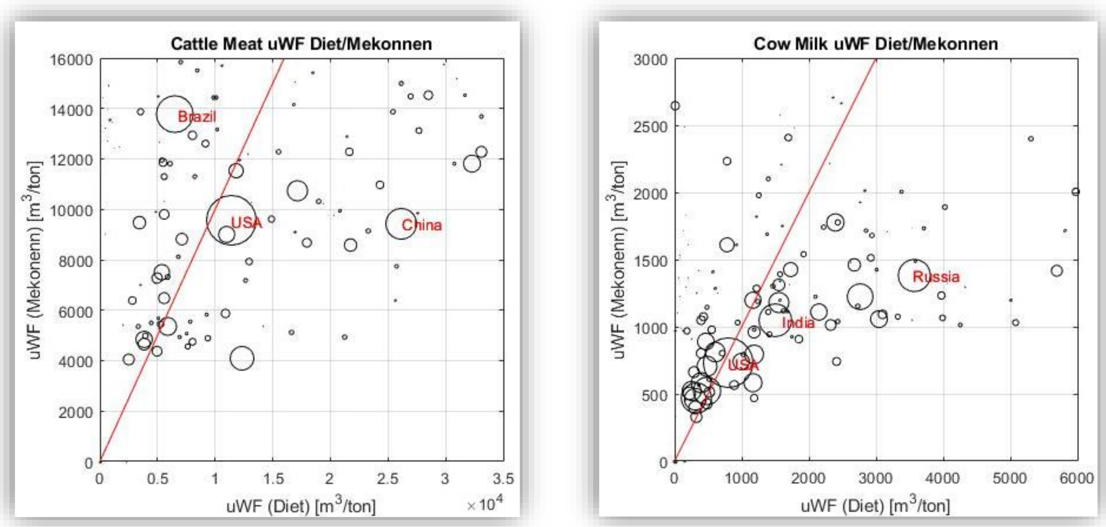



*Figure 6.27 Comparison with WaterStat database – Cattle meat and cow milk*

Scatter plots in Figure 6.27 show the comparison between the uWF provided by the WaterStat dataset and the values obtained in the present thesis. The size of each circle is proportional to the national production of the study animal in year 2000. In the case of cattle meat and cow milk, in the case of the USA there is a good correlation, while significant differences are also observed for large producers. The water footprint of cattle meat in Brazil is lesser if calculated with the method proposed in the work, while for China it is greater; with regard to milk, on the other hand, by focusing on large producers, there is a smaller difference between the two databases.

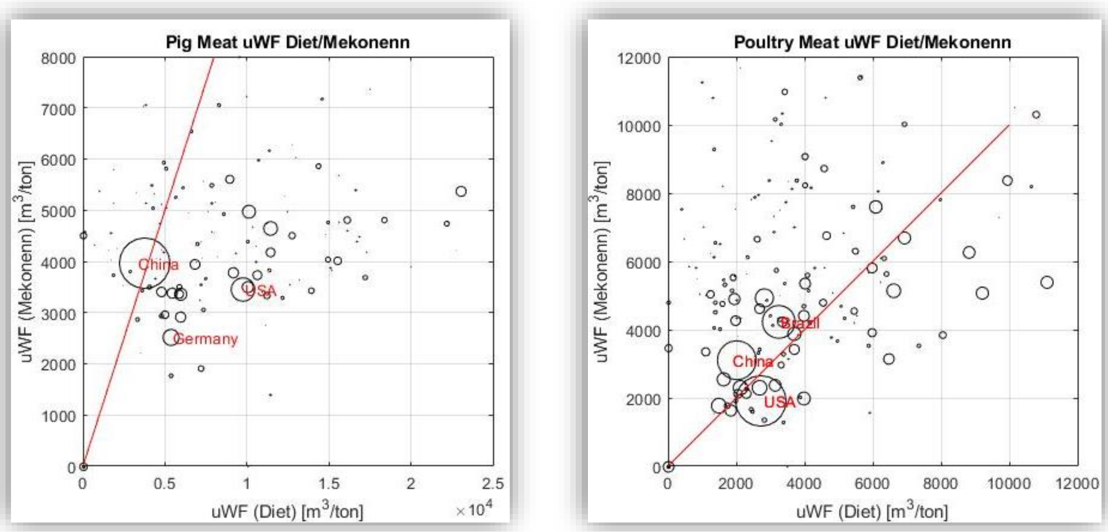



*Figure 6.28 Comparison with WaterStat database – Pig meat and poultry meat*

The water footprint of chicken meat is very similar for the major producers, while there is a lot of variability in smaller countries; however, on average the world average value, as previously observed, is about the same. A bigger estimate in the national unit water footprints of pig meat occurs if our model is used compared to that relating to the WaterStat database; it is interesting however to note that in the case of China, there is not a big difference and both methods calculate the same value.

The reason why these differences are observed, and in general for those which distinguish the two methods under analysis, are the following:

- Time effect: as repeatedly stressed, thanks to the enormous amount of data available, in particular crop yields and uWFs, this work produced results that varied over time, between 1986 and 2016; on the contrary, the results proposed in the database are obtained by averaging the input data used over 10 years;
- Composition of the diet: when the previous study was carried out, there was no dataset with global coverage on the composition of feed. For this reason, a worldwide and time constant valid diet was used for each animal category, calculated considering different assumptions based on animal production and feed conversion efficiencies; this study, on the other hand, is based on the database described in 3.1.3 which increases its resolution and accuracy;
- uWF of feed: as regards the crops, the water footprint was obtained from that of the WaterStat database and modified as described in 3.2; for this reason, for the year 2000 there are no substantial differences. On the contrary, as regards grass, there are

differences which cannot be ignored: in (Mekonnen and Hoekstra, 2010) only the water footprints for some countries are shown, which are considerably lower when compared with those used here. This is the main reason why, for many products, the water footprint of this work is greater than that of the database related to the cited paper;

- Methodology: this analysis uses animal yields to calculate the uWF of derivative products; on the contrary, the results proposed in the database are calculated by correcting the water footprint of the animals with the production and value factors.

However, for several reasons, a comparison between the two methods cannot be done in a systematic and precise manner. As a matter of fact, as previously described, the difference in the uWF calculation methods of derivative products is such that yields cannot be compared with the corrective factors (both productive and economic ones). Referring to two different concepts, this impossibility is also due to the fact that yields are expressed in $\frac{kg}{ton}$, while the corrective factors are dimensionless. In addition, a further difficulty is due to the classification of derivative products used in (Mekonnen and Hoekstra, 2010) in order to define the two corrective factors: often this classification is not of immediate association with that used in this work.

# 7. DISCUSSION

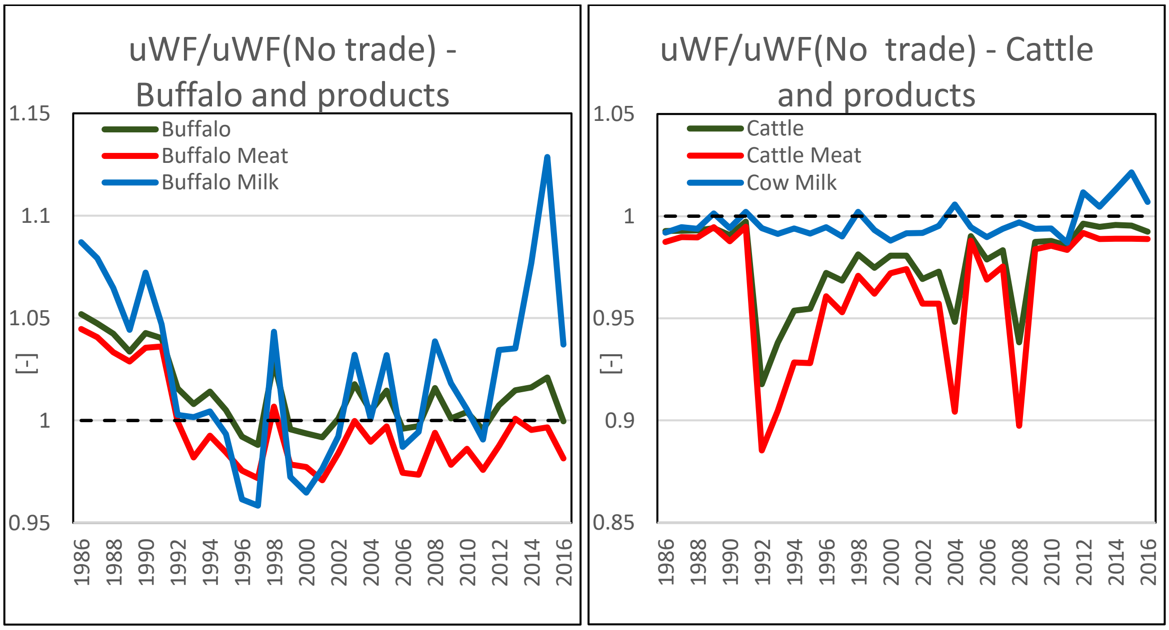
So far, the results obtained have been presented and commented, analyzing first the worldwide averaged values and subsequently carrying out more in-depth considerations on a national scale for some animal products. Attention was also focused on the use of blue water and on the temporal evolution of the water footprint and above all the volumes consumed.

In this chapter, on the other hand, we want to analyze the effect that the trade of crops has on the unit water footprint of animals and their derived products. In fact, it is necessary to consider that a portion of feed with which the animals are raised is imported from other nations, which are characterized by different water footprints. In order to do this, a hypothetical scenario was considered, in which the feed given to the animals comes entirely from national production.

The results obtained are described below, with analysis on a global, national and regional scale.

### *7.1.1. Comparison between the scenarios – Global scale*

To quantify the order of magnitude that differentiates the results obtained with and without feed trade, the ratio of the world averages of the water footprints of the products calculated in the two scenarios was assessed, and the results are shown in Figure 7.1.



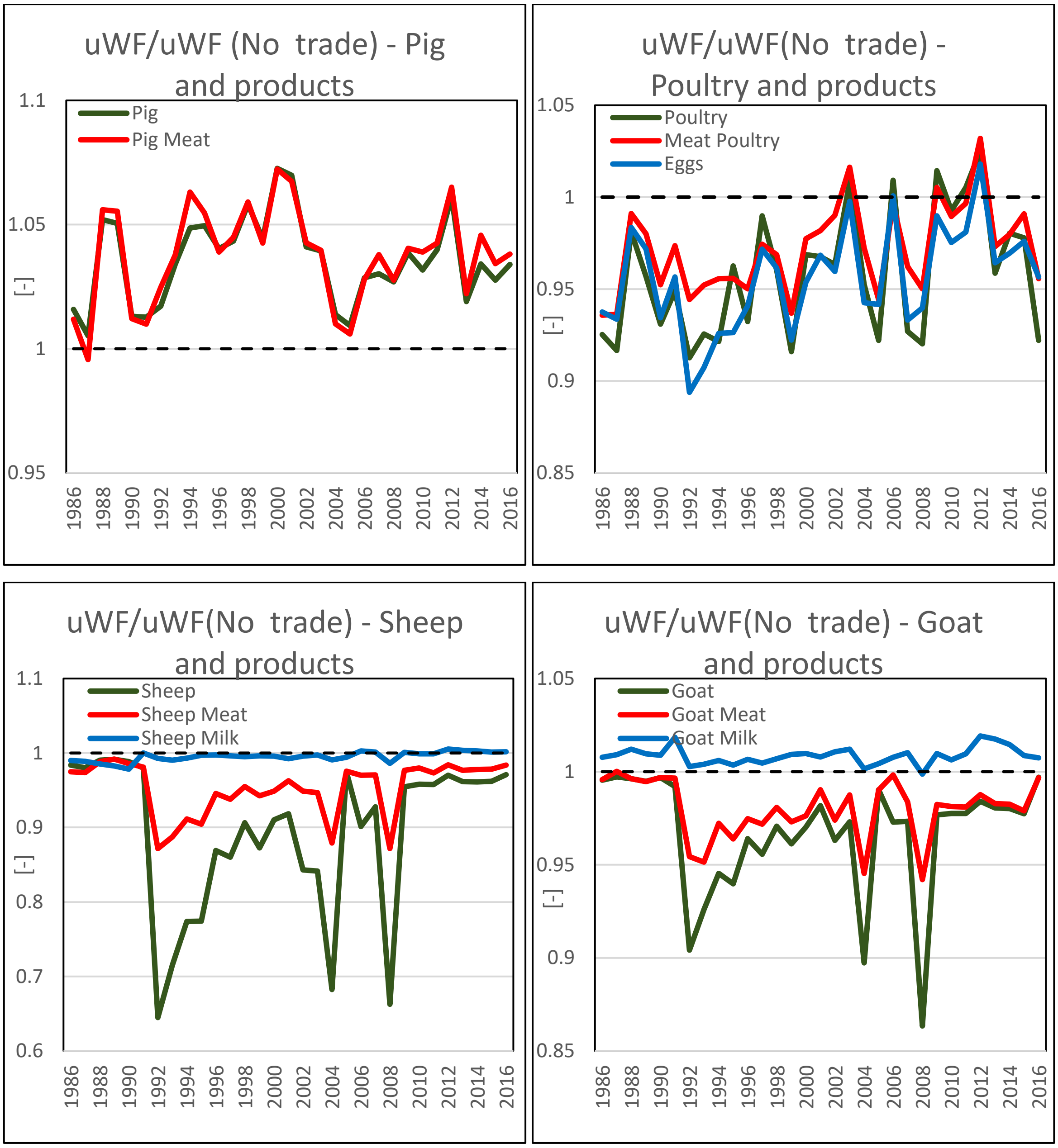



*Figure 7.1 Time series of the ratio between the unit water footprints calculated in the two scenarios*

from what emerges from the graphs, it can be said that the trade does not have a big effect in terms of water footprint of the products considered, since the calculated ratio is rarely distant from the unit: the most evident cases are those of sheep's, goat's and cow's milk, therefore, in particular for sheep, the ratio has always remained equal to one in the thirty years analyzed. The case of pigs is singular, since it is observed that without trade, less water would be needed to produce the same quantities.

In general a fluctuation of the calculated ratio is always observed, with peaks that are temporally localized in 1992, 2004 and 2008: this phenomenon can be explained by the evolution of trade between nations, especially in years of particular drought or production crisis, in which the increase in imported quantities is reflected in changes in the water footprint.

It should also be emphasized that animals and products often have the same trend (the case of pigs and their meat is very evident); the cases in which the trend is different are those that refer to a different diet (as in the case of milk, produced only from dairy herds).

It is important to also analyze the effect of the trade from the point of view of volumetric water consumption, quantifying the water difference between the two scenarios. For this purpose, only two products were analyzed in detail, poultry meat and pig meat. The results are quite consistent with the trend of the ratio between the water footprints calculated with the two scenarios. Excluding a couple of years in which, due to the feed trade, more water is used to produce chicken meat, for the whole time period analyzed the trade reduces consumption. On average, 5 billion are saved by importing feed from other countries, with peaks of around 10 billion (Figure 7.2). The volumes, although significant, represent only a small part of the total ones (averagely, only 2%).

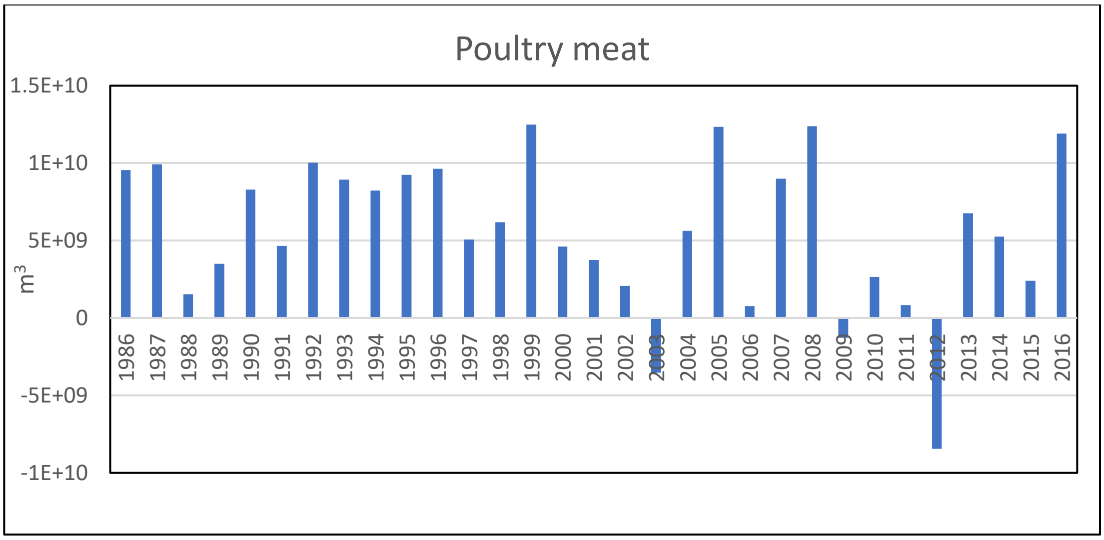



*Figure 7.2 Difference in water consumption for poultry meat production between the two scenarios*

on the contrary, as noted, the trade of the animal feed increases the quantities of water needed to produce pork. The difference between the two scenarios is very low as about the previous product, which is why also in this case the volumes quantified in Figure 7.2 represent only about 4% of all the water used. On average, 2 billion cubic meters are 'lost' due to the feed trade.

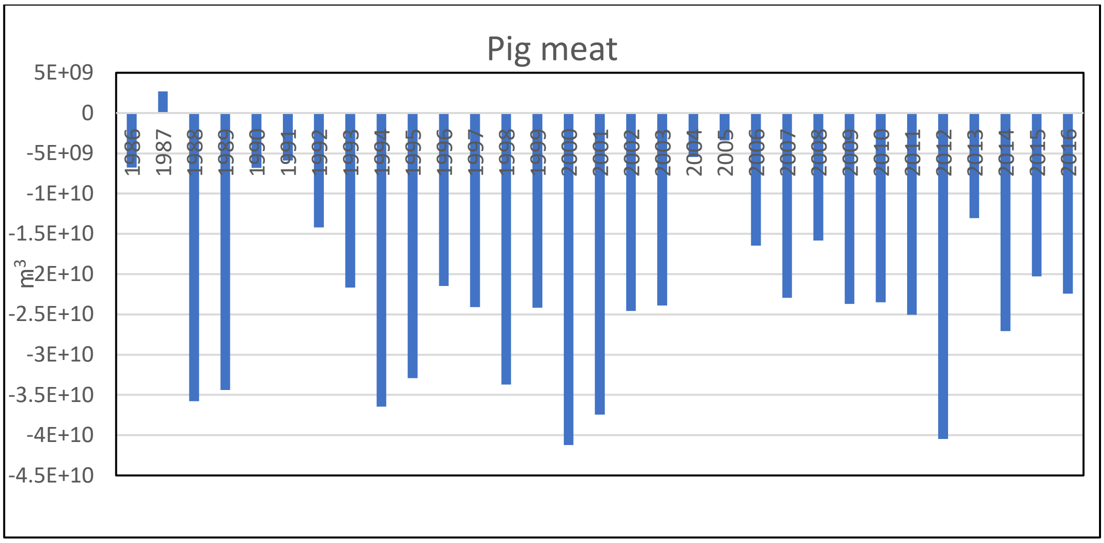



*Figure 7.3 Difference in water consumption for pig meat production between the two scenarios*

### *7.1.2. Analysis on a country scale*

Once again, a more detailed analysis was carried out regarding the goods produced the most, analyzing the results on a national scale, taking the first and last of those considered as reference years.

In the following graphs the three major producers have been highlighted in red, while in blue you can appreciate the countries with a not negligible production which present the greatest differences in terms of virtual water content calculated with or without crop trade. In this chapter the differences between the uWF in the different countries (which are even more evident in a graphic way) will not be underlined as it has already been discussed in the Chapter 6.2.

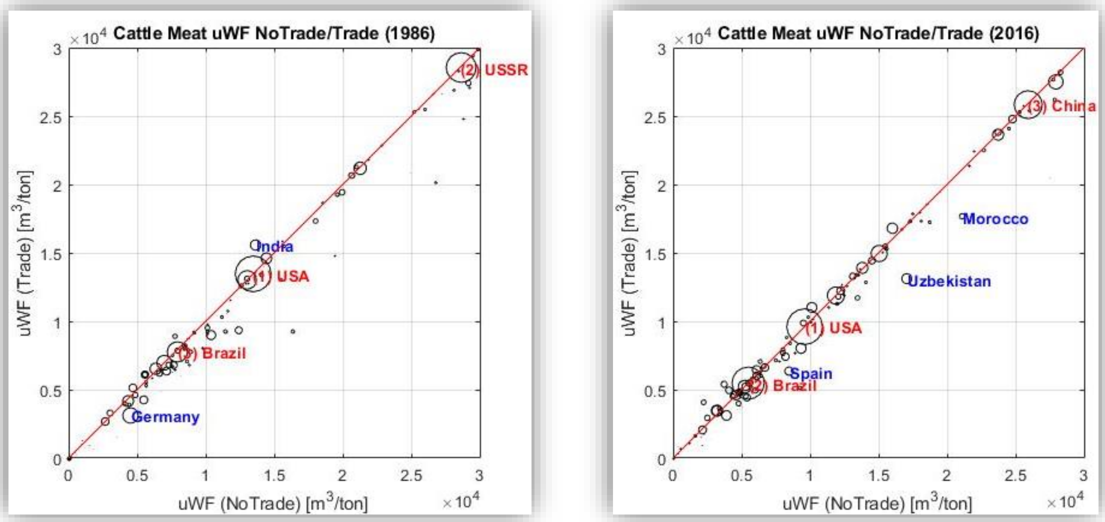



*Figure 7.4 uWFs of cattle meat in 1986 and 2016 with two scenarios*

In the case of cattle meat (Figure 7.4) and cow milk (Figure 7.5) it can be observed that the crop trade does not have a significant impact on the relative water footprint: the main reason is that the cattle diet is composed of a very high percentage of grass, which is not traded, limiting the effects of the crop trade. The biggest differences in cattle meat uWF are observed in 2016, in countries where the percentage exported compared to that produced domestically is greater, like Uzbekistan and Morocco.

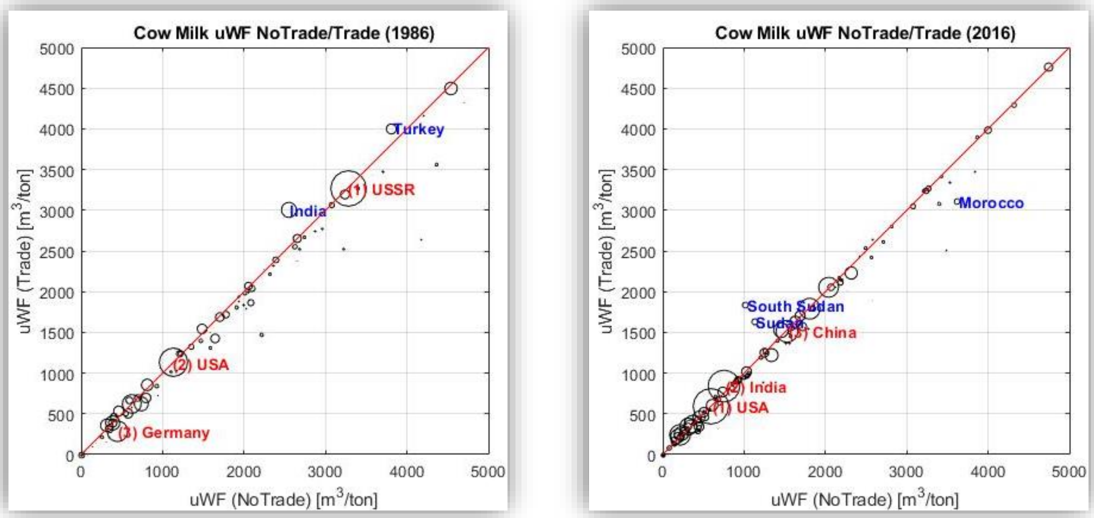



*Figure 7.5 uWFs of cow milk in 1986 and 2016 with two scenarios*

As regards milk, the differences are even less marked, and among those with the greatest differences there is (as for meat) Morocco, as well as Sudan.

As regards pigs and chickens, these are bred only with grains, which is why the effect of the trade has a more significant effect on the unit water footprint of the products. It is observed, however, that for the major producers the water efficiency is affected to a very limited extent by the variation in the water footprint of the ingredients making up the diet. These countries (which are often USA, China, sometimes Brazil, and the USSR before 1992) import crops in a more limited way, as their national production is very high: the major producers of animal products are often those with a high agricultural production.

In 2016 nations with an appreciable pork production, but highly dependent on grains trade, are Guinea and South Korea, for which the trade increases water efficiency, and Thailand, which instead due to the composition of its commercial network needs more virtual water in reality than the hypothetical case of using crops that come entirely from local production.

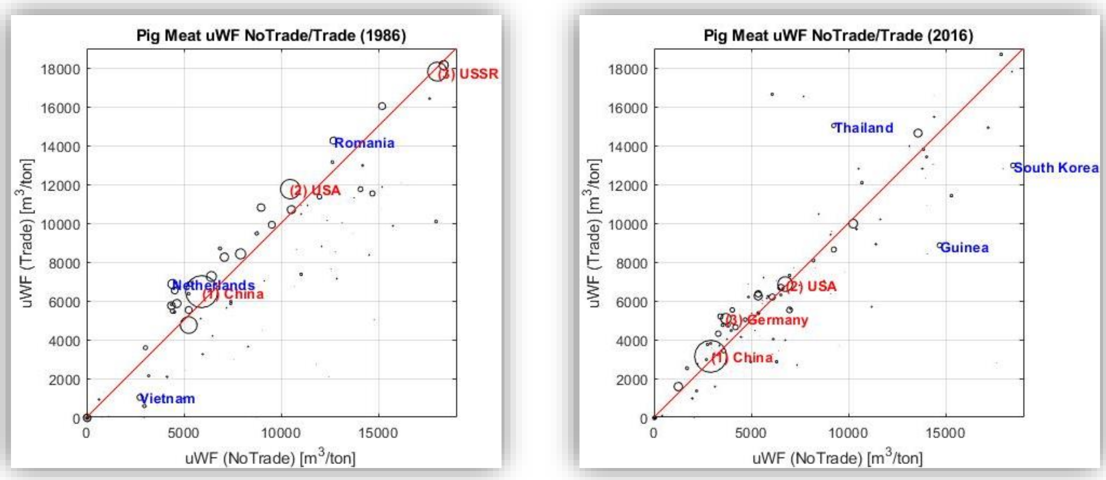



*Figure 7.6 uWFs of pig meat in 1986 and 2016 with two scenarios*

Finally, by analyzing the water footprints of poultry meat, the same behavior as pork is observed; it is interesting to note that Thailand in 1986 produced the aforementioned product more efficiently with the trade, but the evolution of the commercial network meant that in 2016 the situation reversed. Other countries are highlighted with a high production and the positive effect that the trade has (Pakistan and Colombia).

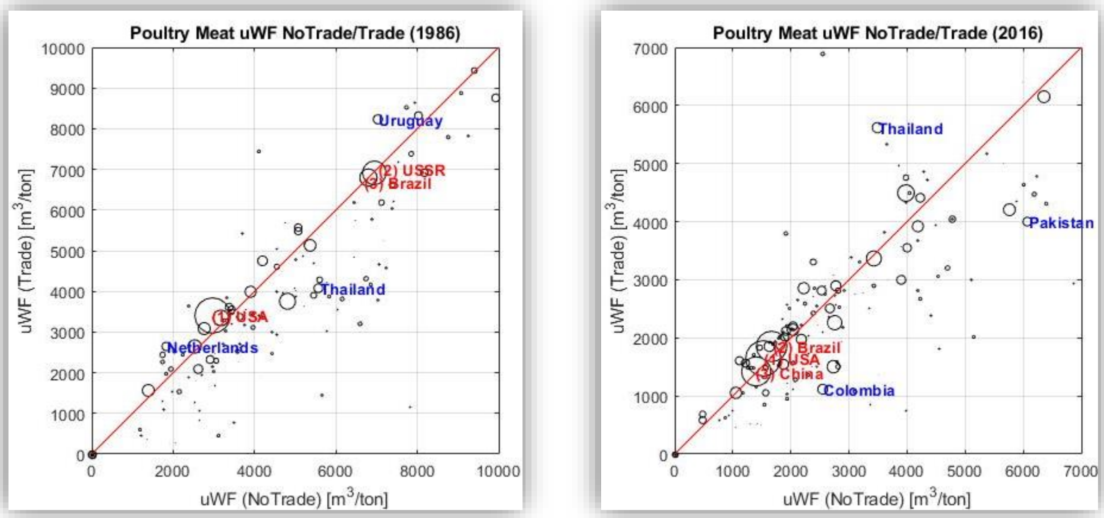



*Figure 7.7 uWFs of poultry meat in 1986 and 2016 with two scenarios*

### *7.1.3. uWF on a macro reginal scale*

Finally, as the last analysis carried out in this work, the unit water footprint of the four products was calculated on a macro regional scale, in 1986 and 2016. In this way it was possible to investigate the hypothetical presence of the effect of the trade on a scale larger than the national one, in addition to analyzing the variation of the water footprint between regions.

In general, as already observed in Chapter 6.2.1, it is confirmed that the countries that need a greater quantity of water are concentrated in Africa (MNA and SSA regions); Europe is an often efficient region, while Oceania and the Indian subcontinent (SAS region) have a variable behavior depending on the products. Moreover, the effect of the trade is not very visible in the case of cattle meat and pig meat, while it is more appreciable for pig meat and poultry meat.

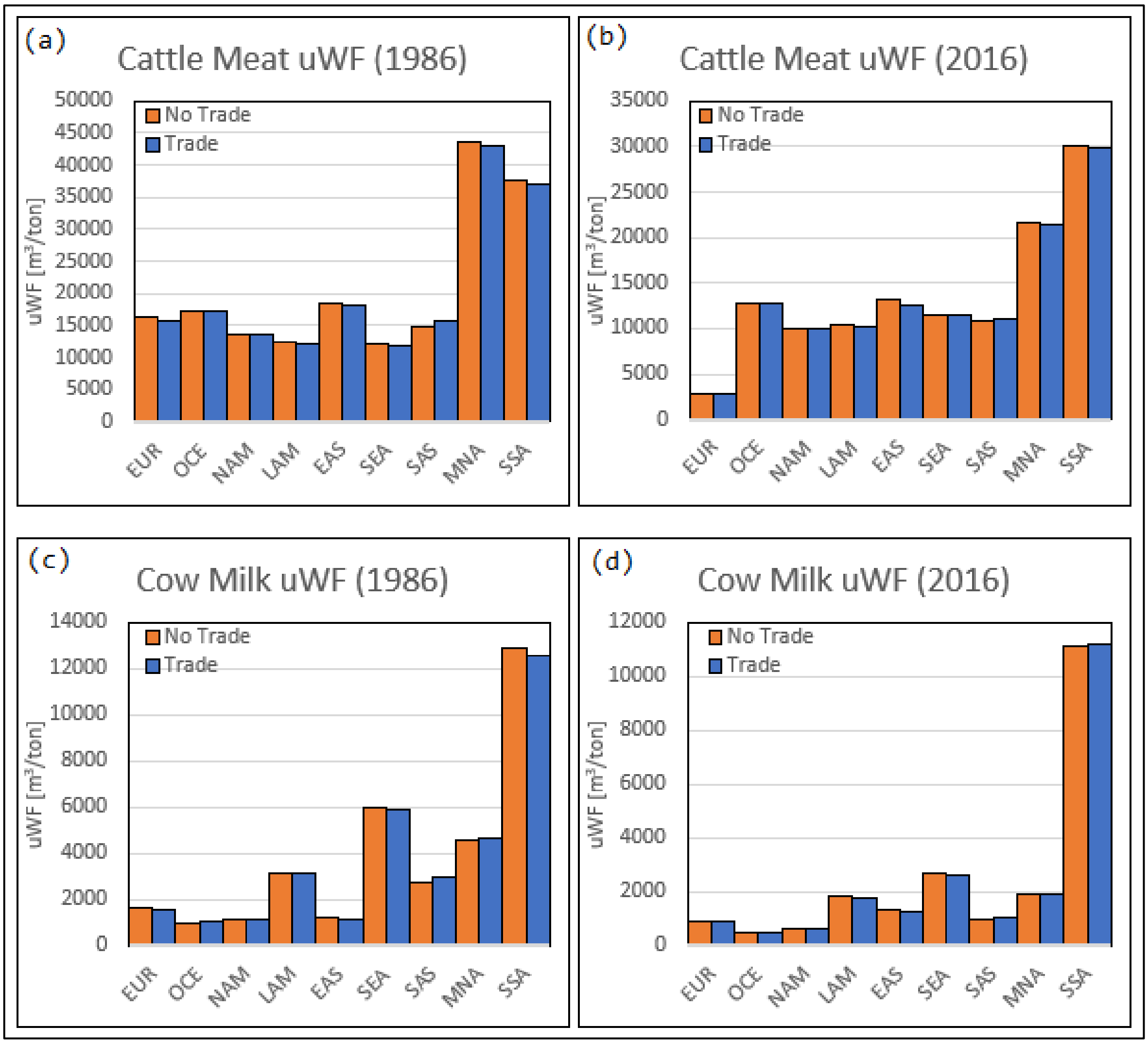



*Figure 7.8 uWF of (a)(b) cattle meat and (c)(d) cow milk on a macro-regional scale in (a)(c) 1986 and (b)(d) 2016*

Europe has developed a significant improvement in water efficiency of cattle meat production over time, significantly reducing the uWF; the same thing happens in the MNA region, but the value is still very high; in SSA region the water footprint is the highest.

On the contrary, in order to produce cow's milk in the region, a unit water footprint which is only twice as high as that of the most efficient regions is needed, while in SSA the value is 10 times greater than that of Europe. High values are also found in SEA and LAM regions, especially in 1986, while in 2016 they stood at values similar to those of MNA region (2000 $\frac{m^3}{ton}$).

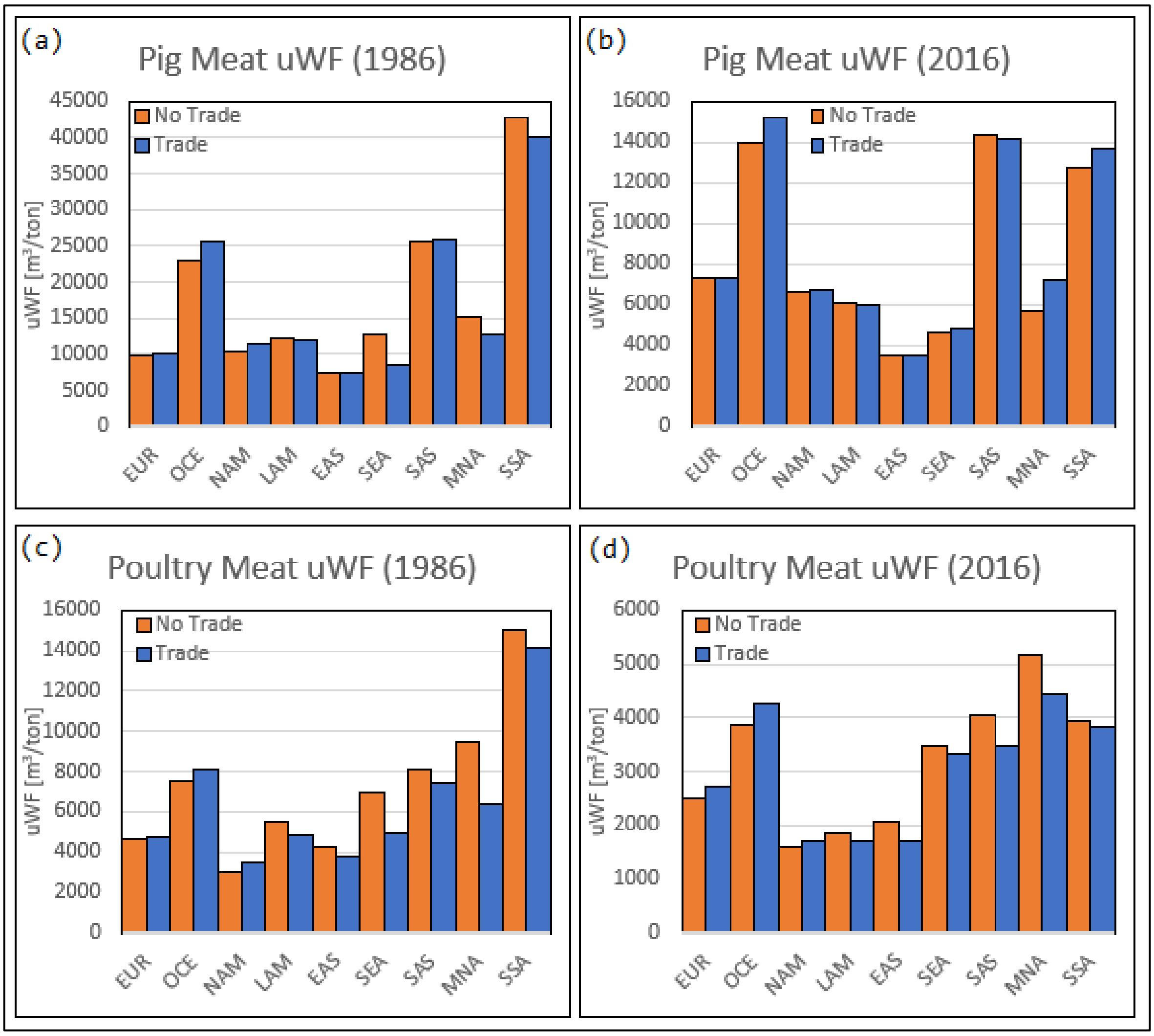



*Figure 7.9 uWF of (a)(b) pig meat and (c)(d) poultry meat on a macro-regional scale in (a)(c) 1986 and (b)(d) 2016*

About pork and chickens, it is observed that the trade increases the average unit water footprint in Oceania and, to a lesser extent, in Europe. In SSA the trade went from playing a positive role to a negative one between 1986 and 2016.

The nations that use the most water to produce pork are concentrated in SSA, SAS and Oceania; however the general improvement in efficiency in the first two regions was faster than that in Oceania, so much so that in 2016 the average water footprint in the three regions is approximately equal and is approximately equal to 1400 $\frac{m^3}{ton}$.

NAM, LAM and EAS regions are the ones where the uWF of chicken meat is lower (less than 2000 $\frac{m^3}{ton}$); Europe uses 2500 $\frac{m^3}{ton}$ in 2016, while the less efficient regions are, once again, Oceania and SSA region.

# CONCLUSIONS

The investigation of the water footprint of farm animal products is definitely important because agriculture and livestock are the sectors that consume most of the water used by mankind to complete their production cycle (about 70% of the resource according to statistics provided by the FAO). In addition, the simultaneous growth of the world population and the spread of protein and meat-based diets give rise to the need for more water to meet the demand of the world population. Moreover, the research adds another level of accuracy with respect to the analyzes carried out and the results proposed in (Mekonnen and Hoekstra, 2010) and relating to the year 2000, according to which for example, about 15000 liters are needed to produce a ton of cattle meat while pig meat is produced with 5400 $\frac{m^3}{ton}$.

The objective of this work is the assessment of the uWF of farm animal products. The research has been focused on the period 1986-2016 and the evaluation has been accomplished on a country-scale using a number of inputs from different databases. The adopted methodology allowed to obtain the unit and total water footprint of each product, split into its blue and green component.

The data used is this study were obtained from different databases, and for this reason a great pre-elaboration of the data has been required in order to guarantee coherence between different sources. Such elaboration allowed us to obtain an integrated database of uWF of crops, diet compositions, yields of animal products, corrective factors, and international trade flows of feed ingredients. All information is reported on a national scale, with the exception of the composition of the diet, which has been provided on a regional scale. Moreover, all the data are variable over the period considered, except for the diet composition and the water footprint of the grass, which have been kept constant. The method provides that the evaluation of the unitary water footprint is carried out by combining the collected data, calculating the water that the animals 'eat' by consuming the feed with which they are raised. The gray component of the WF and the water used for watering and for services, such as washing, have been excluded from the calculation as they have little impact on the final value.

Firstly, the results obtained in this work were compared with those of previous studies, confirming their validity, although there are dissimilarities due to the different accuracy of the input data used. For example, on average, according to the estimates proposed in this research, in year 2000 a ton of pig meat was produced with 6950 $m^3$, while to produce poultry meat they needed 3470 $\frac{m^3}{ton}$. Analyzing the final results, it can be said that the improvement in yields (both the agricultural and the zootechnical ones) has allowed a general decrease in the unit water footprint of all the derived animal products.

By studying the phenomenon on a more detailed scale, it is observed that the countries with the highest water footprint are concentrated in Africa and in developing regions: this aspect is not to be underestimated, as it is in these countries that in the coming decades there will be the greatest increase in population and the volumes of water consumed will be significantly greater. In terms of irrigation water (blue water), this does not vary considerably over time, and it always represents a low percentage of total water.

In addition, this study has allowed to bring to light an interesting about the feed trade, which in general slightly reduces the unit water footprint, but does not affect it; this statement is particularly true for the major countries with high production, in which high quantities of grains are cultivated at the same time, for which the imported quantities are limited or even zero, and on the contrary they are large exporters. For these countries the role of trade is negligible. On the contrary, for other small-medium producers the role of trade is beneficial when they succeed in importing products for feed from countries having relatively lower unit water footprint.

However, this phenomenon is opposed to the growth of the world population, so the increase in goods needed for human needs is responsible for an increase in the volumes of water used to produce most of the goods.

As already said, it's clear that the database obtained is of considerable use thanks to its spatial and temporal variability. It provided useful information on which countries are the most water efficient, and which nations have adopted the best production techniques obtaining high reductions in water consumption over time. in this way, it is possible to do the groundwork for further reducing the water footprint in countries where it is still above the world average. Anyway, even more precise databases can be used in order to carry out the same analysis conducted here and complete them with considerations on the variability that characterizes each individual nation. In particular, the unit water footprint database with high spatial resolution (cell scale) could be implemented (CWASI database), as well as temporal variability of the feed composition with possibly a higher spatial resolution should be considered. For the latter, however, research is currently not available in the literature.

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FAOSTAT website (http://www.fao.org/faostat/en/#data) http://www.fao.org/faostat/en/
WaterStat website (https://waterfootprint.org/en/resources/waterstat/)

# APPENDICES

## *uWFs of buffalo products, on a country scale, years 1986 and 2016*

| [m$^3$/ton] | Buffalo | | Buffalo Meat | | Buffalo Milk | |
|---|---|---|---|---|---|---|
| | 1986 | 2016 | 1986 | 2016 | 1986 | 2016 |
| Afghanistan | 15746 | 15107 | 0 | 0 | 0 | 0 |
| Albania | 6922 | 6582 | 0 | 0 | 5523 | 4705 |
| Algeria | 32581 | 32339 | 0 | 0 | 0 | 0 |
| American Samoa | 0 | 0 | 0 | 0 | 0 | 0 |
| Andorra | 5703 | 2516 | 0 | 0 | 0 | 0 |
| Angola | 11933 | 11852 | 0 | 0 | 0 | 0 |
| Anguilla | 0 | 0 | 0 | 0 | 0 | 0 |
| Antarctica | 0 | 0 | 0 | 0 | 0 | 0 |
| Antigua and Barbuda | 0 | 0 | 0 | 0 | 0 | 0 |
| Argentina | 8738 | 8618 | 0 | 0 | 0 | 0 |
| Armenia | 0 | 17715 | 0 | 0 | 0 | 0 |
| Aruba | 0 | 0 | 0 | 0 | 0 | 0 |
| Australia | 12696 | 12622 | 0 | 0 | 0 | 0 |
| Austria | 5197 | 4821 | 0 | 0 | 0 | 0 |
| Azerbaijan | 0 | 12343 | 0 | 0 | 0 | 0 |
| Bahamas | 6783 | 6773 | 0 | 0 | 0 | 0 |
| Bahrain | 1972 | 1442 | 0 | 0 | 0 | 0 |
| Bangladesh | 3032 | 2061 | 6291 | 3993 | 1808 | 1612 |
| Barbados | 929 | 551 | 0 | 0 | 0 | 0 |
| Belarus | 0 | 6073 | 0 | 0 | 0 | 0 |
| Belgium | 0 | 2885 | 0 | 0 | 0 | 0 |
| Belgium-Luxembourg | 3360 | 0 | 0 | 0 | 0 | 0 |
| Belize | 6651 | 6494 | 0 | 0 | 0 | 0 |
| Benin | 11859 | 11829 | 0 | 0 | 0 | 0 |
| Bermuda | 0 | 0 | 0 | 0 | 0 | 0 |
| Bhutan | 18127 | 17960 | 36254 | 36090 | 4769 | 1868 |
| Bolivia, Plurinational State of | 7504 | 7402 | 0 | 0 | 0 | 0 |
| Bosnia and Herzegovina | 0 | 10394 | 0 | 0 | 0 | 0 |
| Botswana | 51102 | 51114 | 0 | 0 | 0 | 0 |
| Bouvet Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Brazil | 4603 | 4314 | 0 | 0 | 0 | 0 |
| British Indian Ocean Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| British Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Brunei Darussalam | 6013 | 5947 | 11692 | 9457 | 10777 | 2034 |
| Bulgaria | 8976 | 8723 | 16978 | 26559 | 2390 | 3155 |
| Burkina Faso | 11750 | 11657 | 0 | 0 | 0 | 0 |
| Burundi | 4803 | 4593 | 0 | 0 | 0 | 0 |
| Cambodia | 3281 | 3148 | 6561 | 6295 | 0 | 0 |
| Cameroon | 10734 | 10725 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Canada | 11767 | 11316 | 0 | 0 | 0 | 0 |
| Canton and Enderbury Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Cape Verde | 285 | 762 | 0 | 0 | 0 | 0 |
| Cayman Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Central African Republic | 13838 | 13841 | 0 | 0 | 0 | 0 |
| Chad | 27483 | 25375 | 0 | 0 | 0 | 0 |
| Chile | 6557 | 6142 | 0 | 0 | 0 | 0 |
| China, Hong Kong SAR | 0 | 0 | 0 | 0 | 0 | 0 |
| China, Macao SAR | 0 | 0 | 0 | 0 | 0 | 0 |
| China, Mainland | 17017 | 16766 | 35782 | 36978 | 8617 | 7277 |
| China, Taiwan Province of | 0 | 0 | 0 | 0 | 0 | 0 |
| Christmas Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Cocos Islands (Keeling) | 0 | 0 | 0 | 0 | 0 | 0 |
| Colombia | 2542 | 2164 | 0 | 0 | 0 | 0 |
| Comoros | 70 | 284 | 0 | 0 | 0 | 0 |
| Congo | 8455 | 8451 | 0 | 0 | 0 | 0 |
| Congo, Democratic Republic of the | 10565 | 10566 | 0 | 0 | 0 | 0 |
| Cook Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Costa Rica | 2460 | 2374 | 0 | 0 | 0 | 0 |
| Cote de Ivoire | 11875 | 11247 | 0 | 0 | 0 | 0 |
| Croatia | 0 | 9513 | 0 | 0 | 0 | 0 |
| Cuba | 4134 | 3895 | 0 | 0 | 0 | 0 |
| Cyprus | 6574 | 5932 | 0 | 0 | 0 | 0 |
| Czech Republic | 0 | 4684 | 0 | 0 | 0 | 0 |
| Czechoslovakia | 5231 | 0 | 0 | 0 | 0 | 0 |
| Denmark | 3533 | 3081 | 0 | 0 | 0 | 0 |
| Djibouti | 247 | 345 | 0 | 0 | 0 | 0 |
| Dominica | 414 | 292 | 0 | 0 | 0 | 0 |
| Dominican Republic | 6493 | 6306 | 0 | 0 | 0 | 0 |
| Ecuador | 3735 | 2655 | 0 | 0 | 0 | 0 |
| Egypt | 16285 | 16392 | 34818 | 13557 | 4611 | 3216 |
| El Salvador | 3082 | 2784 | 0 | 0 | 0 | 0 |
| Equatorial Guinea | 7497 | 7534 | 0 | 0 | 0 | 0 |
| Eritrea | 0 | 15849 | 0 | 0 | 0 | 0 |
| Estonia | 0 | 11252 | 0 | 0 | 0 | 0 |
| Ethiopia | 0 | 14563 | 0 | 0 | 0 | 0 |
| Falkland Islands (Malvinas) | 0 | 0 | 0 | 0 | 0 | 0 |
| Faroe Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Fiji | 48 | 66 | 0 | 0 | 0 | 0 |
| Finland | 13608 | 13071 | 0 | 0 | 0 | 0 |
| France | 5481 | 5206 | 0 | 0 | 0 | 0 |
| French Guiana | 0 | 0 | 0 | 0 | 0 | 0 |
| French Polynesia | 0 | 0 | 0 | 0 | 0 | 0 |
| French Southern and Antarctic Territories | 0 | 0 | 0 | 0 | 0 | 0 |
| Gabon | 8217 | 8213 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Gambia | 12539 | 11923 | 0 | 0 | 0 | 0 |
| Georgia | 0 | 12640 | 0 | 0 | 0 | 8465 |
| Germany | 2705 | 3539 | 0 | 0 | 0 | 0 |
| Ethiopia PDR | 14770 | 0 | 0 | 0 | 0 | 0 |
| Neutral Zone | 0 | 0 | 0 | 0 | 0 | 0 |
| Ghana | 9149 | 8994 | 0 | 0 | 0 | 0 |
| Gibraltar | 0 | 0 | 0 | 0 | 0 | 0 |
| Greece | 6657 | 6309 | 0 | 8480 | 5539 | 5090 |
| Greenland | 0 | 0 | 0 | 0 | 0 | 0 |
| Grenada | 403 | 295 | 0 | 0 | 0 | 0 |
| Guadeloupe | 0 | 0 | 0 | 0 | 0 | 0 |
| Guam | 0 | 0 | 0 | 0 | 0 | 0 |
| Guatemala | 3896 | 3981 | 0 | 0 | 0 | 0 |
| Guinea | 11849 | 12245 | 0 | 0 | 0 | 0 |
| Guinea-Bissau | 12189 | 12238 | 0 | 0 | 0 | 0 |
| Guyana | 2679 | 2311 | 0 | 0 | 0 | 0 |
| Haiti | 4903 | 4943 | 0 | 0 | 0 | 0 |
| Heard and McDonald Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Holy See | 0 | 0 | 0 | 0 | 0 | 0 |
| Honduras | 4193 | 3593 | 0 | 0 | 0 | 0 |
| Hungary | 0 | 0 | 0 | 0 | 0 | 0 |
| Iceland | 1181 | 964 | 0 | 0 | 0 | 0 |
| India | 4629 | 3661 | 10399 | 8199 | 1713 | 700 |
| Indonesia | 4550 | 4467 | 7362 | 6315 | 0 | 2360 |
| Iran, Islamic Republic of | 13635 | 13196 | 29827 | 16536 | 4190 | 3447 |
| Iraq | 12515 | 11183 | 27532 | 16882 | 3973 | 6348 |
| Ireland | 2554 | 2207 | 0 | 0 | 0 | 0 |
| Israel | 5731 | 5650 | 0 | 0 | 0 | 0 |
| Italy | 4203 | 3693 | 9229 | 6845 | 1804 | 3269 |
| Jamaica | 3978 | 3581 | 0 | 0 | 0 | 0 |
| Japan | 7345 | 6263 | 0 | 0 | 0 | 0 |
| Johnston Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Jordan | 11341 | 10285 | 0 | 0 | 0 | 0 |
| Kazakhstan | 0 | 22714 | 0 | 0 | 0 | 0 |
| Kenya | 17082 | 17089 | 0 | 0 | 0 | 0 |
| Kiribati | 0 | 0 | 0 | 0 | 0 | 0 |
| Korea, Democratic Peoples Republic of | 8958 | 8921 | 0 | 0 | 0 | 0 |
| Korea, Republic of | 5871 | 5132 | 0 | 0 | 0 | 0 |
| Kuwait | 5495 | 5580 | 0 | 0 | 0 | 0 |
| Kyrgyzstan | 0 | 21910 | 0 | 0 | 0 | 0 |
| Lao Peoples Democratic Republic | 10574 | 10525 | 19225 | 19102 | 0 | 0 |
| Latvia | 0 | 13500 | 0 | 0 | 0 | 0 |
| Lebanon | 6410 | 6798 | 0 | 0 | 0 | 0 |
| Lesotho | 16103 | 16044 | 0 | 0 | 0 | 0 |
| Liberia | 8363 | 8209 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Libya | 21725 | 21497 | 0 | 0 | 0 | 0 |
| Liechtenstein | 0 | 0 | 0 | 0 | 0 | 0 |
| Lithuania | 0 | 4493 | 0 | 0 | 0 | 0 |
| Luxembourg | 0 | 3451 | 0 | 0 | 0 | 0 |
| Macedonia | 0 | 9868 | 0 | 0 | 0 | 0 |
| Madagascar | 14745 | 14704 | 0 | 0 | 0 | 0 |
| Malawi | 14131 | 14113 | 0 | 0 | 0 | 0 |
| Malaysia | 4125 | 4072 | 7960 | 3167 | 1493 | 1154 |
| Maldives | 0 | 0 | 0 | 0 | 0 | 0 |
| Mali | 22301 | 21805 | 0 | 0 | 0 | 0 |
| Malta | 1311 | 1516 | 0 | 0 | 0 | 0 |
| Marshall Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Martinique | 0 | 0 | 0 | 0 | 0 | 0 |
| Mauritania | 28845 | 28810 | 0 | 0 | 0 | 0 |
| Mauritius | 80 | 79 | 0 | 0 | 0 | 0 |
| Mayotte | 0 | 0 | 0 | 0 | 0 | 0 |
| Mexico | 21251 | 20849 | 0 | 0 | 0 | 0 |
| Micronesia, Federated States of | 0 | 0 | 0 | 0 | 0 | 0 |
| Midway Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Moldova, Republic of | 0 | 6202 | 0 | 0 | 0 | 0 |
| Monaco | 0 | 0 | 0 | 0 | 0 | 0 |
| Mongolia | 23610 | 23504 | 0 | 0 | 0 | 0 |
| Montenegro | 0 | 1168 | 0 | 0 | 0 | 0 |
| Montserrat | 0 | 0 | 0 | 0 | 0 | 0 |
| Morocco | 15587 | 14455 | 0 | 0 | 0 | 0 |
| Mozambique | 37448 | 37417 | 0 | 0 | 0 | 0 |
| Myanmar | 3650 | 3563 | 6441 | 7346 | 4866 | 2798 |
| Namibia | 107394 | 107394 | 0 | 0 | 0 | 0 |
| Nauru | 0 | 0 | 0 | 0 | 0 | 0 |
| Nepal | 6206 | 5863 | 11255 | 9344 | 1627 | 1787 |
| Netherlands | 3541 | 3160 | 0 | 0 | 0 | 0 |
| Netherlands Antilles | 427 | 0 | 0 | 0 | 0 | 0 |
| New Caledonia | 0 | 0 | 0 | 0 | 0 | 0 |
| New Zealand | 3232 | 2937 | 0 | 0 | 0 | 0 |
| Nicaragua | 3368 | 3178 | 0 | 0 | 0 | 0 |
| Niger | 24905 | 23971 | 0 | 0 | 0 | 0 |
| Nigeria | 8903 | 8902 | 0 | 0 | 0 | 0 |
| Niue | 0 | 0 | 0 | 0 | 0 | 0 |
| Norfolk Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Northern Mariana Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Norway | 16405 | 15866 | 0 | 0 | 0 | 0 |
| Occupied Palestinian Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| Oman | 371 | 446 | 0 | 0 | 0 | 0 |
| Pacific Islands Trust Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| Pakistan | 7456 | 6123 | 16513 | 12757 | 1055 | 778 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Palau | 0 | 0 | 0 | 0 | 0 | 0 |
| Panama | 3410 | 3246 | 0 | 0 | 0 | 0 |
| Papua New Guinea | 6233 | 6171 | 0 | 0 | 0 | 0 |
| Paraguay | 6087 | 5598 | 0 | 0 | 0 | 0 |
| Peru | 5737 | 5312 | 0 | 0 | 0 | 0 |
| Philippines | 2241 | 2176 | 4873 | 3668 | 2542 | 0 |
| Pitcairn Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Poland | 5022 | 5496 | 0 | 0 | 0 | 0 |
| Portugal | 6437 | 3929 | 0 | 0 | 0 | 0 |
| Puerto Rico | 0 | 0 | 0 | 0 | 0 | 0 |
| Qatar | 536 | 607 | 0 | 0 | 0 | 0 |
| Reunion | 0 | 0 | 0 | 0 | 0 | 0 |
| Romania | 8827 | 8001 | 0 | 0 | 0 | 0 |
| Russian Federation | 0 | 20059 | 0 | 0 | 0 | 0 |
| Rwanda | 3273 | 3145 | 0 | 0 | 0 | 0 |
| Saint Helena, Ascension and Tristan da Cunha | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Kitts and Nevis | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Lucia | 238 | 366 | 0 | 0 | 0 | 0 |
| Saint Pierre and Miquelon | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Vincent and the Grenadines | 404 | 351 | 0 | 0 | 0 | 0 |
| Samoa | 0 | 0 | 0 | 0 | 0 | 0 |
| San Marino | 0 | 0 | 0 | 0 | 0 | 0 |
| Sao Tome and Principe | 0 | 0 | 0 | 0 | 0 | 0 |
| Saudi Arabia | 32248 | 32100 | 0 | 0 | 0 | 0 |
| Senegal | 14134 | 13889 | 0 | 0 | 0 | 0 |
| Serbia | 0 | 1121 | 0 | 0 | 0 | 0 |
| Serbia and Montenegro | 0 | 0 | 0 | 0 | 0 | 0 |
| Seychelles | 0 | 0 | 0 | 0 | 0 | 0 |
| Sierra Leone | 12715 | 14449 | 0 | 0 | 0 | 0 |
| Singapore | 130 | 89 | 284 | 0 | 0 | 0 |
| Slovakia | 0 | 7076 | 0 | 0 | 0 | 0 |
| Slovenia | 0 | 6241 | 0 | 0 | 0 | 0 |
| Solomon Islands | 0 | 15 | 0 | 0 | 0 | 0 |
| Somalia | 25094 | 25345 | 0 | 0 | 0 | 0 |
| South Africa | 22818 | 22719 | 0 | 0 | 0 | 0 |
| South Georgia and the South Sandwich Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Spain | 6770 | 5440 | 0 | 0 | 0 | 0 |
| Sri Lanka | 4809 | 4637 | 9617 | 9274 | 2702 | 1355 |
| Sudan (former) | 14527 | 0 | 0 | 0 | 0 | 0 |
| Suriname | 2585 | 2285 | 0 | 0 | 0 | 0 |
| Svalbard and Jan Mayen Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Swaziland | 9730 | 9966 | 0 | 0 | 0 | 0 |
| Sweden | 8590 | 8124 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Switzerland | 5825 | 5171 | 0 | 0 | 0 | 0 |
| Syrian Arab Republic | 12746 | 12079 | 25493 | 15343 | 2671 | 2405 |
| Tajikistan | 0 | 8185 | 0 | 0 | 0 | 0 |
| Tanzania, United Republic of | 11582 | 11565 | 0 | 0 | 0 | 0 |
| Thailand | 1563 | 1553 | 3126 | 2609 | 0 | 0 |
| Timor-Leste | 0 | 0 | 0 | 0 | 0 | 0 |
| Togo | 10662 | 10335 | 0 | 0 | 0 | 0 |
| Tokelau | 0 | 0 | 0 | 0 | 0 | 0 |
| Tonga | 0 | 0 | 0 | 0 | 0 | 0 |
| Trinidad and Tobago | 548 | 354 | 0 | 0 | 0 | 0 |
| Tunisia | 11694 | 9887 | 0 | 0 | 0 | 0 |
| Turkey | 16595 | 15276 | 36906 | 19429 | 5624 | 4737 |
| Turkmenistan | 0 | 36854 | 0 | 0 | 0 | 0 |
| Turks and Caicos Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Tuvalu | 0 | 0 | 0 | 0 | 0 | 0 |
| Uganda | 7457 | 7441 | 0 | 0 | 0 | 0 |
| Ukraine | 0 | 7105 | 0 | 0 | 0 | 0 |
| United Arab Emirates | 1036 | 507 | 0 | 0 | 0 | 0 |
| United Kingdom | 3625 | 3646 | 0 | 0 | 0 | 0 |
| United States Minor Is. | 0 | 0 | 0 | 0 | 0 | 0 |
| United States Of America | 11860 | 11385 | 0 | 0 | 0 | 0 |
| United States Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 | 0 |
| Uruguay | 4292 | 4150 | 0 | 0 | 0 | 0 |
| Ussr | 17852 | 0 | 0 | 0 | 0 | 0 |
| Uzbekistan | 0 | 8013 | 0 | 0 | 0 | 0 |
| Vanuatu | 230 | 192 | 0 | 0 | 0 | 0 |
| Venezuela, Bolivarian Republic of | 4155 | 3867 | 0 | 0 | 0 | 0 |
| Viet Nam | 2185 | 2160 | 4370 | 4257 | 1197 | 1035 |
| Wake Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Wallis and Futuna Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Western Sahara | 0 | 0 | 0 | 0 | 0 | 0 |
| Yemen | 36109 | 35700 | 0 | 0 | 0 | 0 |
| Sudan | 0 | 1903 | 0 | 0 | 0 | 0 |
| South Sudan | 0 | 2088 | 0 | 0 | 0 | 0 |
| Yugoslav SFR | 9646 | 0 | 0 | 0 | 0 | 0 |
| Zambia | 14532 | 14547 | 0 | 0 | 0 | 0 |
| Zimbabwe | 18392 | 18398 | 0 | 0 | 0 | 0 |

*uWFs of cattle products, on a country scale, years 1986 and 2016*

| [m³/ton] | Cattle | | Cattle Meat | | Cow Milk | |
|---|---|---|---|---|---|---|
| | 1986 | 2016 | 1986 | 2016 | 1986 | 2016 |
| Afghanistan | 21339 | 20473 | 38615 | 26160 | 10740 | 8110 |
| Albania | 11007 | 10467 | 26602 | 17268 | 1933 | 879 |
| Algeria | 31836 | 31599 | 70087 | 48486 | 10816 | 3983 |
| American Samoa | 0 | 0 | 0 | 0 | 0 | 0 |
| Andorra | 5057 | 2231 | 0 | 0 | 0 | 0 |
| Angola | 12398 | 12315 | 25441 | 22499 | 8290 | 7749 |
| Anguilla | 0 | 0 | 0 | 0 | 0 | 0 |
| Antarctica | 0 | 0 | 0 | 0 | 0 | 0 |
| Antigua and Barbuda | 0 | 0 | 0 | 0 | 0 | 0 |
| Argentina | 6930 | 6835 | 13050 | 11907 | 2658 | 1637 |
| Armenia | 0 | 20837 | 0 | 51461 | 0 | 3236 |
| Aruba | 0 | 0 | 0 | 0 | 0 | 0 |
| Australia | 9182 | 9129 | 21151 | 14943 | 1689 | 1021 |
| Austria | 2972 | 2757 | 6087 | 4518 | 659 | 337 |
| Azerbaijan | 0 | 20038 | 0 | 34412 | 0 | 3267 |
| Bahamas | 6041 | 6032 | 12437 | 12419 | 3595 | 3542 |
| Bahrain | 2561 | 1873 | 5122 | 3746 | 215 | 180 |
| Bangladesh | 3615 | 2457 | 7806 | 4493 | 3566 | 3079 |
| Barbados | 744 | 442 | 1665 | 840 | 185 | 148 |
| Belarus | 0 | 6268 | 0 | 9900 | 0 | 515 |
| Belgium | 0 | 1491 | 0 | 2945 | 0 | 221 |
| Belgium-Luxembourg | 1737 | 0 | 3331 | 0 | 461 | 0 |
| Belize | 6116 | 5971 | 13281 | 9917 | 3552 | 3632 |
| Benin | 16801 | 16760 | 33603 | 17830 | 28748 | 18305 |
| Bermuda | 0 | 0 | 0 | 0 | 0 | 0 |
| Bhutan | 18127 | 17960 | 36254 | 29643 | 7422 | 1366 |
| Bolivia, Plurinational State of | 6839 | 6746 | 13365 | 11789 | 4161 | 2164 |
| Bosnia and Herzegovina | 0 | 11612 | 0 | 15083 | 0 | 1399 |
| Botswana | 45510 | 45521 | 84100 | 79661 | 47071 | 11851 |
| Bouvet Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Brazil | 3756 | 3520 | 7773 | 5446 | 4493 | 1798 |
| British Indian Ocean Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| British Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Brunei Darussalam | 8418 | 8326 | 14030 | 10408 | 0 | 4579 |
| Bulgaria | 10209 | 9922 | 19237 | 25007 | 1321 | 1193 |
| Burkina Faso | 16648 | 16516 | 34552 | 38614 | 20023 | 26269 |
| Burundi | 5989 | 5726 | 11516 | 7090 | 4315 | 2505 |
| Cambodia | 4815 | 4620 | 8748 | 8394 | 7459 | 5527 |
| Cameroon | 11152 | 11144 | 29426 | 31185 | 6017 | 5029 |
| Canada | 6196 | 5958 | 14636 | 13909 | 1535 | 763 |
| Canton and Enderbury Islands | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cape Verde | 342 | 914 | 694 | 1531 | 209 | 421 |
| Cayman Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Central African Republic | 15404 | 15407 | 33178 | 27690 | 18462 | 16249 |
| Chad | 30270 | 27948 | 57882 | 66297 | 30971 | 76666 |
| Chile | 4129 | 3868 | 8163 | 7683 | 1980 | 1557 |
| China, Hong Kong SAR | 0 | 0 | 0 | 0 | 0 | 0 |
| China, Macao SAR | 0 | 0 | 0 | 0 | 0 | 0 |
| China, Mainland | 11679 | 11507 | 36761 | 25856 | 2392 | 1520 |
| China, Taiwan Province of | 0 | 0 | 0 | 0 | 0 | 0 |
| Christmas Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Cocos Islands (Keeling) | 0 | 0 | 0 | 0 | 0 | 0 |
| Colombia | 2037 | 1734 | 4280 | 3076 | 1857 | 1578 |
| Comoros | 100 | 403 | 199 | 806 | 136 | 84 |
| Congo | 8447 | 8443 | 16893 | 16885 | 4688 | 1733 |
| Congo, Democratic Republic of the | 10868 | 10869 | 22837 | 17957 | 3384 | 2788 |
| Cook Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Costa Rica | 1839 | 1775 | 3882 | 3218 | 1020 | 945 |
| Cote de Ivoire | 13509 | 12795 | 27018 | 32251 | 27215 | 35503 |
| Croatia | 0 | 7197 | 0 | 12629 | 0 | 799 |
| Cuba | 4505 | 4246 | 8058 | 7172 | 1396 | 1502 |
| Cyprus | 3509 | 3166 | 6290 | 5934 | 1027 | 544 |
| Czech Republic | 0 | 2797 | 0 | 4908 | 0 | 213 |
| Czechoslovakia | 3124 | 0 | 6834 | 0 | 506 | 0 |
| Denmark | 2202 | 1921 | 4588 | 3683 | 321 | 169 |
| Djibouti | 320 | 448 | 699 | 952 | 220 | 308 |
| Dominica | 359 | 253 | 717 | 507 | 114 | 107 |
| Dominican Republic | 3907 | 3794 | 10326 | 11302 | 2518 | 2424 |
| Ecuador | 2531 | 1799 | 7099 | 3979 | 509 | 809 |
| Egypt | 18790 | 18914 | 33294 | 14388 | 5112 | 3237 |
| El Salvador | 3021 | 2729 | 6431 | 5244 | 1841 | 544 |
| Equatorial Guinea | 10622 | 10674 | 21244 | 21348 | 0 | 0 |
| Eritrea | 0 | 23193 | 0 | 51459 | 0 | 31754 |
| Estonia | 0 | 13593 | 0 | 10165 | 0 | 522 |
| Ethiopia | 0 | 18157 | 0 | 41799 | 0 | 15448 |
| Falkland Islands (Malvinas) | 0 | 0 | 0 | 0 | 0 | 0 |
| Faroe Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Fiji | 40 | 54 | 79 | 305 | 101 | 128 |
| Finland | 9102 | 8743 | 21273 | 13384 | 1241 | 685 |
| France | 3279 | 3115 | 6956 | 5240 | 624 | 376 |
| French Guiana | 0 | 0 | 0 | 0 | 0 | 0 |
| French Polynesia | 0 | 0 | 0 | 0 | 0 | 0 |
| French Southern and Antarctic Territories | 0 | 0 | 0 | 0 | 0 | 0 |
| Gabon | 9665 | 9661 | 19404 | 19395 | 8891 | 1594 |
| Gambia | 16285 | 15485 | 32570 | 30971 | 20759 | 2477 |
| Georgia | 0 | 14071 | 0 | 54722 | 0 | 5279 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Germany | 1519 | 1988 | 3123 | 3476 | 285 | 240 |
| Ethiopia PDR | 18415 | 0 | 44394 | 0 | 20092 | 0 |
| Neutral Zone | 0 | 0 | 0 | 0 | 0 | 0 |
| Ghana | 12399 | 12189 | 24799 | 21319 | 22952 | 21738 |
| Gibraltar | 0 | 0 | 0 | 0 | 0 | 0 |
| Greece | 4894 | 4638 | 9259 | 8850 | 2220 | 705 |
| Greenland | 0 | 0 | 0 | 0 | 0 | 0 |
| Grenada | 414 | 303 | 830 | 577 | 250 | 128 |
| Guadeloupe | 0 | 0 | 0 | 0 | 0 | 0 |
| Guam | 0 | 0 | 0 | 0 | 0 | 0 |
| Guatemala | 3355 | 3428 | 6703 | 6707 | 3476 | 2794 |
| Guinea | 14773 | 15267 | 33883 | 31517 | 20947 | 16297 |
| Guinea-Bissau | 21107 | 21191 | 34538 | 34677 | 21535 | 2645 |
| Guyana | 2626 | 2265 | 6033 | 3593 | 3423 | 2055 |
| Haiti | 5458 | 5503 | 10755 | 9941 | 12521 | 11970 |
| Heard and McDonald Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Holy See | 0 | 0 | 0 | 0 | 0 | 0 |
| Honduras | 4507 | 3862 | 9071 | 6022 | 2770 | 1456 |
| Hungary | 0 | 0 | 0 | 0 | 0 | 0 |
| Iceland | 1628 | 1329 | 3217 | 1548 | 217 | 113 |
| India | 7000 | 5535 | 15598 | 11017 | 2999 | 840 |
| Indonesia | 4049 | 3976 | 7890 | 6598 | 1993 | 1005 |
| Iran, Islamic Republic of | 17044 | 16495 | 53027 | 12241 | 6000 | 1251 |
| Iraq | 16926 | 15124 | 37544 | 17358 | 5298 | 5341 |
| Ireland | 1301 | 1124 | 2650 | 2039 | 394 | 246 |
| Israel | 2703 | 2664 | 6790 | 5585 | 211 | 134 |
| Italy | 3422 | 3006 | 6521 | 4608 | 851 | 461 |
| Jamaica | 2844 | 2560 | 5851 | 4789 | 2376 | 2008 |
| Japan | 3193 | 2723 | 6369 | 4420 | 694 | 344 |
| Johnston Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Jordan | 11404 | 10341 | 39279 | 13340 | 2267 | 519 |
| Kazakhstan | 0 | 23919 | 0 | 40737 | 0 | 4754 |
| Kenya | 20558 | 20567 | 43430 | 24776 | 10854 | 7971 |
| Kiribati | 0 | 0 | 0 | 0 | 0 | 0 |
| Korea, Democratic Peoples Republic of | 9628 | 9588 | 18615 | 18538 | 1121 | 1207 |
| Korea, Republic of | 3660 | 3200 | 9561 | 4973 | 842 | 323 |
| Kuwait | 4798 | 4872 | 10579 | 6581 | 513 | 255 |
| Kyrgyzstan | 0 | 18260 | 0 | 38453 | 0 | 5471 |
| Lao Peoples Democratic Republic | 16267 | 16192 | 25478 | 16706 | 11068 | 1533 |
| Latvia | 0 | 14974 | 0 | 22370 | 0 | 875 |
| Lebanon | 5217 | 5532 | 14801 | 10271 | 719 | 529 |
| Lesotho | 20078 | 20004 | 33463 | 32988 | 17178 | 3473 |
| Liberia | 10426 | 10235 | 20853 | 20470 | 20715 | 1899 |
| Libya | 16929 | 16752 | 33858 | 32976 | 5864 | 6108 |
| Liechtenstein | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Lithuania | 0 | 5149 | 0 | 5828 | 0 | 308 |
| Luxembourg | 0 | 1784 | 0 | 2941 | 0 | 243 |
| Macedonia | 0 | 18094 | 0 | 24846 | 0 | 1248 |
| Madagascar | 18384 | 18333 | 36046 | 35947 | 18110 | 16409 |
| Malawi | 11012 | 10998 | 21806 | 40396 | 9876 | 8935 |
| Malaysia | 4813 | 4750 | 12733 | 4547 | 3195 | 1853 |
| Maldives | 0 | 0 | 0 | 0 | 0 | 0 |
| Mali | 26735 | 26141 | 52383 | 52282 | 27635 | 38331 |
| Malta | 933 | 1079 | 1554 | 1710 | 159 | 110 |
| Marshall Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Martinique | 0 | 0 | 0 | 0 | 0 | 0 |
| Mauritania | 33055 | 33015 | 64221 | 71554 | 25363 | 6371 |
| Mauritius | 63 | 61 | 140 | 91 | 36 | 69 |
| Mayotte | 0 | 0 | 0 | 0 | 0 | 0 |
| Mexico | 17250 | 16923 | 33455 | 27524 | 3188 | 2236 |
| Micronesia, Federated States of | 0 | 0 | 0 | 0 | 0 | 0 |
| Midway Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Moldova, Republic of | 0 | 6137 | 0 | 12660 | 0 | 676 |
| Monaco | 0 | 0 | 0 | 0 | 0 | 0 |
| Mongolia | 27666 | 27542 | 50131 | 54470 | 20284 | 15618 |
| Montenegro | 0 | 1035 | 0 | 1729 | 0 | 109 |
| Montserrat | 0 | 0 | 0 | 0 | 0 | 0 |
| Morocco | 16195 | 15018 | 29006 | 17641 | 9384 | 3110 |
| Mozambique | 40250 | 40217 | 77816 | 116629 | 71349 | 9486 |
| Myanmar | 4761 | 4647 | 9125 | 4785 | 2673 | 2109 |
| Namibia | 83687 | 83686 | 154333 | 126034 | 84040 | 76908 |
| Nauru | 0 | 0 | 0 | 0 | 0 | 0 |
| Nepal | 13433 | 12692 | 26867 | 25384 | 3865 | 2543 |
| Netherlands | 2469 | 2204 | 5141 | 4963 | 357 | 224 |
| Netherlands Antilles | 378 | 0 | 886 | 0 | 154 | 0 |
| New Caledonia | 0 | 0 | 0 | 0 | 0 | 0 |
| New Zealand | 2963 | 2692 | 6105 | 6479 | 538 | 347 |
| Nicaragua | 3608 | 3404 | 6426 | 5864 | 2310 | 2607 |
| Niger | 28229 | 27170 | 71547 | 82928 | 30398 | 21501 |
| Nigeria | 8235 | 8233 | 19393 | 23796 | 11829 | 11593 |
| Niue | 0 | 0 | 0 | 0 | 0 | 0 |
| Norfolk Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Northern Mariana Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Norway | 10903 | 10545 | 25314 | 17328 | 1228 | 894 |
| Occupied Palestinian Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| Oman | 445 | 534 | 890 | 1068 | 23 | 14 |
| Pacific Islands Trust Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| Pakistan | 5422 | 4453 | 13158 | 8062 | 2039 | 1224 |
| Palau | 0 | 0 | 0 | 0 | 0 | 0 |
| Panama | 2952 | 2811 | 5296 | 4663 | 1878 | 1370 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Papua New Guinea | 6476 | 6412 | 12953 | 12823 | 19245 | 22268 |
| Paraguay | 5499 | 5058 | 9282 | 7438 | 2734 | 2149 |
| Peru | 6387 | 5914 | 13034 | 11718 | 3263 | 1796 |
| Philippines | 2073 | 2013 | 5529 | 3422 | 712 | 306 |
| Pitcairn Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Poland | 6115 | 6692 | 9006 | 5969 | 628 | 339 |
| Portugal | 4540 | 2771 | 9281 | 5092 | 1464 | 291 |
| Puerto Rico | 0 | 0 | 0 | 0 | 0 | 0 |
| Qatar | 696 | 789 | 1392 | 1577 | 39 | 53 |
| Reunion | 0 | 0 | 0 | 0 | 0 | 0 |
| Romania | 11094 | 10056 | 17325 | 15347 | 1711 | 909 |
| Russian Federation | 0 | 22572 | 0 | 31278 | 0 | 2052 |
| Rwanda | 4436 | 4262 | 9810 | 10978 | 1790 | 1536 |
| Saint Helena, Ascension and Tristan da Cunha | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Kitts and Nevis | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Lucia | 203 | 312 | 408 | 626 | 232 | 107 |
| Saint Pierre and Miquelon | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Vincent and the Grenadines | 345 | 300 | 696 | 501 | 125 | 93 |
| Samoa | 0 | 0 | 0 | 0 | 0 | 0 |
| San Marino | 0 | 0 | 0 | 0 | 0 | 0 |
| Sao Tome and Principe | 0 | 0 | 0 | 0 | 0 | 0 |
| Saudi Arabia | 26245 | 26124 | 70737 | 50028 | 6453 | 1259 |
| Senegal | 17622 | 17317 | 35244 | 24052 | 11459 | 21024 |
| Serbia | 0 | 994 | 0 | 1595 | 0 | 81 |
| Serbia and Montenegro | 0 | 0 | 0 | 0 | 0 | 0 |
| Seychelles | 0 | 0 | 0 | 0 | 0 | 0 |
| Sierra Leone | 22018 | 25021 | 44036 | 43725 | 16139 | 3346 |
| Singapore | 109 | 74 | 186 | 62 | 0 | 0 |
| Slovakia | 0 | 5252 | 0 | 8753 | 0 | 384 |
| Slovenia | 0 | 4036 | 0 | 6380 | 0 | 405 |
| Solomon Islands | 0 | 13 | 0 | 26 | 0 | 37 |
| Somalia | 34007 | 34349 | 71106 | 71820 | 18825 | 20732 |
| South Africa | 18190 | 18111 | 33266 | 23645 | 3061 | 2059 |
| South Georgia and the South Sandwich Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Spain | 4443 | 3570 | 9300 | 6320 | 1428 | 458 |
| Sri Lanka | 4010 | 3867 | 8014 | 7683 | 2644 | 891 |
| Sudan (former) | 20867 | 0 | 27443 | 31734 | 8953 | 11772 |
| Suriname | 2941 | 2599 | 4889 | 3572 | 1825 | 1114 |
| Svalbard and Jan Mayen Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Swaziland | 7021 | 7191 | 12727 | 13812 | 11941 | 10884 |
| Sweden | 5250 | 4965 | 12547 | 7931 | 697 | 424 |
| Switzerland | 4975 | 4416 | 8897 | 7024 | 463 | 282 |
| Syrian Arab Republic | 12746 | 12079 | 25493 | 17256 | 1310 | 979 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tajikistan | 0 | 8890 | 0 | 11867 | 0 | 3897 |
| Tanzania, United Republic of | 17525 | 17498 | 34981 | 36228 | 20938 | 16180 |
| Thailand | 2173 | 2158 | 3954 | 6220 | 582 | 238 |
| Timor-Leste | 0 | 0 | 0 | 0 | 0 | 0 |
| Togo | 13293 | 12886 | 26587 | 25771 | 15356 | 2434 |
| Tokelau | 0 | 0 | 0 | 0 | 0 | 0 |
| Tonga | 0 | 0 | 0 | 0 | 0 | 0 |
| Trinidad and Tobago | 496 | 321 | 983 | 731 | 140 | 302 |
| Tunisia | 10414 | 8805 | 20149 | 12814 | 2519 | 960 |
| Turkey | 16376 | 15073 | 42341 | 16760 | 4005 | 1527 |
| Turkmenistan | 0 | 36584 | 0 | 63536 | 0 | 9618 |
| Turks and Caicos Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Tuvalu | 0 | 0 | 0 | 0 | 0 | 0 |
| Uganda | 7498 | 7481 | 15496 | 15493 | 5193 | 4292 |
| Ukraine | 0 | 8264 | 0 | 13318 | 0 | 610 |
| United Arab Emirates | 673 | 330 | 1292 | 633 | 473 | 52 |
| United Kingdom | 2077 | 2089 | 4194 | 3464 | 382 | 251 |
| United States Minor Is. | 0 | 0 | 0 | 0 | 0 | 0 |
| United States Of America | 6859 | 6584 | 13438 | 9648 | 1128 | 598 |
| United States Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 | 0 |
| Uruguay | 3034 | 2933 | 6837 | 5185 | 1803 | 919 |
| Ussr | 20088 | 0 | 28535 | 0 | 3270 | 0 |
| Uzbekistan | 0 | 7829 | 0 | 13097 | 0 | 1706 |
| Vanuatu | 160 | 133 | 400 | 313 | 4043 | 3409 |
| Venezuela, Bolivarian Republic of | 3113 | 2898 | 6209 | 5507 | 2549 | 3049 |
| Viet Nam | 3404 | 3366 | 7469 | 4828 | 1496 | 366 |
| Wake Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Wallis and Futuna Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Western Sahara | 0 | 0 | 0 | 0 | 0 | 0 |
| Yemen | 65821 | 65075 | 123685 | 122284 | 19653 | 19731 |
| Sudan | 0 | 2733 | 0 | 5436 | 0 | 1634 |
| South Sudan | 0 | 2999 | 0 | 4050 | 0 | 1835 |
| Yugoslav SFR | 6833 | 0 | 20635 | 0 | 2064 | 0 |
| Zambia | 14659 | 14674 | 28310 | 28163 | 15632 | 3414 |
| Zimbabwe | 15969 | 15974 | 29859 | 25307 | 14226 | 13695 |

***uWFs of sheep products, on a country scale, years 1986 and 2016***

| [m$^3$/ton] | Sheep | | Sheep Meat | | Sheep Milk | |
|---|---|---|---|---|---|---|
| | 1986 | 2016 | 1986 | 2016 | 1986 | 2016 |
| Afghanistan | 4050 | 3887 | 8092 | 7766 | 4680 | 4717 |
| Albania | 3146 | 3027 | 8606 | 4281 | 1364 | 821 |
| Algeria | 8718 | 8644 | 19374 | 16663 | 7504 | 10495 |
| American Samoa | 0 | 0 | 0 | 0 | 0 | 0 |
| Andorra | 1139 | 399 | 0 | 0 | 0 | 0 |
| Angola | 1619 | 1433 | 5281 | 3112 | 0 | 0 |
| Anguilla | 0 | 0 | 0 | 0 | 0 | 0 |
| Antarctica | 0 | 0 | 0 | 0 | 0 | 0 |
| Antigua and Barbuda | 0 | 0 | 0 | 0 | 0 | 0 |
| Argentina | 2602 | 2484 | 5172 | 4100 | 0 | 0 |
| Armenia | 0 | 3517 | 0 | 7957 | 0 | 1119 |
| Aruba | 0 | 0 | 0 | 0 | 0 | 0 |
| Australia | 3626 | 3577 | 7655 | 5961 | 0 | 0 |
| Austria | 1179 | 1063 | 2791 | 2053 | 217 | 136 |
| Azerbaijan | 0 | 2080 | 0 | 5281 | 0 | 959 |
| Bahamas | 1359 | 926 | 2913 | 1985 | 0 | 0 |
| Bahrain | 332 | 246 | 664 | 492 | 53 | 54 |
| Bangladesh | 1092 | 911 | 2307 | 1951 | 252 | 317 |
| Barbados | 618 | 406 | 1325 | 346 | 0 | 0 |
| Belarus | 0 | 792 | 0 | 2044 | 0 | 0 |
| Belgium | 0 | 662 | 0 | 1404 | 0 | 0 |
| Belgium-Luxembourg | 786 | 0 | 1513 | 0 | 0 | 0 |
| Belize | 1144 | 983 | 2136 | 1336 | 0 | 0 |
| Benin | 5588 | 5781 | 11175 | 11563 | 0 | 0 |
| Bermuda | 0 | 0 | 0 | 0 | 0 | 0 |
| Bhutan | 4353 | 4253 | 9575 | 9356 | 0 | 0 |
| Bolivia, Plurinational State of | 3115 | 2900 | 6062 | 4725 | 4980 | 4542 |
| Bosnia and Herzegovina | 0 | 3490 | 0 | 5424 | 0 | 1383 |
| Botswana | 8131 | 8905 | 13938 | 15266 | 0 | 0 |
| Bouvet Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Brazil | 1723 | 1501 | 3231 | 2815 | 0 | 0 |
| British Indian Ocean Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| British Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Brunei Darussalam | 1488 | 1303 | 0 | 2260 | 0 | 0 |
| Bulgaria | 2167 | 2079 | 5313 | 7054 | 1276 | 901 |
| Burkina Faso | 7419 | 7509 | 16693 | 22527 | 0 | 2130 |
| Burundi | 1594 | 1385 | 3321 | 2886 | 4002 | 2435 |
| Cambodia | 763 | 314 | 0 | 0 | 0 | 0 |
| Cameroon | 2998 | 3024 | 5996 | 6719 | 3274 | 3174 |
| Canada | 2151 | 2045 | 4490 | 3780 | 0 | 0 |
| Canton and Enderbury Islands | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cape Verde | 80 | 93 | 249 | 309 | 0 | 0 |
| Cayman Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Central African Republic | 3193 | 3204 | 6385 | 6408 | 0 | 0 |
| Chad | 6969 | 6935 | 14672 | 15497 | 13027 | 9821 |
| Chile | 2176 | 2016 | 3679 | 3862 | 0 | 0 |
| China, Hong Kong SAR | 0 | 0 | 0 | 0 | 0 | 0 |
| China, Macao SAR | 0 | 0 | 0 | 0 | 0 | 0 |
| China, Mainland | 1501 | 1217 | 2692 | 1644 | 4015 | 3439 |
| China, Taiwan Province of | 0 | 0 | 0 | 0 | 0 | 0 |
| Christmas Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Cocos Islands (Keeling) | 0 | 0 | 0 | 0 | 0 | 0 |
| Colombia | 1042 | 722 | 1967 | 1344 | 0 | 0 |
| Comoros | 90 | 659 | 180 | 1318 | 0 | 0 |
| Congo | 2582 | 2566 | 5681 | 5645 | 0 | 0 |
| Congo, Democratic Republic of the | 3230 | 3215 | 7035 | 7003 | 0 | 0 |
| Cook Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Costa Rica | 662 | 428 | 1456 | 942 | 0 | 0 |
| Cote de Ivoire | 4581 | 4492 | 7047 | 6371 | 0 | 0 |
| Croatia | 0 | 3579 | 0 | 6479 | 0 | 1180 |
| Cuba | 766 | 507 | 1531 | 774 | 0 | 0 |
| Cyprus | 1604 | 1502 | 3709 | 3077 | 760 | 666 |
| Czech Republic | 0 | 537 | 0 | 1366 | 0 | 822 |
| Czechoslovakia | 1406 | 0 | 2927 | 0 | 607 | 0 |
| Denmark | 629 | 555 | 1153 | 1137 | 0 | 0 |
| Djibouti | 126 | 231 | 255 | 467 | 0 | 0 |
| Dominica | 748 | 585 | 1603 | 1253 | 0 | 0 |
| Dominican Republic | 1374 | 1115 | 2290 | 1843 | 0 | 0 |
| Ecuador | 845 | 515 | 3013 | 1838 | 1130 | 995 |
| Egypt | 2363 | 2381 | 5167 | 4031 | 4083 | 2505 |
| El Salvador | 800 | 509 | 1600 | 1019 | 0 | 0 |
| Equatorial Guinea | 2201 | 2312 | 4401 | 4624 | 0 | 0 |
| Eritrea | 0 | 9144 | 0 | 19202 | 0 | 3088 |
| Estonia | 0 | 2203 | 0 | 3342 | 0 | 0 |
| Ethiopia | 0 | 5553 | 0 | 11106 | 0 | 3174 |
| Falkland Islands (Malvinas) | 0 | 0 | 0 | 0 | 0 | 0 |
| Faroe Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Fiji | 5739 | 2968 | 0 | 3906 | 0 | 0 |
| Finland | 3145 | 3046 | 8540 | 6700 | 0 | 0 |
| France | 1538 | 1443 | 2957 | 2744 | 398 | 256 |
| French Guiana | 0 | 0 | 0 | 0 | 0 | 0 |
| French Polynesia | 0 | 0 | 0 | 0 | 0 | 0 |
| French Southern and Antarctic Territories | 0 | 0 | 0 | 0 | 0 | 0 |
| Gabon | 2014 | 2010 | 4364 | 4355 | 0 | 0 |
| Gambia | 5797 | 6032 | 11593 | 12064 | 0 | 0 |
| Georgia | 0 | 2842 | 0 | 4223 | 0 | 1815 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Germany | 615 | 842 | 1195 | 1165 | 0 | 0 |
| Ethiopia PDR | 5770 | 0 | 11540 | 0 | 4250 | 0 |
| Neutral Zone | 0 | 0 | 0 | 0 | 0 | 0 |
| Ghana | 3528 | 3485 | 7056 | 4458 | 0 | 0 |
| Gibraltar | 0 | 0 | 0 | 0 | 0 | 0 |
| Greece | 3415 | 3283 | 6528 | 6684 | 1204 | 921 |
| Greenland | 0 | 0 | 0 | 0 | 0 | 0 |
| Grenada | 574 | 231 | 1192 | 330 | 0 | 0 |
| Guadeloupe | 0 | 0 | 0 | 0 | 0 | 0 |
| Guam | 0 | 0 | 0 | 0 | 0 | 0 |
| Guatemala | 967 | 821 | 1933 | 1640 | 0 | 0 |
| Guinea | 4216 | 4304 | 8783 | 6853 | 5270 | 1810 |
| Guinea-Bissau | 6424 | 6478 | 12205 | 12308 | 4695 | 1546 |
| Guyana | 1332 | 743 | 2664 | 1486 | 0 | 0 |
| Haiti | 1107 | 1061 | 2215 | 1657 | 0 | 0 |
| Heard and McDonald Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Holy See | 0 | 0 | 0 | 0 | 0 | 0 |
| Honduras | 1612 | 987 | 3225 | 1973 | 0 | 0 |
| Hungary | 0 | 0 | 0 | 0 | 0 | 0 |
| Iceland | 286 | 235 | 579 | 423 | 0 | 0 |
| India | 2202 | 1550 | 4036 | 2841 | 0 | 1977 |
| Indonesia | 2293 | 1981 | 4814 | 4623 | 2533 | 2804 |
| Iran, Islamic Republic of | 3600 | 3507 | 8100 | 4208 | 4014 | 5027 |
| Iraq | 3218 | 2952 | 6837 | 4031 | 1868 | 5132 |
| Ireland | 595 | 511 | 1068 | 1017 | 0 | 0 |
| Israel | 1245 | 1228 | 2628 | 2065 | 377 | 503 |
| Italy | 3086 | 2754 | 5798 | 4111 | 792 | 759 |
| Jamaica | 591 | 361 | 1656 | 671 | 0 | 0 |
| Japan | 1651 | 1286 | 3048 | 2348 | 0 | 0 |
| Johnston Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Jordan | 3378 | 3034 | 6996 | 9165 | 1681 | 2203 |
| Kazakhstan | 0 | 2257 | 0 | 2942 | 0 | 2469 |
| Kenya | 5336 | 5369 | 11117 | 10168 | 6507 | 3532 |
| Kiribati | 0 | 0 | 0 | 0 | 0 | 0 |
| Korea, Democratic Peoples Republic of | 847 | 843 | 1860 | 1852 | 0 | 0 |
| Korea, Republic of | 841 | 699 | 1801 | 1498 | 0 | 0 |
| Kuwait | 973 | 980 | 2806 | 2809 | 531 | 193 |
| Kyrgyzstan | 0 | 2127 | 0 | 1789 | 0 | 2590 |
| Lao Peoples Democratic Republic | 637 | 351 | 0 | 0 | 0 | 0 |
| Latvia | 0 | 2643 | 0 | 6167 | 0 | 0 |
| Lebanon | 1001 | 1042 | 2276 | 1974 | 405 | 880 |
| Lesotho | 652 | 1190 | 2919 | 3494 | 0 | 0 |
| Liberia | 3115 | 3137 | 6230 | 6274 | 0 | 0 |
| Libya | 6883 | 6796 | 12389 | 12232 | 5090 | 5743 |
| Liechtenstein | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Lithuania | 0 | 904 | 0 | 3088 | 0 | 0 |
| Luxembourg | 0 | 780 | 0 | 1663 | 0 | 0 |
| Macedonia | 0 | 2026 | 0 | 4936 | 0 | 1044 |
| Madagascar | 2192 | 1951 | 4526 | 4046 | 0 | 0 |
| Malawi | 2510 | 2365 | 4469 | 5468 | 0 | 1465 |
| Malaysia | 1730 | 1597 | 2721 | 798 | 0 | 0 |
| Maldives | 0 | 0 | 0 | 0 | 0 | 0 |
| Mali | 9595 | 9668 | 21142 | 20110 | 9591 | 11414 |
| Malta | 539 | 643 | 1113 | 1225 | 133 | 108 |
| Marshall Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Martinique | 0 | 0 | 0 | 0 | 0 | 0 |
| Mauritania | 11157 | 11757 | 22313 | 23513 | 7462 | 11726 |
| Mauritius | 403 | 460 | 444 | 400 | 0 | 0 |
| Mayotte | 0 | 0 | 0 | 0 | 0 | 0 |
| Mexico | 6412 | 6192 | 12665 | 9907 | 0 | 4468 |
| Micronesia, Federated States of | 0 | 0 | 0 | 0 | 0 | 0 |
| Midway Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Moldova, Republic of | 0 | 1348 | 0 | 1974 | 0 | 1201 |
| Monaco | 0 | 0 | 0 | 0 | 0 | 0 |
| Mongolia | 2452 | 1102 | 2616 | 2459 | 16165 | 16083 |
| Montenegro | 0 | 191 | 0 | 155 | 0 | 0 |
| Montserrat | 0 | 0 | 0 | 0 | 0 | 0 |
| Morocco | 4236 | 4028 | 10678 | 8334 | 3254 | 3207 |
| Mozambique | 5440 | 5306 | 10878 | 10611 | 0 | 0 |
| Myanmar | 1592 | 1307 | 2114 | 2610 | 2063 | 2501 |
| Namibia | 14803 | 14414 | 26016 | 26624 | 0 | 0 |
| Nauru | 0 | 0 | 0 | 0 | 0 | 0 |
| Nepal | 2910 | 2686 | 8146 | 8449 | 2176 | 1478 |
| Netherlands | 667 | 592 | 1382 | 1297 | 0 | 0 |
| Netherlands Antilles | 484 | 0 | 1512 | 0 | 0 | 0 |
| New Caledonia | 0 | 0 | 0 | 0 | 0 | 0 |
| New Zealand | 960 | 929 | 2189 | 1627 | 0 | 0 |
| Nicaragua | 798 | 597 | 1729 | 1294 | 0 | 0 |
| Niger | 9549 | 10087 | 13846 | 36566 | 16307 | 7875 |
| Nigeria | 3551 | 4506 | 7102 | 11802 | 0 | 0 |
| Niue | 0 | 0 | 0 | 0 | 0 | 0 |
| Norfolk Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Northern Mariana Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Norway | 3229 | 3141 | 7511 | 6836 | 0 | 0 |
| Occupied Palestinian Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| Oman | 86 | 91 | 144 | 152 | 7 | 2 |
| Pacific Islands Trust Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| Pakistan | 1445 | 1158 | 4009 | 2954 | 1446 | 1002 |
| Palau | 0 | 0 | 0 | 0 | 0 | 0 |
| Panama | 716 | 437 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Papua New Guinea | 6960 | 1728 | 15311 | 3802 | 0 | 0 |
| Paraguay | 1858 | 1542 | 3840 | 3187 | 0 | 0 |
| Peru | 2298 | 1937 | 5315 | 3434 | 0 | 0 |
| Philippines | 1450 | 1238 | 2900 | 2476 | 0 | 0 |
| Pitcairn Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Poland | 861 | 965 | 1615 | 1746 | 630 | 2593 |
| Portugal | 3577 | 2492 | 6273 | 2430 | 0 | 333 |
| Puerto Rico | 0 | 0 | 0 | 0 | 0 | 0 |
| Qatar | 180 | 187 | 336 | 348 | 9 | 11 |
| Reunion | 0 | 0 | 0 | 0 | 0 | 0 |
| Romania | 2986 | 2698 | 6157 | 5397 | 1080 | 535 |
| Russian Federation | 0 | 3388 | 0 | 6180 | 0 | 138127 |
| Rwanda | 1140 | 1013 | 2185 | 526 | 2010 | 334 |
| Saint Helena, Ascension and Tristan da Cunha | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Kitts and Nevis | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Lucia | 515 | 224 | 1081 | 470 | 0 | 0 |
| Saint Pierre and Miquelon | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Vincent and the Grenadines | 493 | 312 | 1137 | 720 | 0 | 0 |
| Samoa | 0 | 0 | 0 | 0 | 0 | 0 |
| San Marino | 0 | 0 | 0 | 0 | 0 | 0 |
| Sao Tome and Principe | 0 | 0 | 0 | 0 | 0 | 0 |
| Saudi Arabia | 7866 | 7818 | 14046 | 13414 | 12129 | 9042 |
| Senegal | 5610 | 5651 | 11220 | 10692 | 7182 | 9858 |
| Serbia | 0 | 184 | 0 | 288 | 0 | 0 |
| Serbia and Montenegro | 0 | 0 | 0 | 0 | 0 | 0 |
| Seychelles | 0 | 0 | 0 | 0 | 0 | 0 |
| Sierra Leone | 4228 | 4326 | 9608 | 9832 | 0 | 0 |
| Singapore | 131 | 83 | 325 | 206 | 0 | 0 |
| Slovakia | 0 | 3045 | 0 | 6553 | 0 | 854 |
| Slovenia | 0 | 1744 | 0 | 3513 | 0 | 297 |
| Solomon Islands | 0 | 728 | 0 | 0 | 0 | 0 |
| Somalia | 10710 | 10832 | 21419 | 21664 | 5628 | 4992 |
| South Africa | 2932 | 2492 | 7350 | 2960 | 0 | 0 |
| South Georgia and the South Sandwich Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Spain | 3698 | 3119 | 6951 | 5914 | 0 | 417 |
| Sri Lanka | 1607 | 1562 | 2813 | 2733 | 0 | 0 |
| Sudan (former) | 4532 | 0 | 9064 | 10348 | 3592 | 8320 |
| Suriname | 704 | 440 | 1466 | 941 | 0 | 0 |
| Svalbard and Jan Mayen Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Swaziland | 879 | 1440 | 1750 | 2774 | 0 | 0 |
| Sweden | 2156 | 2062 | 5248 | 4143 | 0 | 0 |
| Switzerland | 1286 | 1112 | 2698 | 2069 | 0 | 147 |
| Syrian Arab Republic | 1970 | 1895 | 3940 | 1624 | 954 | 995 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tajikistan | 0 | 2059 | 0 | 4347 | 0 | 0 |
| Tanzania, United Republic of | 3482 | 3455 | 6964 | 6909 | 0 | 0 |
| Thailand | 930 | 890 | 2046 | 2191 | 0 | 0 |
| Timor-Leste | 0 | 0 | 0 | 0 | 0 | 0 |
| Togo | 3945 | 3910 | 7890 | 7820 | 0 | 0 |
| Tokelau | 0 | 0 | 0 | 0 | 0 | 0 |
| Tonga | 0 | 0 | 0 | 0 | 0 | 0 |
| Trinidad and Tobago | 379 | 251 | 720 | 1517 | 0 | 0 |
| Tunisia | 4237 | 3783 | 6754 | 5740 | 1547 | 992 |
| Turkey | 2283 | 2133 | 6016 | 4532 | 2150 | 1301 |
| Turkmenistan | 0 | 5427 | 0 | 7856 | 0 | 0 |
| Turks and Caicos Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Tuvalu | 0 | 0 | 0 | 0 | 0 | 0 |
| Uganda | 1892 | 1885 | 3784 | 3770 | 0 | 0 |
| Ukraine | 0 | 1277 | 0 | 2251 | 0 | 999 |
| United Arab Emirates | 259 | 126 | 518 | 252 | 24 | 13 |
| United Kingdom | 825 | 807 | 1623 | 1498 | 0 | 0 |
| United States Minor Is. | 0 | 0 | 0 | 0 | 0 | 0 |
| United States Of America | 1649 | 1580 | 3648 | 3082 | 0 | 0 |
| United States Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 | 0 |
| Uruguay | 1572 | 1339 | 3368 | 2553 | 0 | 0 |
| Ussr | 3025 | 0 | 6361 | 0 | 3510 | 0 |
| Uzbekistan | 0 | 1138 | 0 | 1077 | 0 | 2013 |
| Vanuatu | 5930 | 4937 | 0 | 0 | 0 | 0 |
| Venezuela, Bolivarian Republic of | 1367 | 1140 | 3083 | 2086 | 0 | 0 |
| Viet Nam | 589 | 420 | 0 | 0 | 0 | 0 |
| Wake Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Wallis and Futuna Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Western Sahara | 0 | 0 | 0 | 0 | 0 | 0 |
| Yemen | 15450 | 15280 | 30593 | 27783 | 14585 | 12537 |
| Sudan | 0 | 107 | 0 | 208 | 0 | 378 |
| South Sudan | 0 | 122 | 0 | 366 | 0 | 372 |
| Yugoslav SFR | 2778 | 0 | 5778 | 0 | 1972 | 0 |
| Zambia | 2389 | 2400 | 4914 | 4944 | 0 | 0 |
| Zimbabwe | 3191 | 3162 | 6324 | 6275 | 0 | 0 |

***uWFs of goat products, on a country scale, years 1986 and 2016***

| [m$^3$/ton] | Goat | | Goat Meat | | Goat Milk | |
|---|---|---|---|---|---|---|
| | 1986 | 2016 | 1986 | 2016 | 1986 | 2016 |
| Afghanistan | 3928 | 3769 | 9970 | 9567 | 3007 | 3152 |
| Albania | 2229 | 2144 | 5244 | 3408 | 638 | 414 |
| Algeria | 13949 | 13831 | 27899 | 27661 | 2992 | 3172 |
| American Samoa | 0 | 0 | 0 | 0 | 0 | 0 |
| Andorra | 1328 | 465 | 0 | 0 | 0 | 0 |
| Angola | 1619 | 1433 | 5936 | 3152 | 0 | 0 |
| Anguilla | 0 | 0 | 0 | 0 | 0 | 0 |
| Antarctica | 0 | 0 | 0 | 0 | 0 | 0 |
| Antigua and Barbuda | 0 | 0 | 0 | 0 | 0 | 0 |
| Argentina | 6804 | 6497 | 13402 | 12796 | 0 | 0 |
| Armenia | 0 | 3869 | 0 | 7738 | 0 | 664 |
| Aruba | 0 | 0 | 0 | 0 | 0 | 0 |
| Australia | 2871 | 2831 | 5512 | 8825 | 0 | 0 |
| Austria | 2791 | 2518 | 5525 | 3827 | 148 | 90 |
| Azerbaijan | 0 | 2949 | 0 | 0 | 0 | 1671 |
| Bahamas | 1568 | 1069 | 3398 | 2335 | 522 | 205 |
| Bahrain | 398 | 295 | 797 | 591 | 46 | 45 |
| Bangladesh | 1170 | 976 | 2340 | 1951 | 220 | 409 |
| Barbados | 618 | 406 | 1325 | 870 | 0 | 0 |
| Belarus | 0 | 1330 | 0 | 0 | 0 | 76 |
| Belgium | 0 | 1037 | 0 | 1616 | 0 | 68 |
| Belgium-Luxembourg | 1231 | 0 | 0 | 0 | 0 | 0 |
| Belize | 1335 | 1147 | 2670 | 2294 | 0 | 0 |
| Benin | 5588 | 5781 | 11175 | 11563 | 2908 | 1030 |
| Bermuda | 0 | 0 | 0 | 0 | 0 | 0 |
| Bhutan | 1915 | 1871 | 10639 | 10513 | 0 | 0 |
| Bolivia, Plurinational State of | 3115 | 2900 | 6229 | 3143 | 4150 | 1897 |
| Bosnia and Herzegovina | 0 | 2995 | 0 | 0 | 0 | 0 |
| Botswana | 8870 | 9715 | 16261 | 17810 | 18026 | 3670 |
| Bouvet Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Brazil | 2350 | 2047 | 4535 | 3917 | 2002 | 1094 |
| British Indian Ocean Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| British Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Brunei Darussalam | 1858 | 1628 | 4645 | 4069 | 0 | 0 |
| Bulgaria | 2941 | 2822 | 5147 | 7054 | 341 | 377 |
| Burkina Faso | 8347 | 8448 | 19078 | 22527 | 6185 | 1652 |
| Burundi | 1993 | 1732 | 3986 | 2862 | 2001 | 567 |
| Cambodia | 890 | 366 | 0 | 0 | 0 | 0 |
| Cameroon | 3598 | 3629 | 7196 | 7639 | 1310 | 1255 |
| Canada | 3359 | 3192 | 0 | 0 | 0 | 0 |
| Canton and Enderbury Islands | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cape Verde | 222 | 258 | 399 | 559 | 9 | 29 |
| Cayman Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Central African Republic | 2817 | 2827 | 5321 | 5140 | 0 | 0 |
| Chad | 10722 | 10669 | 22301 | 23117 | 8142 | 5549 |
| Chile | 1692 | 1568 | 3385 | 3136 | 2104 | 1887 |
| China, Hong Kong SAR | 0 | 0 | 0 | 0 | 0 | 0 |
| China, Macao SAR | 0 | 0 | 0 | 0 | 0 | 0 |
| China, Mainland | 1381 | 1119 | 2901 | 2028 | 644 | 538 |
| China, Taiwan Province of | 0 | 0 | 0 | 0 | 0 | 0 |
| Christmas Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Cocos Islands (Keeling) | 0 | 0 | 0 | 0 | 0 | 0 |
| Colombia | 907 | 629 | 1940 | 1241 | 0 | 0 |
| Comoros | 129 | 942 | 270 | 1978 | 0 | 0 |
| Congo | 2840 | 2823 | 6312 | 5377 | 0 | 0 |
| Congo, Democratic Republic of the | 3553 | 3536 | 6832 | 5994 | 0 | 0 |
| Cook Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Costa Rica | 840 | 544 | 1820 | 1178 | 0 | 688 |
| Cote de Ivoire | 4581 | 4492 | 9161 | 9456 | 0 | 0 |
| Croatia | 0 | 2088 | 0 | 4176 | 0 | 188 |
| Cuba | 766 | 507 | 1531 | 755 | 0 | 76 |
| Cyprus | 1643 | 1538 | 3670 | 2991 | 499 | 558 |
| Czech Republic | 0 | 445 | 0 | 3622 | 0 | 44 |
| Czechoslovakia | 1638 | 0 | 3992 | 0 | 84 | 0 |
| Denmark | 629 | 555 | 0 | 0 | 0 | 0 |
| Djibouti | 98 | 180 | 212 | 389 | 0 | 0 |
| Dominica | 863 | 675 | 1870 | 1462 | 0 | 0 |
| Dominican Republic | 1145 | 929 | 2290 | 1859 | 0 | 0 |
| Ecuador | 1056 | 644 | 2817 | 807 | 1130 | 1048 |
| Egypt | 3358 | 3384 | 7251 | 6303 | 4459 | 10978 |
| El Salvador | 800 | 509 | 1600 | 1019 | 0 | 0 |
| Equatorial Guinea | 2201 | 2312 | 4401 | 4624 | 0 | 0 |
| Eritrea | 0 | 10668 | 0 | 22590 | 0 | 1729 |
| Estonia | 0 | 3782 | 0 | 9472 | 0 | 444 |
| Ethiopia | 0 | 6170 | 0 | 13066 | 0 | 1437 |
| Falkland Islands (Malvinas) | 0 | 0 | 0 | 0 | 0 | 0 |
| Faroe Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Fiji | 6887 | 3562 | 16091 | 15094 | 0 | 0 |
| Finland | 5163 | 5000 | 0 | 0 | 0 | 0 |
| France | 4140 | 3884 | 7475 | 4902 | 131 | 85 |
| French Guiana | 0 | 0 | 0 | 0 | 0 | 0 |
| French Polynesia | 0 | 0 | 0 | 0 | 0 | 0 |
| French Southern and Antarctic Territories | 0 | 0 | 0 | 0 | 0 | 0 |
| Gabon | 2182 | 2177 | 5237 | 5225 | 0 | 0 |
| Gambia | 5797 | 6032 | 11593 | 12064 | 0 | 0 |
| Georgia | 0 | 3181 | 0 | 5572 | 0 | 1012 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Germany | 665 | 910 | 1360 | 1870 | 39 | 67 |
| Ethiopia PDR | 6411 | 0 | 13576 | 0 | 2125 | 0 |
| Neutral Zone | 0 | 0 | 0 | 0 | 0 | 0 |
| Ghana | 3881 | 3834 | 8170 | 5146 | 0 | 0 |
| Gibraltar | 0 | 0 | 0 | 0 | 0 | 0 |
| Greece | 3756 | 3611 | 6707 | 6945 | 913 | 737 |
| Greenland | 0 | 0 | 0 | 0 | 0 | 0 |
| Grenada | 861 | 346 | 1677 | 600 | 0 | 0 |
| Guadeloupe | 0 | 0 | 0 | 0 | 0 | 0 |
| Guam | 0 | 0 | 0 | 0 | 0 | 0 |
| Guatemala | 967 | 821 | 1933 | 1641 | 0 | 270 |
| Guinea | 4216 | 4304 | 6587 | 7370 | 2635 | 1181 |
| Guinea-Bissau | 7179 | 7240 | 13561 | 13675 | 2934 | 1013 |
| Guyana | 1269 | 708 | 2664 | 1486 | 0 | 0 |
| Haiti | 1107 | 1061 | 2215 | 2093 | 1369 | 632 |
| Heard and McDonald Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Holy See | 0 | 0 | 0 | 0 | 0 | 0 |
| Honduras | 1612 | 987 | 3225 | 1974 | 0 | 0 |
| Hungary | 0 | 0 | 0 | 0 | 0 | 0 |
| Iceland | 342 | 281 | 0 | 0 | 0 | 0 |
| India | 2691 | 1894 | 4844 | 3410 | 790 | 292 |
| Indonesia | 2293 | 1981 | 4814 | 4334 | 1900 | 1514 |
| Iran, Islamic Republic of | 4800 | 4676 | 9257 | 15211 | 1853 | 2412 |
| Iraq | 4376 | 4015 | 9117 | 5095 | 1335 | 3915 |
| Ireland | 933 | 801 | 0 | 0 | 0 | 0 |
| Israel | 1433 | 1414 | 2956 | 4058 | 178 | 186 |
| Italy | 3527 | 3147 | 6764 | 3865 | 426 | 1210 |
| Jamaica | 841 | 513 | 1608 | 750 | 0 | 71 |
| Japan | 1385 | 1078 | 4770 | 4231 | 0 | 0 |
| Johnston Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Jordan | 4082 | 3666 | 5763 | 6820 | 1401 | 3553 |
| Kazakhstan | 0 | 2194 | 0 | 4488 | 0 | 5085 |
| Kenya | 5800 | 5835 | 12128 | 14278 | 2603 | 1953 |
| Kiribati | 0 | 0 | 0 | 0 | 0 | 0 |
| Korea, Democratic Peoples Republic of | 847 | 843 | 1862 | 1854 | 0 | 0 |
| Korea, Republic of | 841 | 699 | 1681 | 1398 | 406 | 172 |
| Kuwait | 1193 | 1201 | 3669 | 1372 | 289 | 181 |
| Kyrgyzstan | 0 | 2249 | 0 | 3174 | 0 | 29754 |
| Lao Peoples Democratic Republic | 995 | 548 | 1422 | 783 | 0 | 0 |
| Latvia | 0 | 4536 | 0 | 0 | 0 | 409 |
| Lebanon | 1089 | 1133 | 2782 | 2728 | 433 | 774 |
| Lesotho | 1725 | 3149 | 3666 | 6529 | 0 | 0 |
| Liberia | 3461 | 3486 | 6922 | 6971 | 0 | 0 |
| Libya | 8080 | 7977 | 12389 | 12482 | 4894 | 5087 |
| Liechtenstein | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Lithuania | 0 | 1720 | 0 | 4610 | 0 | 143 |
| Luxembourg | 0 | 1223 | 0 | 2291 | 0 | 42 |
| Macedonia | 0 | 2948 | 0 | 0 | 0 | 293 |
| Madagascar | 1713 | 1524 | 3654 | 3252 | 0 | 0 |
| Malawi | 2852 | 2687 | 5229 | 6222 | 0 | 1722 |
| Malaysia | 2163 | 1996 | 4754 | 1141 | 0 | 0 |
| Maldives | 0 | 0 | 0 | 0 | 0 | 0 |
| Mali | 8603 | 8668 | 20964 | 18084 | 4796 | 11599 |
| Malta | 664 | 791 | 1260 | 2058 | 51 | 73 |
| Marshall Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Martinique | 0 | 0 | 0 | 0 | 0 | 0 |
| Mauritania | 11157 | 11757 | 22313 | 23513 | 4560 | 5838 |
| Mauritius | 429 | 491 | 847 | 441 | 0 | 0 |
| Mayotte | 0 | 0 | 0 | 0 | 0 | 0 |
| Mexico | 8208 | 7926 | 18486 | 11587 | 891 | 798 |
| Micronesia, Federated States of | 0 | 0 | 0 | 0 | 0 | 0 |
| Midway Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Moldova, Republic of | 0 | 1458 | 0 | 0 | 0 | 257 |
| Monaco | 0 | 0 | 0 | 0 | 0 | 0 |
| Mongolia | 3524 | 1585 | 7569 | 2914 | 0 | 12440 |
| Montenegro | 0 | 223 | 0 | 471 | 0 | 0 |
| Montserrat | 0 | 0 | 0 | 0 | 0 | 0 |
| Morocco | 3971 | 3776 | 9555 | 8694 | 4611 | 3805 |
| Mozambique | 5440 | 5306 | 10879 | 10612 | 6840 | 2820 |
| Myanmar | 1592 | 1307 | 3184 | 1827 | 2063 | 3079 |
| Namibia | 15331 | 14929 | 35773 | 34834 | 0 | 0 |
| Nauru | 0 | 0 | 0 | 0 | 0 | 0 |
| Nepal | 3394 | 3133 | 9052 | 6539 | 1741 | 1253 |
| Netherlands | 1282 | 1138 | 2604 | 2276 | 0 | 62 |
| Netherlands Antilles | 564 | 0 | 1680 | 0 | 0 | 0 |
| New Caledonia | 0 | 0 | 0 | 0 | 0 | 0 |
| New Zealand | 1419 | 1374 | 2365 | 2873 | 0 | 0 |
| Nicaragua | 692 | 518 | 1297 | 971 | 0 | 0 |
| Niger | 11539 | 12189 | 23077 | 28401 | 6523 | 5250 |
| Nigeria | 3125 | 3966 | 6151 | 10221 | 0 | 0 |
| Niue | 0 | 0 | 0 | 0 | 0 | 0 |
| Norfolk Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Northern Mariana Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Norway | 54653 | 53160 | 12145 | 10970 | 317 | 202 |
| Occupied Palestinian Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| Oman | 108 | 114 | 172 | 182 | 1 | 2 |
| Pacific Islands Trust Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| Pakistan | 1526 | 1223 | 4161 | 2292 | 533 | 453 |
| Palau | 0 | 0 | 0 | 0 | 0 | 0 |
| Panama | 835 | 509 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Papua New Guinea | 6960 | 1728 | 15313 | 3802 | 0 | 0 |
| Paraguay | 2618 | 2173 | 5759 | 4828 | 0 | 0 |
| Peru | 2407 | 2029 | 4595 | 3355 | 1072 | 1032 |
| Philippines | 1257 | 1073 | 3142 | 1818 | 0 | 0 |
| Pitcairn Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Poland | 1157 | 1297 | 0 | 0 | 0 | 125 |
| Portugal | 4769 | 3322 | 11006 | 4489 | 0 | 116 |
| Puerto Rico | 0 | 0 | 0 | 0 | 0 | 0 |
| Qatar | 201 | 209 | 360 | 373 | 10 | 6 |
| Reunion | 0 | 0 | 0 | 0 | 0 | 0 |
| Romania | 2715 | 2453 | 5381 | 5397 | 0 | 0 |
| Russian Federation | 0 | 3840 | 0 | 6329 | 0 | 503 |
| Rwanda | 1192 | 1059 | 2384 | 772 | 1005 | 314 |
| Saint Helena, Ascension and Tristan da Cunha | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Kitts and Nevis | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Lucia | 720 | 314 | 1544 | 672 | 0 | 0 |
| Saint Pierre and Miquelon | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Vincent and the Grenadines | 528 | 334 | 1232 | 780 | 0 | 0 |
| Samoa | 0 | 0 | 0 | 0 | 0 | 0 |
| San Marino | 0 | 0 | 0 | 0 | 0 | 0 |
| Sao Tome and Principe | 0 | 0 | 0 | 0 | 0 | 0 |
| Saudi Arabia | 9832 | 9773 | 18987 | 18872 | 5536 | 5220 |
| Senegal | 7854 | 7912 | 15708 | 15215 | 7182 | 7591 |
| Serbia | 0 | 214 | 0 | 416 | 0 | 0 |
| Serbia and Montenegro | 0 | 0 | 0 | 0 | 0 | 0 |
| Seychelles | 0 | 0 | 0 | 0 | 0 | 0 |
| Sierra Leone | 5285 | 5408 | 11743 | 12017 | 0 | 0 |
| Singapore | 85 | 54 | 819 | 375 | 0 | 0 |
| Slovakia | 0 | 4706 | 0 | 6019 | 0 | 188 |
| Slovenia | 0 | 1822 | 0 | 3564 | 0 | 157 |
| Solomon Islands | 0 | 849 | 0 | 0 | 0 | 0 |
| Somalia | 10710 | 10832 | 21419 | 21665 | 5715 | 5568 |
| South Africa | 3311 | 2814 | 6258 | 5286 | 0 | 0 |
| South Georgia and the South Sandwich Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Spain | 4282 | 3612 | 9245 | 9030 | 0 | 272 |
| Sri Lanka | 1607 | 1562 | 2827 | 2733 | 2136 | 530 |
| Sudan (former) | 5578 | 0 | 11156 | 17748 | 2614 | 2520 |
| Suriname | 800 | 500 | 1759 | 887 | 0 | 0 |
| Svalbard and Jan Mayen Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Swaziland | 879 | 1440 | 1807 | 2959 | 0 | 0 |
| Sweden | 3218 | 3077 | 0 | 0 | 0 | 0 |
| Switzerland | 1676 | 1449 | 4571 | 3464 | 172 | 103 |
| Syrian Arab Republic | 2364 | 2274 | 4299 | 2193 | 524 | 654 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tajikistan | 0 | 2612 | 0 | 0 | 0 | 265 |
| Tanzania, United Republic of | 3482 | 3455 | 6964 | 6909 | 1917 | 1326 |
| Thailand | 930 | 890 | 2046 | 1957 | 0 | 0 |
| Timor-Leste | 0 | 0 | 0 | 0 | 0 | 0 |
| Togo | 4340 | 4301 | 9644 | 9557 | 0 | 0 |
| Tokelau | 0 | 0 | 0 | 0 | 0 | 0 |
| Tonga | 0 | 0 | 0 | 0 | 0 | 0 |
| Trinidad and Tobago | 480 | 318 | 960 | 673 | 0 | 0 |
| Tunisia | 5825 | 5202 | 9609 | 6306 | 2395 | 2744 |
| Turkey | 2218 | 2072 | 5176 | 4835 | 1874 | 947 |
| Turkmenistan | 0 | 5267 | 0 | 11193 | 0 | 0 |
| Turks and Caicos Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Tuvalu | 0 | 0 | 0 | 0 | 0 | 0 |
| Uganda | 2207 | 2199 | 4415 | 4511 | 0 | 0 |
| Ukraine | 0 | 1277 | 0 | 2946 | 0 | 99 |
| United Arab Emirates | 291 | 142 | 583 | 283 | 24 | 10 |
| United Kingdom | 1139 | 1115 | 0 | 0 | 0 | 0 |
| United States Minor Is. | 0 | 0 | 0 | 0 | 0 | 0 |
| United States Of America | 3629 | 3478 | 0 | 6341 | 0 | 0 |
| United States Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 | 0 |
| Uruguay | 1935 | 1648 | 0 | 0 | 0 | 0 |
| Ussr | 3429 | 0 | 6429 | 0 | 732 | 0 |
| Uzbekistan | 0 | 1656 | 0 | 0 | 0 | 1366 |
| Vanuatu | 6910 | 5753 | 18518 | 15419 | 0 | 0 |
| Venezuela, Bolivarian Republic of | 1640 | 1368 | 3662 | 2827 | 0 | 0 |
| Viet Nam | 557 | 397 | 1225 | 873 | 0 | 0 |
| Wake Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Wallis and Futuna Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Western Sahara | 0 | 0 | 0 | 0 | 0 | 0 |
| Yemen | 15450 | 15280 | 30899 | 27783 | 10418 | 9444 |
| Sudan | 0 | 131 | 0 | 379 | 0 | 116 |
| South Sudan | 0 | 151 | 0 | 576 | 0 | 111 |
| Yugoslav SFR | 2006 | 0 | 0 | 0 | 0 | 0 |
| Zambia | 3012 | 3026 | 5773 | 5801 | 0 | 0 |
| Zimbabwe | 3723 | 3689 | 7445 | 7377 | 0 | 0 |

## *uWFs of pig products, on a country scale, years 1986 and 2016*

| [m³/ton] | Pig | | Pig Meat | |
|---|---|---|---|---|
| | 1986 | 2016 | 1986 | 2016 |
| Afghanistan | 17414 | 13711 | 0 | 0 |
| Albania | 12088 | 7672 | 10937 | 7672 |
| Algeria | 5143 | 4044 | 7715 | 6051 |
| American Samoa | 0 | 0 | 0 | 0 |
| Andorra | 0 | 0 | 0 | 0 |
| Angola | 44631 | 17802 | 72303 | 22184 |
| Anguilla | 0 | 0 | 0 | 0 |
| Antarctica | 0 | 0 | 0 | 0 |
| Antigua and Barbuda | 0 | 0 | 0 | 0 |
| Argentina | 7884 | 4189 | 9454 | 5374 |
| Armenia | 0 | 5235 | 0 | 5874 |
| Aruba | 0 | 0 | 0 | 0 |
| Australia | 18296 | 14849 | 29212 | 18684 |
| Austria | 4871 | 3664 | 6881 | 4724 |
| Azerbaijan | 0 | 5021 | 0 | 9383 |
| Bahamas | 12546 | 3595 | 18818 | 5393 |
| Bahrain | 0 | 0 | 0 | 0 |
| Bangladesh | 7040 | 4190 | 0 | 0 |
| Barbados | 1453 | 1921 | 2081 | 3302 |
| Belarus | 0 | 9655 | 0 | 12102 |
| Belgium | 0 | 4579 | 0 | 5507 |
| Belgium-Luxembourg | 4958 | 0 | 6520 | 0 |
| Belize | 7759 | 6850 | 11972 | 6799 |
| Benin | 14386 | 14289 | 20551 | 19052 |
| Bermuda | 0 | 0 | 0 | 0 |
| Bhutan | 19730 | 9455 | 31718 | 15201 |
| Bolivia, Plurinational State of | 9322 | 7328 | 16407 | 12820 |
| Bosnia and Herzegovina | 0 | 5177 | 0 | 5906 |
| Botswana | 17270 | 17191 | 23141 | 30072 |
| Bouvet Island | 0 | 0 | 0 | 0 |
| Brazil | 8878 | 4555 | 16045 | 6233 |
| British Indian Ocean Territory | 0 | 0 | 0 | 0 |
| British Virgin Islands | 0 | 0 | 0 | 0 |
| Brunei Darussalam | 23781 | 12588 | 38050 | 19969 |
| Bulgaria | 7449 | 5659 | 11343 | 9390 |
| Burkina Faso | 15353 | 12315 | 22213 | 13957 |
| Burundi | 6416 | 3270 | 8501 | 2371 |
| Cambodia | 1443 | 656 | 2077 | 945 |
| Cameroon | 639 | 1641 | 959 | 2461 |
| Canada | 8444 | 6271 | 10667 | 6181 |
| Canton and Enderbury Islands | 0 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Cape Verde | 3304 | 3264 | 4494 | 4439 |
| Cayman Islands | 0 | 0 | 0 | 0 |
| Central African Republic | 0 | 0 | 0 | 0 |
| Chad | 25500 | 19055 | 35699 | 22231 |
| Chile | 4354 | 2698 | 5826 | 2555 |
| China, Hong Kong SAR | 0 | 0 | 0 | 0 |
| China, Macao SAR | 0 | 0 | 0 | 0 |
| China, Mainland | 4358 | 2457 | 6468 | 3142 |
| China, Taiwan Province of | 0 | 0 | 0 | 0 |
| Christmas Island | 0 | 0 | 0 | 0 |
| Cocos Islands (Keeling) | 0 | 0 | 0 | 0 |
| Colombia | 5209 | 2695 | 7226 | 2855 |
| Comoros | 0 | 0 | 0 | 0 |
| Congo | 1691 | 1605 | 2416 | 2653 |
| Congo, Democratic Republic of the | 2288 | 2054 | 3229 | 3248 |
| Cook Islands | 0 | 0 | 0 | 0 |
| Costa Rica | 5088 | 3034 | 7048 | 3962 |
| Cote de Ivoire | 18618 | 11630 | 32980 | 22323 |
| Croatia | 0 | 4526 | 0 | 6264 |
| Cuba | 1515 | 914 | 2151 | 1340 |
| Cyprus | 7309 | 7716 | 9867 | 10470 |
| Czech Republic | 0 | 3618 | 0 | 4473 |
| Czechoslovakia | 4961 | 0 | 5534 | 0 |
| Denmark | 3938 | 3489 | 5871 | 4300 |
| Djibouti | 7078 | 6579 | 0 | 0 |
| Dominica | 6352 | 5858 | 9528 | 8787 |
| Dominican Republic | 4884 | 3270 | 8378 | 5716 |
| Ecuador | 15764 | 7704 | 31528 | 6635 |
| Egypt | 13619 | 9774 | 17667 | 21504 |
| El Salvador | 3589 | 2360 | 6212 | 4215 |
| Equatorial Guinea | 1006 | 5942 | 1341 | 7922 |
| Eritrea | 0 | 16615 | 0 | 0 |
| Estonia | 0 | 6571 | 0 | 6800 |
| Ethiopia | 0 | 4740 | 0 | 6162 |
| Falkland Islands (Malvinas) | 0 | 0 | 0 | 0 |
| Faroe Islands | 0 | 0 | 0 | 0 |
| Fiji | 830 | 91 | 1290 | 141 |
| Finland | 6385 | 5447 | 8681 | 6204 |
| France | 5412 | 5044 | 7267 | 6354 |
| French Guiana | 0 | 0 | 0 | 0 |
| French Polynesia | 0 | 0 | 0 | 0 |
| French Southern and Antarctic Territories | 0 | 0 | 0 | 0 |
| Gabon | 0 | 0 | 0 | 0 |
| Gambia | 5174 | 9967 | 6468 | 12459 |
| Georgia | 0 | 10167 | 0 | 29050 |

| | | | | |
|---|---|---|---|---|
| Germany | 3571 | 4085 | 4759 | 5085 |
| Ethiopia PDR | 17470 | 0 | 22711 | 0 |
| Neutral Zone | 0 | 0 | 0 | 0 |
| Ghana | 21641 | 15693 | 27051 | 13046 |
| Gibraltar | 0 | 0 | 0 | 0 |
| Greece | 10065 | 9613 | 13121 | 12785 |
| Greenland | 0 | 0 | 0 | 0 |
| Grenada | 6616 | 2178 | 9284 | 2414 |
| Guadeloupe | 0 | 0 | 0 | 0 |
| Guam | 0 | 0 | 0 | 0 |
| Guatemala | 6567 | 4339 | 10451 | 7029 |
| Guinea | 4297 | 5023 | 7237 | 15697 |
| Guinea-Bissau | 10059 | 10949 | 11317 | 12318 |
| Guyana | 4547 | 1905 | 6333 | 2972 |
| Haiti | 3375 | 2991 | 5063 | 4486 |
| Heard and McDonald Islands | 0 | 0 | 0 | 0 |
| Holy See | 0 | 0 | 0 | 0 |
| Honduras | 14391 | 9759 | 20238 | 6364 |
| Hungary | 0 | 0 | 0 | 0 |
| Iceland | 4628 | 3275 | 6757 | 3275 |
| India | 17910 | 9663 | 25586 | 13804 |
| Indonesia | 9505 | 4231 | 11752 | 13019 |
| Iran, Islamic Republic of | 18531 | 11624 | 0 | 0 |
| Iraq | 12464 | 8196 | 0 | 0 |
| Ireland | 4355 | 3465 | 6369 | 3741 |
| Israel | 8276 | 5868 | 10890 | 6839 |
| Italy | 6190 | 4271 | 8241 | 4621 |
| Jamaica | 4306 | 2424 | 7665 | 3708 |
| Japan | 10839 | 6382 | 15840 | 8836 |
| Johnston Island | 0 | 0 | 0 | 0 |
| Jordan | 17895 | 7884 | 0 | 0 |
| Kazakhstan | 0 | 14172 | 0 | 15446 |
| Kenya | 4098 | 8433 | 5044 | 19669 |
| Kiribati | 0 | 0 | 0 | 0 |
| Korea, Democratic Peoples Republic of | 460 | 3143 | 607 | 4149 |
| Korea, Republic of | 14478 | 11013 | 26060 | 12956 |
| Kuwait | 0 | 0 | 0 | 0 |
| Kyrgyzstan | 0 | 3890 | 0 | 7013 |
| Lao Peoples Democratic Republic | 2412 | 1456 | 3618 | 1588 |
| Latvia | 0 | 5802 | 0 | 7189 |
| Lebanon | 6313 | 6453 | 11477 | 11733 |
| Lesotho | 30075 | 19482 | 27067 | 17534 |
| Liberia | 2198 | 2256 | 2748 | 2820 |
| Libya | 3971 | 1673 | 0 | 0 |
| Liechtenstein | 312 | 224 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Lithuania | 0 | 4584 | 0 | 6160 |
| Luxembourg | 0 | 4170 | 0 | 6041 |
| Macedonia | 0 | 4401 | 0 | 5036 |
| Madagascar | 12083 | 7936 | 18124 | 10189 |
| Malawi | 8243 | 7495 | 11870 | 14908 |
| Malaysia | 11107 | 9043 | 18242 | 6280 |
| Maldives | 0 | 0 | 0 | 0 |
| Mali | 8316 | 10365 | 12058 | 15030 |
| Malta | 7888 | 6081 | 10032 | 6580 |
| Marshall Islands | 0 | 0 | 0 | 0 |
| Martinique | 0 | 0 | 0 | 0 |
| Mauritania | 6199 | 16763 | 0 | 0 |
| Mauritius | 2443 | 2507 | 3637 | 3045 |
| Mayotte | 0 | 0 | 0 | 0 |
| Mexico | 8832 | 8623 | 10810 | 8633 |
| Micronesia, Federated States of | 0 | 0 | 0 | 0 |
| Midway Island | 0 | 0 | 0 | 0 |
| Moldova, Republic of | 0 | 3039 | 0 | 3720 |
| Monaco | 0 | 0 | 0 | 0 |
| Mongolia | 412 | 963 | 628 | 1483 |
| Montenegro | 0 | 4173 | 0 | 2998 |
| Montserrat | 0 | 0 | 0 | 0 |
| Morocco | 9668 | 4537 | 16031 | 5946 |
| Mozambique | 12715 | 7933 | 16954 | 9704 |
| Myanmar | 3581 | 2961 | 5861 | 3421 |
| Namibia | 8135 | 8015 | 11093 | 10929 |
| Nauru | 0 | 0 | 0 | 0 |
| Nepal | 50652 | 26618 | 42738 | 20131 |
| Netherlands | 4896 | 4327 | 6864 | 5174 |
| Netherlands Antilles | 0 | 0 | 0 | 0 |
| New Caledonia | 0 | 0 | 0 | 0 |
| New Zealand | 16531 | 13628 | 25162 | 16508 |
| Nicaragua | 3184 | 2620 | 4202 | 3410 |
| Niger | 17871 | 28412 | 23828 | 37882 |
| Nigeria | 4898 | 13627 | 5986 | 16655 |
| Niue | 0 | 0 | 0 | 0 |
| Norfolk Island | 0 | 0 | 0 | 0 |
| Northern Mariana Islands | 0 | 0 | 0 | 0 |
| Norway | 4125 | 2643 | 5422 | 3233 |
| Occupied Palestinian Territory | 0 | 0 | 0 | 0 |
| Oman | 0 | 0 | 0 | 0 |
| Pacific Islands Trust Territory | 0 | 0 | 0 | 0 |
| Pakistan | 6059 | 2526 | 0 | 0 |
| Palau | 0 | 0 | 0 | 0 |
| Panama | 5476 | 2573 | 5635 | 2687 |

| | | | | |
|---|---|---|---|---|
| Papua New Guinea | 809 | 82 | 910 | 92 |
| Paraguay | 4895 | 2556 | 7343 | 2872 |
| Peru | 8249 | 3934 | 12989 | 5609 |
| Philippines | 7934 | 4797 | 11541 | 5506 |
| Pitcairn Islands | 0 | 0 | 0 | 0 |
| Poland | 6786 | 5435 | 8407 | 6696 |
| Portugal | 15253 | 8429 | 20641 | 11439 |
| Puerto Rico | 0 | 0 | 0 | 0 |
| Qatar | 0 | 0 | 0 | 0 |
| Reunion | 0 | 0 | 0 | 0 |
| Romania | 10980 | 6457 | 14233 | 8100 |
| Russian Federation | 0 | 13017 | 0 | 14612 |
| Rwanda | 6620 | 6486 | 9457 | 7484 |
| Saint Helena, Ascension and Tristan da Cunha | 0 | 0 | 0 | 0 |
| Saint Kitts and Nevis | 0 | 0 | 0 | 0 |
| Saint Lucia | 12824 | 2366 | 19124 | 3528 |
| Saint Pierre and Miquelon | 0 | 0 | 0 | 0 |
| Saint Vincent and the Grenadines | 3546 | 2078 | 5615 | 3291 |
| Samoa | 0 | 0 | 0 | 0 |
| San Marino | 0 | 0 | 0 | 0 |
| Sao Tome and Principe | 0 | 0 | 0 | 0 |
| Saudi Arabia | 0 | 0 | 0 | 0 |
| Senegal | 14324 | 13638 | 16712 | 9566 |
| Serbia | 0 | 4305 | 0 | 7300 |
| Serbia and Montenegro | 0 | 0 | 0 | 0 |
| Seychelles | 0 | 0 | 0 | 0 |
| Sierra Leone | 13478 | 17826 | 16266 | 21514 |
| Singapore | 8663 | 4486 | 15750 | 8397 |
| Slovakia | 0 | 3416 | 0 | 4044 |
| Slovenia | 0 | 4729 | 0 | 5339 |
| Solomon Islands | 0 | 27 | 0 | 40 |
| Somalia | 10263 | 16570 | 14369 | 23198 |
| South Africa | 76897 | 12811 | 117770 | 13394 |
| South Georgia and the South Sandwich Islands | 0 | 0 | 0 | 0 |
| Spain | 13708 | 8778 | 18115 | 9994 |
| Sri Lanka | 7643 | 3617 | 10681 | 5161 |
| Sudan (former) | 8123 | 0 | 0 | 0 |
| Suriname | 2337 | 1306 | 2955 | 1637 |
| Svalbard and Jan Mayen Islands | 0 | 0 | 0 | 0 |
| Swaziland | 10256 | 11361 | 13949 | 15451 |
| Sweden | 4023 | 3304 | 5449 | 3818 |
| Switzerland | 2793 | 2496 | 3592 | 2988 |
| Syrian Arab Republic | 16212 | 10522 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Tajikistan | 0 | 10547 | 0 | 3586 |
| Tanzania, United Republic of | 15593 | 10065 | 19881 | 12833 |
| Thailand | 10907 | 15589 | 15705 | 15005 |
| Timor-Leste | 0 | 0 | 0 | 0 |
| Togo | 14884 | 12437 | 21262 | 16582 |
| Tokelau | 0 | 0 | 0 | 0 |
| Tonga | 0 | 0 | 0 | 0 |
| Trinidad and Tobago | 3872 | 2816 | 5410 | 4332 |
| Tunisia | 3536 | 2953 | 4950 | 4159 |
| Turkey | 11750 | 8286 | 19270 | 0 |
| Turkmenistan | 0 | 10019 | 0 | 14109 |
| Turks and Caicos Islands | 0 | 0 | 0 | 0 |
| Tuvalu | 0 | 0 | 0 | 0 |
| Uganda | 7060 | 7145 | 8825 | 8931 |
| Ukraine | 0 | 3928 | 0 | 5028 |
| United Arab Emirates | 0 | 0 | 0 | 0 |
| United Kingdom | 3913 | 4267 | 5777 | 4747 |
| United States Minor Is. | 0 | 0 | 0 | 0 |
| United States Of America | 8015 | 5607 | 11751 | 6855 |
| United States Virgin Islands | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 |
| Uruguay | 5222 | 4353 | 7166 | 7681 |
| Ussr | 14606 | 0 | 17781 | 0 |
| Uzbekistan | 0 | 5596 | 0 | 2747 |
| Vanuatu | 43 | 36 | 78 | 52 |
| Venezuela, Bolivarian Republic of | 8172 | 3888 | 10080 | 4000 |
| Viet Nam | 682 | 1244 | 1033 | 1596 |
| Wake Island | 0 | 0 | 0 | 0 |
| Wallis and Futuna Islands | 0 | 0 | 0 | 0 |
| Western Sahara | 0 | 0 | 0 | 0 |
| Yemen | 0 | 0 | 0 | 0 |
| Sudan | 0 | 5335 | 0 | 0 |
| South Sudan | 0 | 3978 | 0 | 0 |
| Yugoslav SFR | 5997 | 0 | 9929 | 0 |
| Zambia | 6325 | 13067 | 8625 | 17819 |
| Zimbabwe | 7532 | 13860 | 10133 | 18648 |

***uWFs of poultry products, on a country scale, years 1986 and 2016***

| [m³/ton] | Poultry | | Poultry Meat | | Eggs | |
|---|---|---|---|---|---|---|
| | 1986 | 2016 | 1986 | 2016 | 1986 | 2016 |
| Afghanistan | 575 | 546 | 777 | 737 | 2407 | 2773 |
| Albania | 5270 | 3473 | 7176 | 2573 | 8037 | 2541 |
| Algeria | 4896 | 3441 | 6365 | 4473 | 21004 | 2650 |
| American Samoa | 0 | 0 | 0 | 0 | 0 | 0 |
| Andorra | 972 | 25 | 0 | 0 | 0 | 0 |
| Angola | 20593 | 9853 | 27457 | 13138 | 123557 | 20464 |
| Anguilla | 0 | 0 | 0 | 0 | 0 | 0 |
| Antarctica | 0 | 0 | 0 | 0 | 0 | 0 |
| Antigua and Barbuda | 0 | 0 | 0 | 0 | 0 | 0 |
| Argentina | 2288 | 1237 | 3600 | 1048 | 4676 | 1644 |
| Armenia | 0 | 1933 | 0 | 2718 | 0 | 2254 |
| Aruba | 0 | 0 | 0 | 0 | 0 | 0 |
| Australia | 6193 | 4826 | 8330 | 4418 | 7951 | 5577 |
| Austria | 2071 | 1478 | 2528 | 1705 | 2470 | 1430 |
| Azerbaijan | 0 | 1573 | 0 | 2529 | 0 | 4755 |
| Bahamas | 3778 | 968 | 5038 | 1287 | 7389 | 2062 |
| Bahrain | 4168 | 3736 | 5749 | 3567 | 5696 | 5400 |
| Bangladesh | 2811 | 2025 | 3863 | 2893 | 16751 | 12656 |
| Barbados | 942 | 1202 | 1161 | 1110 | 0 | 3707 |
| Belarus | 0 | 3502 | 0 | 4757 | 0 | 5740 |
| Belgium | 0 | 1383 | 0 | 1823 | 0 | 1919 |
| Belgium-Luxembourg | 1669 | 0 | 2436 | 0 | 1829 | 0 |
| Belize | 1836 | 1675 | 2615 | 2044 | 0 | 7027 |
| Benin | 2313 | 2481 | 3181 | 4962 | 5655 | 30930 |
| Bermuda | 0 | 0 | 0 | 0 | 0 | 0 |
| Bhutan | 6623 | 3865 | 9461 | 3686 | 33113 | 6479 |
| Bolivia, Plurinational State of | 2802 | 2206 | 4792 | 1479 | 10403 | 9842 |
| Bosnia and Herzegovina | 0 | 2846 | 0 | 2214 | 0 | 6489 |
| Botswana | 8460 | 6809 | 11633 | 10299 | 26146 | 14783 |
| Bouvet Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Brazil | 4669 | 2382 | 6810 | 1846 | 12384 | 5839 |
| British Indian Ocean Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| British Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Brunei Darussalam | 4534 | 2284 | 9572 | 2931 | 26021 | 11341 |
| Bulgaria | 3110 | 2432 | 6170 | 2763 | 6391 | 3491 |
| Burkina Faso | 2470 | 1994 | 3396 | 2742 | 7763 | 6961 |
| Burundi | 1263 | 392 | 1684 | 523 | 7975 | 1180 |
| Cambodia | 1459 | 574 | 1897 | 746 | 4493 | 1994 |
| Cameroon | 326 | 461 | 448 | 634 | 1063 | 1470 |
| Canada | 3601 | 2576 | 4748 | 2809 | 4595 | 2693 |
| Canton and Enderbury Islands | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cape Verde | 1299 | 1502 | 1917 | 1368 | 4536 | 2521 |
| Cayman Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Central African Republic | 139 | 195 | 370 | 462 | 968 | 1017 |
| Chad | 2823 | 2206 | 4032 | 2764 | 7840 | 3331 |
| Chile | 1771 | 1106 | 2267 | 690 | 2242 | 842 |
| China, Hong Kong SAR | 0 | 0 | 0 | 0 | 0 | 0 |
| China, Macao SAR | 0 | 0 | 0 | 0 | 0 | 0 |
| China, Mainland | 1963 | 1083 | 3360 | 1416 | 4929 | 1795 |
| China, Taiwan Province of | 0 | 0 | 0 | 0 | 0 | 0 |
| Christmas Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Cocos Islands (Keeling) | 0 | 0 | 0 | 0 | 0 | 0 |
| Colombia | 2092 | 1119 | 4796 | 1121 | 3361 | 1400 |
| Comoros | 1898 | 1798 | 2610 | 2473 | 5220 | 3786 |
| Congo | 1051 | 1247 | 1261 | 1497 | 4744 | 5085 |
| Congo, Democratic Republic of the | 779 | 733 | 1089 | 1221 | 2731 | 2415 |
| Cook Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Costa Rica | 1899 | 944 | 2693 | 949 | 1932 | 835 |
| Cote de Ivoire | 4420 | 3362 | 6179 | 4725 | 12947 | 10927 |
| Croatia | 0 | 2513 | 0 | 3386 | 0 | 2582 |
| Cuba | 2087 | 1266 | 2537 | 1501 | 2662 | 1885 |
| Cyprus | 2131 | 2021 | 2942 | 2332 | 5458 | 2957 |
| Czech Republic | 0 | 1618 | 0 | 2197 | 0 | 1675 |
| Czechoslovakia | 2159 | 0 | 3483 | 0 | 3145 | 0 |
| Denmark | 1508 | 1304 | 2088 | 1476 | 1346 | 1206 |
| Djibouti | 1038 | 976 | 0 | 0 | 0 | 0 |
| Dominica | 2403 | 2355 | 3812 | 3735 | 8470 | 5738 |
| Dominican Republic | 2225 | 1420 | 3829 | 1496 | 4787 | 1745 |
| Ecuador | 5333 | 2569 | 8888 | 2416 | 13264 | 2786 |
| Egypt | 3373 | 2967 | 4298 | 3542 | 5561 | 3198 |
| El Salvador | 1897 | 1194 | 3018 | 1518 | 2532 | 1639 |
| Equatorial Guinea | 2680 | 18441 | 369 | 2536 | 932 | 4329 |
| Eritrea | 0 | 9028 | 0 | 12966 | 0 | 27995 |
| Estonia | 0 | 3053 | 0 | 2372 | 0 | 2329 |
| Ethiopia | 0 | 1334 | 0 | 2094 | 0 | 3391 |
| Falkland Islands (Malvinas) | 0 | 0 | 0 | 0 | 0 | 0 |
| Faroe Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Fiji | 2423 | 1789 | 3550 | 1732 | 8912 | 2986 |
| Finland | 2561 | 2068 | 3834 | 1894 | 2682 | 1615 |
| France | 1936 | 1703 | 2658 | 2205 | 2684 | 1849 |
| French Guiana | 0 | 0 | 0 | 0 | 0 | 0 |
| French Polynesia | 0 | 0 | 0 | 0 | 0 | 0 |
| French Southern and Antarctic Territories | 0 | 0 | 0 | 0 | 0 | 0 |
| Gabon | 202 | 370 | 277 | 509 | 644 | 1072 |
| Gambia | 1302 | 2443 | 1797 | 3372 | 5089 | 8906 |
| Georgia | 0 | 7447 | 0 | 3930 | 0 | 4981 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Germany | 1242 | 1426 | 2086 | 1561 | 1474 | 1232 |
| Ethiopia PDR | 5432 | 0 | 8528 | 0 | 29663 | 0 |
| Neutral Zone | 0 | 0 | 0 | 0 | 0 | 0 |
| Ghana | 2885 | 2199 | 3976 | 3684 | 13502 | 10357 |
| Gibraltar | 0 | 0 | 0 | 0 | 0 | 0 |
| Greece | 3367 | 3189 | 4591 | 2580 | 6440 | 4208 |
| Greenland | 0 | 0 | 0 | 0 | 0 | 0 |
| Grenada | 2195 | 741 | 3927 | 1358 | 4482 | 1446 |
| Guadeloupe | 0 | 0 | 0 | 0 | 0 | 0 |
| Guam | 0 | 0 | 0 | 0 | 0 | 0 |
| Guatemala | 2128 | 1260 | 3296 | 1573 | 4776 | 1911 |
| Guinea | 1849 | 2537 | 2465 | 1899 | 6339 | 8297 |
| Guinea-Bissau | 2469 | 2389 | 3528 | 2994 | 5144 | 5193 |
| Guyana | 3361 | 1443 | 4235 | 1809 | 8515 | 4169 |
| Haiti | 2405 | 2069 | 3207 | 2759 | 3395 | 2860 |
| Heard and McDonald Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Holy See | 0 | 0 | 0 | 0 | 0 | 0 |
| Honduras | 3082 | 1789 | 3996 | 1269 | 4011 | 2028 |
| Hungary | 0 | 0 | 0 | 0 | 0 | 0 |
| Iceland | 2436 | 1821 | 3629 | 1803 | 3540 | 1780 |
| India | 7065 | 3850 | 9420 | 3371 | 7748 | 3876 |
| Indonesia | 6371 | 3189 | 8760 | 4212 | 16853 | 3810 |
| Iran, Islamic Republic of | 5373 | 3941 | 6908 | 6141 | 8382 | 4642 |
| Iraq | 5736 | 2893 | 7457 | 3052 | 8660 | 3703 |
| Ireland | 1895 | 1374 | 1972 | 2004 | 2589 | 1840 |
| Israel | 3311 | 2975 | 4301 | 3297 | 3207 | 2772 |
| Italy | 2376 | 1762 | 3095 | 2024 | 3742 | 3424 |
| Jamaica | 2141 | 1343 | 2473 | 2010 | 6222 | 3846 |
| Japan | 2743 | 1650 | 3758 | 1505 | 4131 | 2246 |
| Johnston Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Jordan | 6762 | 2763 | 7802 | 5080 | 10170 | 1478 |
| Kazakhstan | 0 | 4956 | 0 | 4486 | 0 | 5499 |
| Kenya | 345 | 1492 | 448 | 1917 | 1191 | 4817 |
| Kiribati | 0 | 0 | 0 | 0 | 0 | 0 |
| Korea, Democratic Peoples Republic of | 501 | 1054 | 592 | 1245 | 799 | 1863 |
| Korea, Republic of | 4018 | 3261 | 6619 | 7210 | 7624 | 5847 |
| Kuwait | 3524 | 4704 | 3524 | 5326 | 5881 | 8140 |
| Kyrgyzstan | 0 | 3431 | 0 | 3090 | 0 | 6247 |
| Lao Peoples Democratic Republic | 875 | 396 | 1313 | 590 | 2022 | 879 |
| Latvia | 0 | 2413 | 0 | 2576 | 0 | 2206 |
| Lebanon | 3365 | 3293 | 4166 | 2651 | 3560 | 4803 |
| Lesotho | 4160 | 3437 | 10400 | 8592 | 29715 | 13583 |
| Liberia | 595 | 614 | 819 | 844 | 1310 | 1339 |
| Libya | 4245 | 2250 | 5219 | 3070 | 9263 | 4880 |
| Liechtenstein | 50 | 36 | 0 | 0 | 0 | 84 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Lithuania | 0 | 2154 | 0 | 2016 | 0 | 2656 |
| Luxembourg | 0 | 1245 | 0 | 1783 | 0 | 1258 |
| Macedonia | 0 | 3009 | 0 | 6404 | 0 | 4805 |
| Madagascar | 3675 | 2253 | 7809 | 4788 | 52156 | 8478 |
| Malawi | 2814 | 2643 | 3870 | 1157 | 6772 | 6507 |
| Malaysia | 3355 | 2880 | 5582 | 2890 | 9063 | 7378 |
| Maldives | 0 | 0 | 0 | 0 | 0 | 0 |
| Mali | 1567 | 2019 | 2154 | 2813 | 9575 | 7814 |
| Malta | 2947 | 2376 | 4083 | 2216 | 4458 | 2343 |
| Marshall Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Martinique | 0 | 0 | 0 | 0 | 0 | 0 |
| Mauritania | 3527 | 10480 | 4850 | 14441 | 13041 | 35984 |
| Mauritius | 1595 | 1515 | 3031 | 2992 | 3334 | 3227 |
| Mayotte | 0 | 0 | 0 | 0 | 0 | 0 |
| Mexico | 2988 | 2176 | 4002 | 2256 | 6384 | 3085 |
| Micronesia, Federated States of | 0 | 0 | 0 | 0 | 0 | 0 |
| Midway Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Moldova, Republic of | 0 | 1790 | 0 | 2102 | 0 | 2748 |
| Monaco | 0 | 0 | 0 | 0 | 0 | 0 |
| Mongolia | 328 | 920 | 256 | 980 | 0 | 1191 |
| Montenegro | 0 | 1693 | 0 | 1783 | 0 | 2518 |
| Montserrat | 0 | 0 | 0 | 0 | 0 | 0 |
| Morocco | 5155 | 3469 | 11598 | 6007 | 15464 | 10427 |
| Mozambique | 4339 | 2644 | 5786 | 1058 | 12550 | 5987 |
| Myanmar | 2195 | 1815 | 3117 | 1983 | 11473 | 3756 |
| Namibia | 5306 | 6215 | 7296 | 8546 | 18263 | 21713 |
| Nauru | 0 | 0 | 0 | 0 | 0 | 0 |
| Nepal | 2178 | 2244 | 3540 | 3822 | 6758 | 5569 |
| Netherlands | 1916 | 1675 | 2639 | 1615 | 1584 | 1729 |
| Netherlands Antilles | 1880 | 0 | 2851 | 0 | 3943 | 0 |
| New Caledonia | 0 | 0 | 0 | 0 | 0 | 0 |
| New Zealand | 4897 | 3990 | 7428 | 3789 | 6467 | 4511 |
| Nicaragua | 1096 | 865 | 1958 | 852 | 2095 | 2192 |
| Niger | 3404 | 5113 | 4681 | 7031 | 13275 | 20402 |
| Nigeria | 1840 | 5510 | 2300 | 6887 | 5574 | 15205 |
| Niue | 0 | 0 | 0 | 0 | 0 | 0 |
| Norfolk Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Northern Mariana Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Norway | 3523 | 2374 | 5426 | 2504 | 2708 | 2092 |
| Occupied Palestinian Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| Oman | 4024 | 5836 | 6035 | 8754 | 5633 | 4342 |
| Pacific Islands Trust Territory | 0 | 0 | 0 | 0 | 0 | 0 |
| Pakistan | 5983 | 3448 | 7386 | 3994 | 16793 | 9451 |
| Palau | 0 | 0 | 0 | 0 | 0 | 0 |
| Panama | 2443 | 1112 | 3446 | 1074 | 4922 | 1460 |

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|---|---|---|---|---|---|---|
| Papua New Guinea | 4270 | 1458 | 5694 | 1944 | 17081 | 2638 |
| Paraguay | 3530 | 1839 | 4589 | 2391 | 8515 | 2318 |
| Peru | 3661 | 1744 | 3371 | 1543 | 7622 | 1938 |
| Philippines | 3239 | 2371 | 3902 | 2992 | 8624 | 6712 |
| Pitcairn Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Poland | 2720 | 2302 | 3557 | 2148 | 5558 | 3126 |
| Portugal | 6446 | 3377 | 8622 | 3207 | 7891 | 2588 |
| Puerto Rico | 0 | 0 | 0 | 0 | 0 | 0 |
| Qatar | 4048 | 5348 | 5262 | 2894 | 4941 | 5562 |
| Reunion | 0 | 0 | 0 | 0 | 0 | 0 |
| Romania | 4437 | 2308 | 8241 | 2824 | 11713 | 5944 |
| Russian Federation | 0 | 4647 | 0 | 4490 | 0 | 6173 |
| Rwanda | 1847 | 1807 | 2257 | 663 | 7258 | 3794 |
| Saint Helena, Ascension and Tristan da Cunha | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Kitts and Nevis | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Lucia | 6682 | 1095 | 8352 | 1369 | 16065 | 2038 |
| Saint Pierre and Miquelon | 0 | 0 | 0 | 0 | 0 | 0 |
| Saint Vincent and the Grenadines | 1481 | 947 | 2513 | 1606 | 2773 | 1175 |
| Samoa | 0 | 0 | 0 | 0 | 0 | 0 |
| San Marino | 0 | 0 | 0 | 0 | 0 | 0 |
| Sao Tome and Principe | 0 | 0 | 0 | 0 | 0 | 0 |
| Saudi Arabia | 4415 | 3107 | 5739 | 4040 | 4608 | 3751 |
| Senegal | 2590 | 2636 | 3367 | 2558 | 13625 | 10280 |
| Serbia | 0 | 1849 | 0 | 1479 | 0 | 2764 |
| Serbia and Montenegro | 0 | 0 | 0 | 0 | 0 | 0 |
| Seychelles | 0 | 0 | 0 | 0 | 0 | 0 |
| Sierra Leone | 4669 | 5448 | 6225 | 7265 | 24360 | 27558 |
| Singapore | 3201 | 1572 | 3201 | 1579 | 11854 | 2897 |
| Slovakia | 0 | 1660 | 0 | 1934 | 0 | 2486 |
| Slovenia | 0 | 2467 | 0 | 2157 | 0 | 2614 |
| Solomon Islands | 27 | 594 | 37 | 817 | 74 | 1488 |
| Somalia | 4978 | 6215 | 6845 | 8545 | 16708 | 20908 |
| South Africa | 25448 | 4140 | 32774 | 3924 | 39934 | 5564 |
| South Georgia and the South Sandwich Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Spain | 3868 | 2339 | 5129 | 2505 | 5748 | 2803 |
| Sri Lanka | 3585 | 2157 | 4661 | 2670 | 4975 | 4090 |
| Sudan (former) | 5033 | 0 | 6040 | 215 | 10515 | 388 |
| Suriname | 934 | 526 | 1073 | 524 | 4566 | 2271 |
| Svalbard and Jan Mayen Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Swaziland | 4382 | 5657 | 6573 | 8485 | 28076 | 15428 |
| Sweden | 1705 | 1343 | 2437 | 1474 | 1418 | 1298 |
| Switzerland | 2453 | 2101 | 3638 | 2848 | 2830 | 2010 |
| Syrian Arab Republic | 5020 | 3806 | 5757 | 4626 | 7727 | 5750 |

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|---|---|---|---|---|---|---|
| Tajikistan | 0 | 4272 | 0 | 5012 | 0 | 6939 |
| Tanzania, United Republic of | 2108 | 1078 | 3007 | 1354 | 10294 | 2038 |
| Thailand | 3292 | 4564 | 4086 | 5622 | 7630 | 9948 |
| Timor-Leste | 0 | 0 | 0 | 0 | 0 | 0 |
| Togo | 3540 | 3529 | 4868 | 4853 | 8077 | 7736 |
| Tokelau | 0 | 0 | 0 | 0 | 0 | 0 |
| Tonga | 0 | 0 | 0 | 0 | 0 | 0 |
| Trinidad and Tobago | 1172 | 851 | 1445 | 1041 | 5757 | 4686 |
| Tunisia | 6115 | 3724 | 8075 | 4309 | 24238 | 13230 |
| Turkey | 4451 | 3252 | 5563 | 2859 | 8847 | 4687 |
| Turkmenistan | 0 | 3349 | 0 | 4344 | 0 | 4364 |
| Turks and Caicos Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Tuvalu | 0 | 0 | 0 | 0 | 0 | 0 |
| Uganda | 1653 | 1761 | 2034 | 2172 | 13221 | 5112 |
| Ukraine | 0 | 2675 | 0 | 2128 | 0 | 4266 |
| United Arab Emirates | 6910 | 3457 | 8637 | 4321 | 10106 | 4468 |
| United Kingdom | 1133 | 1285 | 1576 | 1856 | 2023 | 2059 |
| United States Minor Is. | 0 | 0 | 0 | 0 | 0 | 0 |
| United States Of America | 2403 | 1676 | 3415 | 1654 | 3442 | 2102 |
| United States Virgin Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Unspecified | 0 | 0 | 0 | 0 | 0 | 0 |
| Uruguay | 2907 | 2542 | 3779 | 3304 | 5398 | 1827 |
| Ussr | 5466 | 0 | 6917 | 0 | 7617 | 0 |
| Uzbekistan | 0 | 2585 | 0 | 2144 | 0 | 5135 |
| Vanuatu | 4211 | 3678 | 5474 | 4781 | 13685 | 11102 |
| Venezuela, Bolivarian Republic of | 1885 | 892 | 2311 | 1052 | 3404 | 1067 |
| Viet Nam | 1280 | 1071 | 1533 | 581 | 2593 | 1381 |
| Wake Island | 0 | 0 | 0 | 0 | 0 | 0 |
| Wallis and Futuna Islands | 0 | 0 | 0 | 0 | 0 | 0 |
| Western Sahara | 129 | 108 | 0 | 0 | 0 | 0 |
| Yemen | 8619 | 5440 | 11781 | 7001 | 16916 | 10499 |
| Sudan | 0 | 3685 | 0 | 4040 | 0 | 7598 |
| South Sudan | 0 | 2082 | 0 | 2499 | 0 | 0 |
| Yugoslav SFR | 3633 | 0 | 5481 | 0 | 7086 | 0 |
| Zambia | 2244 | 4309 | 2693 | 5171 | 6733 | 10998 |
| Zimbabwe | 1183 | 2155 | 1542 | 2811 | 5913 | 6650 |