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Short Communication

Estimation of water requirements by livestock in Europe

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ABSTRACT

Ecosystem-based thinking can be more easily incorporated into policy and decision making if natural resources are better accounted for. The Blueprint to Safeguard Europe's Water aims to positively contribute to the European Union's Water Policy through a series of studies to assess the quantity and quality of this precious resource. An important part of that water balance is the accounting of water removed from rivers or aquifers by different sectorial needs.

The map series presented in this short note shows the water requirements for the livestock sector in particular. These maps are calculated based on livestock density maps for 2005, normalized by the best available field data at continental scale. Water requirements are calculated for cattle, pigs, poultry and sheep and goats. A relationship using air temperature is inferred for the daily water requirements per livestock category. Daily average temperature maps are used in conjunction with the livestock density maps in order to create a temporal series of water requirements for the livestock sector in Europe. This map series is then ingested by the hydrological model along with other water requirements maps for other sectors in order to contribute to the efforts to quantify total water use in the EU.

1. Introduction

Clean water is an invaluable resource to our economy for drinking, recreation and irrigation of crops to name just a few uses. Ecosystems, in particular wetlands, lakes, streams and rivers, contribute directly to supplying water. But there is more. In periods of heavy rainfall, these ecosystems and others such as forests can act as buffers, storing water that would otherwise flood cities, industries and farms. In addition, as water moves through these ecosystems, pollutants such as heavy metals, excess nutrients, and pesticides are partially or completely absorbed and filtered. By demonstrating the value of these ecosystems through the services they deliver to our economy, we can integrate ecosystem based thinking into policy and decision making (Keeler et al., 2012; Maes et al., 2013).

The EU Biodiversity Strategy to 2020 (EC, 2011) integrates the concept of ecosystem services as underpinning elements of our economy, thus contributing to the Europe 2020 targets through the resource efficiency flagship. As a result, the EU water policy is aligning its objectives with the target of the Europe 2020 strategy. In particular, the Blueprint to Safeguard Europe's Water Resources (European Commission, 2012) aims to improve the status of the current situation on water resources both in terms of quantity and quality, and seeks to integrate ecosystem protection and restoration to maintain or enhance the delivery of water-related ecosystem services.

Ecosystem services flow from sites where they are produced, to sites where they are consumed (Costanza, 2008). This is particularly evident for water provision and water regulation services. However, the complexity of tracing the spatial and temporal quantitative differences between supply and demand of ecosystem services remains a constraint on the development of maps of demand and actual use of ecosystem services (Burkhard et al., 2012). This paper addresses the need for better data that is able to describe the demand (or user side) of ecosystems services, making the case of drinking water for livestock. Livestock are significant users of water in Europe, especially in Northern Europe where their use comparable to that for irrigation (Florke and Alcamo, 2004). The goods derived from livestock, such as meat and dairy products, are thus directly dependent on the supply of drinking water.

The work presented here contributed to the policy impact assessment that preceded the communication of the Blueprint and provided the scientific background upon which the policy options are based (De Roo et al., 2012). The context of this particular study is the understanding of current water balances, as well as forecasting future ones by estimating the net water availability at catchment level by taking into consideration the amount of water removed from rivers or aquifers for different sectors. In particular, we describe an approach for calculating water required for a sub-sector of agriculture: livestock. The resulting daily maps representing livestock water

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requirements are ingested by the hydrological model LISFLOOD (De Roo et al., 2000, 2001, 2003), along with other sector-specific water requirement maps. LISFLOOD then calculates water availability on a daily basis given the requirements, as well as biophysical factors such as climate and land cover.

2. Methods

The livestock water requirement map series is based upon the Food and Agriculture Organization of the United Nations (FAO) livestock density maps (FAO, 2012) for 2005 (described in Robinson et al., 2007). Actual livestock figures for 2005 as given by the Complete and Consistent database (CoCo) made available through the Common Agricultural Policy Regionalized Impact Modeling System (CAPRI, 2012) are used to refine the livestock density maps. A series of water requirements per livestock type data is taken from the literature in order to compute water requirements per livestock type on a daily basis.

2.1. Mapping livestock densities

The FAO livestock density maps are a 1 km-resolution gridded product with global coverage and are detailed in terms of livestock decomposition. In this study, we use the livestock density maps for 2005 estimates on sheep, goats, cattle, poultry and pigs.

The CoCo data is given at aggregates of regions we call "CAPRI-regions". These regions correspond for the most part to level 2 of Nomenclature of territorial units for statistics (NUTS-2, EUROSTAT, 2011) with few exceptions in Germany, the UK and Italy for example where the regions correspond to NUTS, level 1 delimitations. For non EU countries only, the CAPRI-regions correspond to national level boundaries. Most of the data within CoCo are derived from EUROSTAT (farm and market balances, economic indicators, acreages, herd sizes and national input output coefficients). The datasets used in CoCo, and the derivation of secondary data and imputation techniques are described in detail in Witzke et al. (2011).

The CoCo data is more refined in terms of livestock typologies, but was aggregated to match this FAO classification and the two datasets were compared. The different cattle activities in the CoCo database correspond well with the FAO summed heads of cattle for the same regions, there is little discrepancy between the two datasets. The correspondences between FAO and CoCo data in terms of sums of heads per CAPRI region were evaluated at two levels: for EU 27 and for EU27 + Norway, Kosovo, Serbia, Bosnia and Herzegovina, Montenegro, Croatia, Macedonia, Albania and Turkey in order to understand the reliability of the CoCo data with respect to the FAO data. It was found that the correspondences were higher between FAO and CoCo at EU27 level for cattle and sheep than for all CAPRI-regions together. This was not true however for pigs or poultry. Given this mixed response, an analysis was made on country-level data. The degree of uncertainty for the FAO dataset, using CoCo as a reference showed which countries were compatible between the datasets.

The sums given by FAO are rescaled to match the sums given by CoCo. The rescaling is done equally for all cells within the region by using a correction coefficient. The original livestock density maps from the FAO were corrected using the correction coefficient for each CAPRI region only if, based on the exercise described above, the correction coefficient did not surpass a threshold of ten (implying that the FAO dataset would need to be multiplied by ten times in order to match the CoCo data). The threshold was selected after several tests were run. For those regions whose correction coefficient was above the cut-off point, the raw FAO data was plugged in.

For the cattle, the situation is more complicated given the large discrepancies in water requirements within this category. First, detailed density maps per cattle category were created based on the cattle layer from the FAO. These were computed using the CoCo data by redistributing the proportion of each of the cattle type evenly over each region. To do this, each CAPRI region cattle number is subdivided into its proportion of sub-categories using the CoCo data as a reference.

The statistics available in the literature are not detailed enough to assign a water consumption value to each of the cattle classes so these are aggregated as follows, based on the available water uptake statistics: heifers, bulls, high-yield dairy cows, low-yield dairy cows, calves and "other" cattle.

In total, a series of nine livestock density maps were created: Sheep and goats, poultry, pigs, heifers, bulls, calves, high-yield dairy cows, low-yield dairy cows and "other" cows. A summary of the methodology for weighting the correction coefficients for all livestock classes is shown in Fig. 1.

2.2. Quantifying livestock water requirements

An algorithm for each livestock density type was derived from data given in the literature for different water requirements based on *temperature*. A temporal series of daily average temperature was used to calculate the temporal series of water requirements for each livestock category. The individual layers were then summed to provide a final temporal series of daily livestock water requirements.

The quantifications of water intake per head per day were derived from a temperature scale. Values found in the literature whereby temperature, livestock category and possibly livestock weight or ages were reconciled in a database from which the water requirements vs. temperature curves were derived for each livestock category. The main sources of data were the North Dakota State University (1999), Mississippi State University (2008), New Mexico State University (2002) and the FAO (2006). Fig. 2 shows the water requirements for heifers, bulls and calves in liters per head per day, and their variation according to temperature. Curves such as these are derived for each livestock category.

Dairy cow water requirements are higher than those of other cattle categories, the excessive water requirements due to their milk production. In order to calculate water requirements, a more refined approach is taken whereby milk yields are factored in, as is the amount of dry feed eaten by the animals. In order to quantify water requirements for dairy cows, we rely on the data provided by CoCo on milk yields and dry matter consumption. This data also comes from the CAPRI database. Fig. 3 shows a summary of milk production for 2004 in the EU 27 according to DG AGRI (IPTS, 2009).

2.3. Calculating water use per grid cell

A water use map is generated for each livestock category. Livestock category "cattle" is further refined based on the cattle "sub-category" (dairy cows, calves, bulls, heifers) as these represent significantly differing water use levels.

Each class has a specific water uptake algorithm based on figures given by the literature based on weight and air temperature. Heifers are assumed to have a final weight of 300 kg (Eq. (1)), and bulls are assumed to have a final weight of 335 kg (Eq. (2)). "Other" cows are assumed to have a final weight of 575 kg (Eq. (3)) (Britz, 2011).

$$WU_{HEI} = 0.20t^2 - 0.63t + 23 \quad (1)$$

$$WU_{BUL} = 0.25t^2 - 0.91t + 28 \quad (2)$$