Science of the Total Environment 642 (2018) 887–893

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Short Communication

Terra incognita: The unknown risks to environmental quality posed by the spatial distribution and abundance of concentrated animal feeding operations

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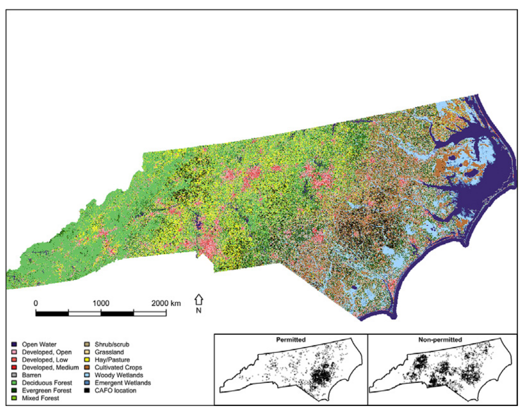
HIGHLIGHTS

- Environmental risk assessments of CAFOs are complicated by a lack of spatial data.
- North Carolina CAFOs are concentrated in the Coastal Plain, subject to large storms.
- 19% of CAFO points (1262) across the state are within 100 m of streams.
- Data gaps prohibit landscape modeling of impacts under changing conditions.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 2 February 2018
Received in revised form 4 May 2018
Accepted 6 June 2018
Available online xxxx

Editor: Jay Gan

Keywords:
Animal agroecosystems
Environmental footprint
Land cover
Nutrients
Pollution
Water quality

ABSTRACT

Concentrated animal feeding operations (CAFOs) pose wide ranging environmental risks to many parts of the US and across the globe, but datasets for CAFO risk assessments are not readily available. Within the United States, some of the greatest concentrations of CAFOs occur in North Carolina. It is also one of the only states with publicly accessible location data for classes of CAFOs that are required to obtain water quality permits from the U.S. Environmental Protection Agency (EPA); however, there are no public data sources for the large number of CAFOs that do not require EPA water quality permits. We combined public records of CAFO locations with data collected in North Carolina by the Waterkeeper and Riverkeeper Alliances to examine the distribution of both permitted and non-permitted CAFOs across the state. Over half (55%) of the state's 6646 CAFOs are located in the Coastal Plain, a low-lying region vulnerable to flooding associated with regular cyclonic and convective storms. We identified 19% of CAFOs ≤ 100 m of the nearest stream, and some as close as 15 m to the nearest stream, a common riparian buffer width for water quality management. Future climate scenarios suggest large storm events are expected to become increasingly extreme, and dry interstorm periods could lengthen. Such extremes could exacerbate the environmental impacts of CAFOs. Understanding the potential impacts of CAFO agroecosystems will require remote sensing to identify CAFOs, fieldwork to determine the extent of environmental footprints, and modeling to identify thresholds that determine environmental risk under changing conditions.

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https://doi.org/10.1016/j.scitotenv.2018.06.072

1. Introduction

Beginning in the mid twentieth century, there was a significant shift in US agriculture toward concentrated animal feeding operations, or CAFOs (Mallin, 2000). The transition from small, family farms to consolidated operations began in the poultry industry during the 1950s, and the model was adopted by swine farmers in the Midwest during the 1970s and 80s. The trend of increasing CAFOs reached the southeastern US in the late 1980s (Mallin, 2000). As a result, North Carolina experienced a nearly four-fold increase in swine inventory from 1975 to 2000 (Yang et al., 2016). Poultry production has increased in North Carolina during the same approximate time period, and the state has been one of the top poultry producers in the United States (Yang et al., 2016). The state Department of Environmental Quality estimated that from 1992 to 2014, poultry inventory increased where it is most concentrated (16% increase Yadkin-Pee Dee River basin, 9% increase Cape Fear River basin), and expanded rapidly in new areas of the state (393% increase Lumber River basin, 331% increase Broad River basin) (Patt, 2017). Although CAFOs provide a rapid and profitable way to provide food to a growing human population, they present significant risks to human health and environmental quality (Burkholder et al., 2007; Greger and Koneswaran, 2010; Mallin et al., 2015). Due to the high volumes of animal waste produced, CAFOs have high potential to contribute to soil, air, and water pollution, posing health risks to nearby communities (Burkholder et al., 2007; Donham et al., 2007; Greger and Koneswaran, 2010; Nicole, 2013). These operations tend to be spatially clustered in areas with environmental regulations and zoning requirements that favor industrial agriculture, particularly the southeastern US (Mallin, 2000) and in rural, impoverished, minority communities (Emanuel, 2018; Nicole, 2013; Wing et al., 2002).

Understanding the impacts of CAFOs and developing and implementing best management practices to mitigate impacts, requires fine-scale spatial data on CAFO locations. Existing research on the spatial distribution of CAFOs and potential impacts to environmental and human health have been conducted at relatively large spatial scales, such as counties (Yang et al., 2016) or watersheds (Harden, 2015). County level agricultural statistics such as the total number of animals housed are available from USDA (https://www.nass.usda.gov/). However, county-scale assessments and similar large-scale studies are not aligned with many ecological processes, and thus are limited in their ability to evaluate the potential impacts of CAFOs on nutrient cycling and water resources at scales that are most appropriate for improving management practices. Data are not publicly or readily available at finer spatial scales or scales more aligned with ecological processes, such as watersheds.

Recognizing the potential environmental and human health risks of CAFOS, some federally mandated best management practices have been developed and implemented. Large CAFOs that meet the EPA definition of >1000 animal units using a liquid waste disposal system are recognized as point sources of pollution and thus, a water quality permit is required (hereafter, permitted CAFOs). Liquid waste disposal is primarily used in swine, egg-producing poultry operations, and some cattle operations. The EPA considers an animal unit to be the equivalent of 1000 pounds of live weight, and large CAFOs are defined as having a minimum of 1000 head of beef cattle, 2500 swine, or 125,000 broiler chickens. The site must also house confined animals for at least 45 days a year and not sustain vegetation during the normal growing season over any portion of the lot to meet the regulatory CAFO definition. CAFO water quality permits regulate waste lagoons, from which liquid waste is generally transferred to a spray field, often of Bermuda grass (Mallin et al., 2015). EPA permitted CAFOs also require Comprehensive Nutrient Management Plans that detail feed, manure, and land management. States can add requirements to permits; for example, all CAFOS are inspected annually in North Carolina. As long as farms maintain a nutrient management plan, spray fields are not regulated by the water quality permit (Centner and Feitshans, 2006). Therefore, the locations or extents of spray fields associated with permitted CAFOs are generally unknown (Patt, 2017). The regulatory assumption is that nutrients and other contaminants from spray fields will remain on site, although this is not always the case (Wing et al., 2002). The environmental risk posed by spray fields is likely underestimated because impacts on agricultural runoff, groundwater recharge, or dispersal of airborne substances cannot be assessed without additional data. Further, public perceptions might not include farmland and spray fields as potential sources of CAFO impacts, resulting in an underestimate of the full risks to their communities posed by this form of industrial agriculture.

Farms with <1000 animal units and CAFOs without liquid waste disposal systems are not regulated in the same way as larger, permitted operations (hereafter, non-permitted CAFOs). Most poultry operations and some cattle operations generate dry litter waste and are thus not required to have water quality permits. In North Carolina, the state Department of Environmental Quality estimates that over 96% of poultry and over 88% of cattle operations use dry waste disposal (Patt, 2017). Waste from these operations is commonly spread on fields as fertilizer, often after transport far from the source farm, complicating the geography of the environmental impact (Patt, 2017).

Our goal was to identify the distribution of potential CAFO risk in a region with high CAFO concentrations as a first step toward improving the ability to evaluate and project the footprint of CAFO land use on environmental quality, including the export of nutrients, microbes, pathogens, and pollutants throughout surface water, ground water, the atmosphere and the terrestrial system. This assessment is also a first step toward assessing the effectiveness of mitigation practices. In some US states, locations of permitted CAFOs are publicly available. For example, an online search identified that Wisconsin, Michigan, Missouri, and North Carolina have publicly available, spatial datasets of permitted CAFOs; however, public records or datasets on the spatial locations are not available for non-permitted CAFOs. In some states, such as North Carolina, private nonprofits (e.g., Waterkeeper and Riverkeeper Alliances) have collected data on non-permitted CAFO locations. As location data are available for both permitted and non-permitted CAFOs, and because of the proliferation of CAFOs throughout the state, North Carolina provides an excellent case study to examine the spatial distribution of CAFOs.

We determined how CAFOs were distributed spatially among and within watersheds in North Carolina. We also evaluated the predominant NLCD land cover classifications surrounding CAFOs. In the United States, the National Land Cover Database (NLCD) is a publicly available dataset that aims to provide information necessary to assess ecosystem health and facilitate nutrient modeling, land use planning, and the development of best land management practices (BMPs) (Homer et al., 2015). The NLCD is scaled to at a 30-m resolution grid and updated every 5 years. Watershed models frequently use NLCD data to inform hydrologic simulations by assuming relationships between land cover and nutrient loading rates, infiltration capacities, or other factors that influence water availability and quality (Karcher et al., 2013). NLCD data layers are considered the most comprehensive, publicly available, datasets of land cover. Previous studies (Burkholder et al., 2007; Rothenberger et al., 2009) have identified the NLCD category "hay/pasture" as animal agriculture and thus, a proxy to identify CAFO locations; however, the EPA defines CAFOs as areas that do not produce crops, forage, or other vegetation. We tested whether CAFO locations are consistently categorized this way or whether they fall into other NLCD categories that are not typically associated with the water quality footprints of CAFOs.

2. Methods

We collected data on permitted CAFO locations from the North Carolina Department of Environmental Quality, which maintains a publicly available spatial dataset (https://deq.nc.gov/cafo-map). Spatial point