TRENDS IN AGRICULTURAL SOURCES OF NITROGEN IN THE ALTAMAHA RIVER WATERSHED

Sylvia C. Schaefer[1] and Merryl Alber[2]

AUTHORS: [1]Institute of Ecology, Ecology Building, University of Georgia, Athens, GA 30602-2202, [2]Department of Marine Sciences, Marine Sciences Building, University of Georgia, Athens, GA 30602-3636.
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Abstract. We compiled USDA Census of Agriculture data on livestock production and agricultural land use along with USGS estimates of fertilizer use to evaluate trends in agricultural sources of nitrogen (N) to the watershed of the Altamaha River. Between 1954 and 2002, the estimated contribution of N from the three major livestock crops (cattle, chickens, and pigs) remained fairly stable, averaging approximately 1,000 kg N/km^2. However, the source of the waste shifted from primarily cattle in 1954 to a mix of cattle and chickens in 2002, due in large part to a ten-fold increase in the number of chickens in the watershed. We did not have fertilizer data through 2002, but between 1954 and 1991 estimated fertilizer N use doubled, from 503 to 1,055 kg N/km^2 (calculated based on the area of the watershed). These changes in N sources were accompanied by decreases in the amount of cultivated land in the watershed. The amount of land classified as harvested cropland decreased from 6,528 in 1954 to 2,448 km^2 in 1992, which suggests there has been an increase in the amount of fertilizer applied per unit area. The amount of pastureland showed an even larger decrease, from 11,421 in 1954 to 3,294 km^2 in 2002, which we take as evidence of increased confinement of livestock. When these numbers are considered in the context of all of the sources of N to the watershed, we estimate that the proportion of agricultural-derived N accounted for approximately 66% of the N input to the watershed in 2000, with the remainder coming from human waste and atmospheric deposition.

BACKGROUND

The Altamaha watershed spans 36,718 square kilometers in Georgia and includes the Oconee, Ocmulgee, and lower Altamaha basins. The watershed is largely rural, with approximately 50% of the land area in forests and 19% in agricultural use (estimated based on 1998 land cover data, NARSAL 2003). Important crops include peanuts, pecans, cotton, and corn. Chickens are the most abundant type of livestock in the region, but cattle and hogs are also important.

Land used for agriculture can be a source of nitrogen to rivers and streams, either via runoff from fertilizer or through the transport of animal waste. A recent study of nutrient loads in the Chesapeake Bay found that 42% of the N load was from agricultural sources (CBF 2004). This study also pointed to increased concentration of livestock into intensive animal production. In a study of nutrient inputs to six southeastern rivers for the period 1986-1990, Asbury and Oaksford (1997) found that either fertilizer or animal waste was the primary source of nitrogen in all cases. Of particular interest here was their finding that N input to the watershed of the Altamaha River basin, which was dominated by animal waste, was the highest per unit area of any of the basins studied.

In this paper we present data on livestock, fertilizer use, and the amount of land used for agriculture in the watershed of the Altamaha River during the last 50 years in order to evaluate trends in agricultural sources of N. Understanding the relative importance of different sources of N is necessary for evaluating the contribution of agriculture to instream nutrient loads, and can help to guide efforts to control non-point source pollution.

METHODS

The United States Department of Agriculture (USDA) conducts a nationwide Agricultural Census approximately every five years, which includes information on crop and livestock production in each county in the US (US Bureau of the Census, 1956-1984; USDA/NASS, 1987-2004). Following the method of Boyer et al. (2002), we compiled data on the production of cows, chickens, and hogs/pigs (the 3 most abundant livestock in the watershed) for each of the 64 counties entirely or partially within the Altamaha watershed for the 11 censuses conducted between 1954 and 2002. Note that the census does not report data for counties where there are only a few farms owning a given type of livestock. In these cases, we divided the difference between the state total and the sum of reported county totals evenly into all the counties in the state for which data were withheld. This assumes the production is evenly distributed among these counties, which may be a source of error. County data were weighted by the proportion of the county in the watershed (calculated using a GIS). Livestock production was converted to animal waste N using literature values for excretion rates, as follows: 58.51 kg N/animal/year for beef cattle, 121.00 kg N/animal/year for dairy cattle, 5.84 kg N/animal/year for hogs and pigs, 0.55 kg N/animal/year for layer chickens, and 0.07 kg N/animal/year for broiler chickens (van Horn 1998).

Estimates of the amount of both crop- and pastureland in the watershed were also obtained from the USDA Agricultural Census. Total cropland in each county was estimated by adding together the acreage of cropland harvested, cropland used only for pasture, and other cropland (which includes fallow land and land on which all crops failed). The totals for pastureland reported here were adjusted to reflect the fact that we assumed that cropland used only for pasture was already accounted for in the total cropland estimate. Data were again apportioned using information on the percentage of each county that actually fell within the watershed.

Nitrogen introduced to the watershed as fertilizer was estimated on the basis of two USGS studies of the amount and type of fertilizer sold in each county in the US and their corresponding N content. Alexander and Smith (1990) provided estimates of fertilizer N for the years 1945-1985 and Battaglin and Goolsby (1994) used a similar methodology for the years 1985-1991. We assumed that all fertilizer bought within the watershed was applied there. We further assumed that these estimates include fertilizer sold for commercial use only, such that fertilizer used for residential purposes would increase these estimates.

RESULTS

The most common types of livestock in the Altamaha River watershed are chickens, cattle, and hogs. The watershed also has smaller numbers of other livestock, such as horses, sheep, and turkeys, but these are not considered here. The number of chickens in the watershed have shown a dramatic increase, from approximately 20 million in 1954 to over 260 million in 2002 (Fig. 1, top). This increase was almost exclusively due to the increase in broiler chickens raised for meat; the standing stock of older layer chickens increased only slightly. The rate of increase in chickens was linear between 1954 and 1992, at which point the slope increases sharply. The total number of cattle and calves remained relatively constant throughout the study period (averaging 382,578), but there was an increase in the number of beef cattle and a concurrent decline in the number of dairy cows (Fig. 1, middle). The number of hogs varied between 300,000 and

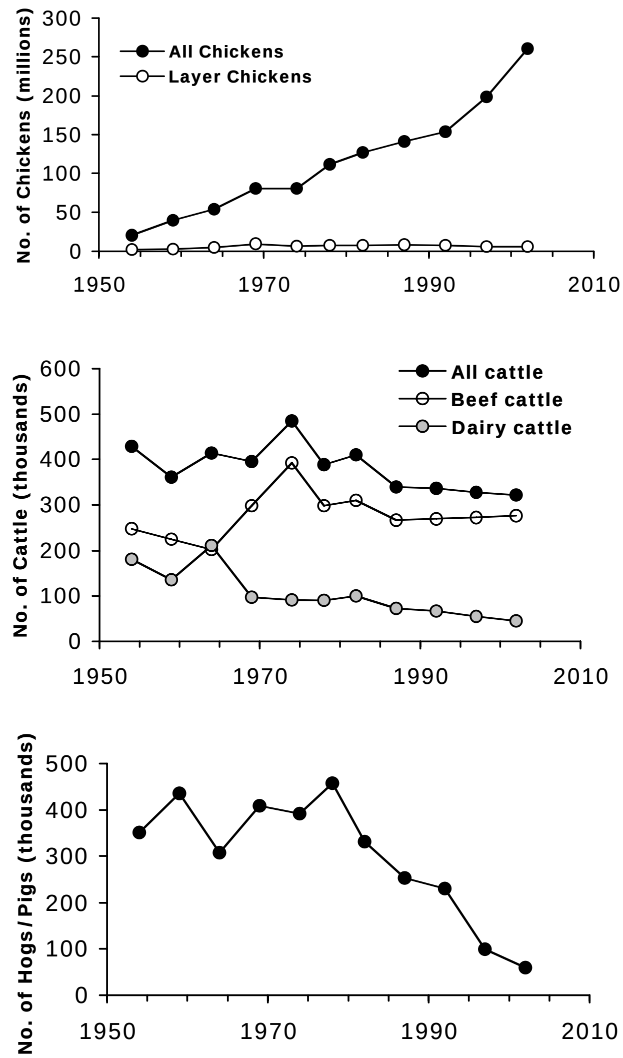

Figure 1. Livestock numbers in the Altamaha watershed, 1954-2002.

450,000 between 1954 and 1959, after which it declined sharply to less than 60,000 animals in 2002 (Fig. 1, bottom).

When we converted information on livestock production into kilograms of nitrogen excreted, the total amount of manure N produced exhibited no clear trend, varying between 985 and 1,238 kg/km^2 of the watershed (Fig. 2). However, the composition of the waste stream changed over time. There was a steady decrease in the amount of manure N contributed by cattle and calves, which is the result of the fact that estimated N production from beef cattle (which have increased in number) is less than that from dairy cows (which have decreased). At the same time, the contribution from chickens increased. In 2002, chickens produced 49% of the total manure N in the watershed, compared with only 6% in 1954.

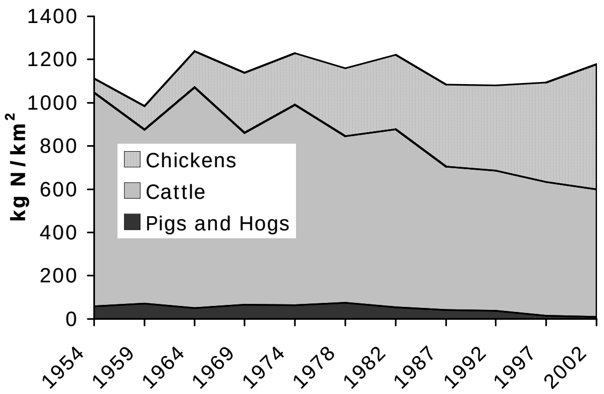

Figure 2. Nitrogen excreted by 3 major livestock types per unit area in the Altamaha watershed, 1954-2002.

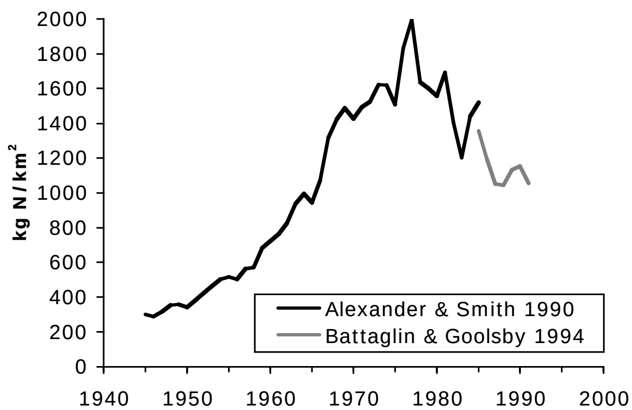

Figure 3. N in fertilizer sold per unit area in the Altamaha watershed, 1945-1991.

The amount of fertilizer N sold in the watershed increased steadily between 1945 (299 kg N/km^2) and 1977 (1,996 kg N/km^2), and then declined to 1,055 km/km^2 in 1991, the last year for which data were available (Fig. 3). It would be informative to have estimates for the past decade to determine whether the decreasing trend has continued, and it would also be useful to include residential use. Although fertilizer sales are reported in the agricultural census, it is not reported in a consistent manner and converting this to N requires additional information on the specific types of fertilizer sold.

Figure 4 summarizes the trends in the amount of agricultural land over the study period. The amount of harvested cropland (which is the amount that is likely to be fertilized) declined from 6,528 km^2 in 1954 to 2,493 km^2 in 1992, after which it remained relatively constant. Total pastureland (which includes cropland used for pasture) declined from 11,421 km^2 in 1954 to 3,294 km^2 in 2002, with most of the reduction occurring by 1964. Total agricultural land decreased from 19,414 km^2 to 6,370 km^2 over the study period, a decline of about two-thirds.

DISCUSSION

Over the past 50 years, the estimated contribution of agriculture-derived nitrogen to the Altamaha River watershed has increased, largely as a consequence of increased fertilizer application. Although the total contribution of N from the three major livestock crops (cows, chickens, and pigs) remains the largest source of nitrogen to the watershed, it has remained fairly stable. However, the relative importance of chickens to the waste stream has increased substantially while that of cows has decreased. The fact that the total amount of agricultural land has decreased over the same period, both in terms of crop and pastureland, implies that there have been changes in agricultural practices as well. Increased fertilizer N coupled with decreased acreage of cropland, particularly the acreage of harvested cropland, suggests increases in the amount of fertilizer per unit area and an increased risk for runoff. This may be due to shifts in the crops that are cultivated, or to changes in growing techniques. It is also possible that some of the commercially sold fertilizer was applied to golf courses and the like, which would not be included in the estimate of cultivated land.

The large increase in chicken production, taken together with decreased pastureland, reflects a national trend towards concentrating livestock in animal feeding operations (AFOs). To the extent that manure is stored in waste lagoons and spread on croplands in excess, these AFOs present a potential risk to water quality in the Altamaha basin. Organic waste spills from AFOs and over-application of manure onto limited cropland can result in both surface and groundwater contamination (Mallin and Cahoon 2003, NRC 1993).

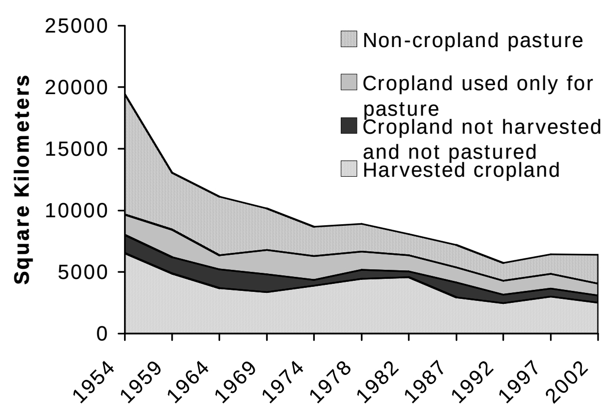

Figure 4. Area in agricultural land in the Altamaha watershed, 1954-2002.

In order to determine the relative importance of agricultural-derived N to the total N budget of the watershed, we developed preliminary estimates of the contribution of nitrogen inputs from both human waste and atmospheric deposition. The contribution of N from human waste was estimated by multiplying the population of the watershed (based on 2000 census data) by a conversion rate of 4.75 kg N/person/y) (Mulder 2003). Atmospheric N deposition was estimated based on data from the National Atmospheric Deposition Program (NADP) and the Clean Air Status and Trends Network (CASTNET) (averaged between 1992 and 2001). These numbers were compared to estimated N excretion from livestock in 2002 (considering all livestock present in the watershed). We did not have a current estimate of fertilizer use so for the present purposes the value calculated for 1991 was used. N input from all sources totaled 3,405 kg/km^2. Out of this, animal excretion comprised the largest portion of the total (35%); fertilizer was second (31%). An estimated 25% was contributed from atmospheric deposition, and 9% from human waste. Note that biological nitrogen fixation may represent an additional source of N inputs to the watershed; however, this is difficult to quantify. The total N estimated here is considerably lower than the estimate of 5,470 kg N/km^2 calculated by Asbury and Oaksford (1997), in large part due to differences in the conversion factors used to estimate animal waste N. In their calculation, animal waste was considerably higher and comprised an even greater proportion of the total input (more than 60%).

Predicting the load of nitrogen to receiving water requires an understanding of N transport and transformations in the landscape, which is a complicated undertaking. However, the information on N sources presented here is useful for evaluating the relative importance of agriculture as a source of N to the watershed and can help to guide efforts to control non-point source pollution. Given that agriculture is an important source of N in the Altamaha River watershed, attention should focus on limiting nitrogen input from both livestock and fertilizer. AFOs, and particularly chicken AFOs, should be encouraged to adopt Best Management Practices, such as Georgia's voluntary Nutrient Management Program for poultry producers, to reduce discharge of excess nutrients. Fertilizer use should be reviewed, as current application rates have not been tallied, but it would clearly be useful to avoid excess fertilization to limit the likelihood of nutrient runoff to rivers and streams.

ACKNOWLEDGMENTS

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