Evaluation of RZWQM2 Model and Management of Poultry Litter as Corn Nitrogen Source in the Mid-Southern United States

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Introduction

Half of the U.S. broiler chicken production was located in the Mid-South. Georgia, Arkansas, Alabama and Mississippi are the top four states with the highest broiler chicken production and associated manure generation. About 48% of total litter in the U.S. was generated in the four states. Better manure management for optimum yield and minimum environmental impact is important for agricultural sustainability. Computer simulation models can extend short-term site-specific field experimental results to other soil and weather conditions. The Root Zone Water Quality Model (RZWQM2) is such an agricultural system model developed by the USDA-ARS for assessing agriculture sustainability and many other agricultural applications with emphasis on water and nutrient management effects on both water and soil quality and crop production.

Objectives

1) Calibrate and validate RZWQM2 (V6.25); 2) Analyze simulated N balance in response to manure rate and timing.

Materials & Methods

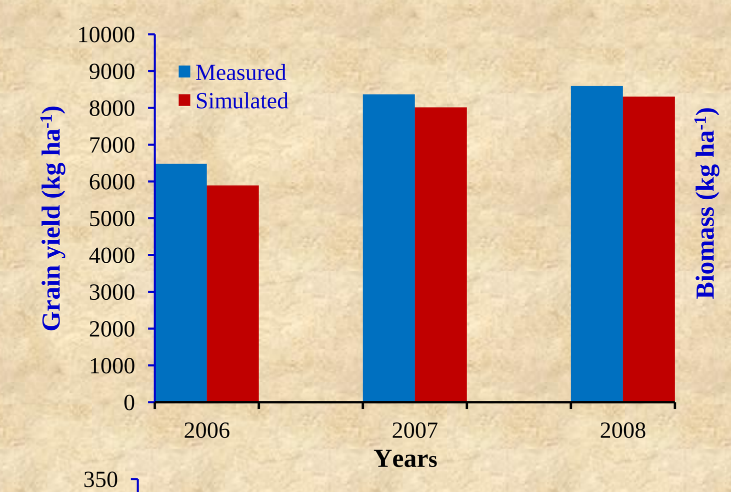
The experiment site was located on a Leeper silty clay loam at the R.R. Foil Plant Science Research Center of Mississippi State University near Starkville, Mississippi. Two rates of litter (9 or 18 Mg/ha) and one rate of NH4NO3-N at 202 kg/ha were applied in the fall and spring of 2006, 2007 and 2008 corn growing seasons.

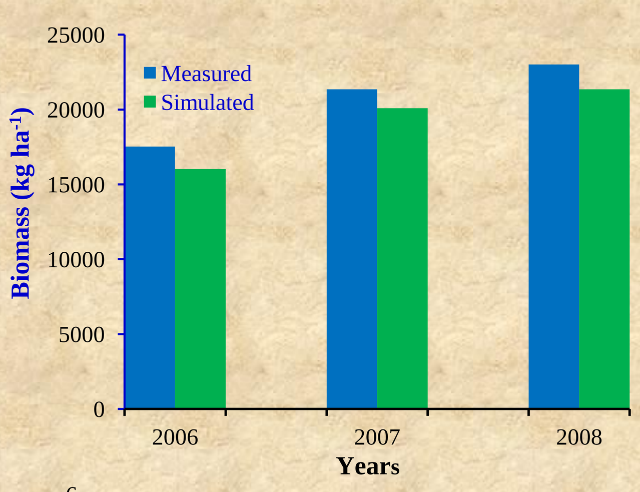
RZWQM2 model was calibrated and evaluated using the three years of field data to simulate nitrogen balance derived from broiler litter applied to a continuous corn production system.

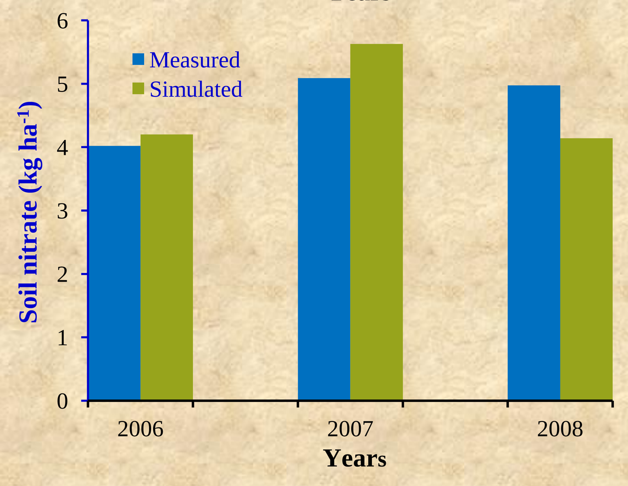
Results & Discussion

Calibration (Figs)

The following plots show calibrated results using three years of data from field applied 18 Mg ha^{-1} litter in spring.







Those plots show that the model under-predicted yield, biomass and plant N uptake, which resulted in higher soil nitrate prediction in 2006 and 2007. RMSE or MAE is still within 10% of the measured mean values for all measurements, it is a very good calibration.

Validation (Table 1)

Moriasi et al. (2007) rated model performance as acceptable when $R^2>0.5$, $EF>0.5$, $d > 0.65$. Table 1 indicated that the calibrated model can simulate corn growth, yield and nitrogen uptake, soil nitrate and soil water content at acceptable resolution.

Table 1. RZWQM2 validation by measured data of five treatments over three years

kg ha^{-1}	n	R^2	EF	d	RMSE	Observed		Simulated	
						Mean	Std	Mean	Std
Yield	18	0.80	0.88	0.87	1333	5864	1943	6418	1964
Biomass	91	0.85	0.96	0.95	2516	7623	6050	8609	5314
LAI	160	0.60	0.82	0.85	0.71	2.35	0.84	2.51	1.09
Grain N	18	0.59	0.90	0.87	31	98	49	102	40
Plant N	70	0.72	0.61	0.89	41	74	66	95	61
Soil nitrate	100	0.57	0.80	0.76	47	48	54	36	50

Simulated N balance (Table 2)

Overall, 76% of N in applied litter was mineralized at the end of three years' experiment. Corn required N was solely supplied by mineralized N from litter applied in spring (**L18S, L9S**) and fall (**L18F, L9F**). Soil profile down to 1.8 m **gained 207 and 306 kg ha^{-1}** of total N after application of 9 and 18 Mg ha^{-1} litter for three years, instead, soil profile **lost 260 kg ha^{-1}** total N after three years' continuous application of mineral fertilizer.

N loss by runoff, volatilization and immobilization are negligible

Simulated results of all treatments indicate that N loss by runoff and volatilization ranged from 0.2 to 5.3 kg N ha^{-1}. Simulated annual N immobilization was similar among the treatments, and was 13, 11 and 9 kg N ha^{-1} for the fertilizer, 18 and 9 Mg ha^{-1}manure treatments respectively.

Leaching and denitrification are N major loss

Most occurred in fall and winter, less during the growing season.

Lost 21% of N in litter as applied in fall

Poultry litter in this region lost its nitrogen value by 21% if it is applied in the fall to fertilize spring-planted corn. Approximately 33% of applied N in litter was mineralized before planting.

Only 24% of N mineralized from litter available to plant

51% and 34% of litter were mineralized in the first year for fall and spring application. After taking N loss by leaching and denitrification into consideration, only 24% of fall and spring applied litter that was mineralized became plant available in the first growing season.

40% & 45% of litter N mineralized in the second & third year

In the following second and third year of repeating fall and spring application, the mineralized percentage increased to 40% and 45% of applied N in litter.

Table 2. Simulated soil N balance (unit: kg ha^{-1}) in 0-1.8m soil profile from Nov. to Apr. for fall litter application and from Apr. to Aug. for spring litter application.

Treatment	Year	Fall litter application N balance major components						Spring litter application N balance major components					
		Soil inN Nov	Total app N in fall	Minera-lized N	N leaching	Denitri-fication N	Soil inN Apr.	Total app N in spring	Minera-lized N	N leaching	Dnitri-fication N	Plant N uptake	Soil inN Aug
L18F	2006	114	491	109	52	34	130		141	6	23	188	52
	2007	138	427	161	38	18	250		132	4	19	220	135
	2008	157	589	233	55	94	237		177	20	50	238	102
L18S	2006	114		33	48	9	90	491	136	5	9	151	52
	2007	136		80	28	5	193	427	180	3	24	222	144
	2008	178		70	34	6	204	589	313	23	79	239	169
L9F	2006	114	246	103	59	8	153		24	8	1	87	79
	2007	95	213	34	58	1	81		56	4	1	92	42
	2008	69	294	48	30	12	75		134	9	16	130	53
L9S	2006	114		29	57	8	151	246	68	10	3	125	78
	2007	136		33	57	2	116	213	118	5	7	156	66
	2008	144		28	45	14	116	294	150	23	12	142	92
AN202F	2006	114	202	26	48	36	257		27	9	1	145	128
	2007	159	202	19	57	10	308		28	10	1	216	110
	2008	337	202	20	56	20	280		30	15	4	214	78
AN202S	2006	114		25	57	8	353	202	25	10	12	210	142
	2007	172		14	81	2	305	202	24	10	5	214	100
	2008	149		9	73	7	277	202	24	16	27	204	53

Conclusions

- Simulated N balance reveals that only 24% of applied total N in litter becomes available to plant in the first growing season regardless of timing.
- Repeated application of litter in the same field increased plant N availability to 40% and 45% in the second and third years, respectively.
- Twenty three percent of the total N in litter applied over the three years was left in soil after harvest in the third year.
- Poultry litter lost 21% of its N value when it is applied in the fall to fertilize spring-planted corn.
- Leaching and denitrification are the pathways of nitrogen loss. On average across the three years, fall application of 18 Mg ha^{-1} litter lost 54 kg N ha^{-1} more than spring application of the same rate, whereas application of 9 Mg ha^{-1} litter lost 59 kg N ha^{-1} regardless of the application timing.