Yield Mapping of On-Farm Cooperative Fields in the Southeast Coastal Plain

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ABSTRACT

Long-term research in the SE Coastal Plain shows that soil variability is widespread. Areas of low-yielding soils within fields often significantly reduce yield below that expected for the typical soils within the field. Farmers, though qualitatively aware of both variability and its effect on yield, appear to perceive that purported economic and environmental benefits of variable-rate technology do not justify the initial cost. They need data on economic effects of field-scale variability to allow rational strategic decisions. A multi-agency project was funded to both document existing variability in on-farm yields and to communicate the significance of the problem. Yield monitors were installed on three combines in Duplin and Sampson Counties, NC. These monitors collected data during 1997, totaling 900 ha of wheat and 120 ha of rye, followed by approximately 1500 ha of corn and similar area of soybean. Preliminary data were processed in vendor's yield mapping software. For further analyses and presentation, they were aggregated into ARC/Info GIS. Dramatic variability was documented both within and among fields, operators, and soil types.

INTRODUCTION

Adoption of site-specific farming in the Southeastern Coastal Plain has lagged that in other areas of the USA and world, despite research that indicates soil and concomitant yield variation is a significant problem. Information that would change the wait-and-see attitude farmers have toward the technology would include evidence of either economic or environmental benefits, which have been promised but not conclusively demonstrated. A clear need exists in the Southeast for data documenting the extent of the variability problem in space and time and for data

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documenting the economic and environmental effect of site-specific management.

Consequently, funding was obtained to address these issues in a multi-agency, watershed-scale cooperative research and demonstration project within the ASEQ (Agricultural Systems for Environmental Quality) projects. The CSREES-funded project, titled "Management Practices to Reduce Nonpoint Source Pollution on a Watershed Basis", included cooperators from Biological and Agricultural Engineering and from Cooperative Extension Service, both of North Carolina State University; USDA-NRCS at the state, district, and county levels; USDA-ARS at Florence, SC; US Geological Survey; and several local farmer-cooperators. This project followed a 5-yr documentation of the conditions in the Herrings Marsh Run watershed, for which the water quality status was described by Stone et al. (1995). Within the current project, the site-specific management effort was one of three objectives. Paraphrased for this context, this objective was to improve and adopt precision farming as a best management practice, with the following subobjectives: (i) to show existing variation in crop yield with combine monitors, (ii) to use computer models to predict yield and relate precision farming to water quality, and (iii) to improve and encourage site-specific nitrogen management. The purpose of this paper is to present preliminary results for the first subobjective.

MATERIALS AND METHODS

Two farmer cooperators were involved in the project. Most of the data collected were from Duplin and Sampson Counties, North Carolina. Fields in Wayne, Bladen, and Pender Counties were also studied (Fig. 1), but most of these fields were proximal to the Duplin or Sampson County borders.

The cooperator based in Duplin County operated two John Deere 9500[1] (Deere & Co., Moline, IL) combines with 20-ft grain and 4-row corn headers. Both had GreenStar yield monitors installed in March 1997. The DGPS units used satellite-based differential correction. They wrote to 5-MB data cards, which were read into JDMap V2.1.1 software.

The cooperator based in Sampson County operated two Case 2188 combines with 20-ft grain and 4-row corn headers. One machine previously had an AFS yield monitor without DGPS. A DGPS unit (GPS2000, AgLeader Technology, Ames, IA) was installed by project personnel on that machine before wheat harvest in June 1997. This unit used the Ft. Macon Coast Guard beacon for differential correction. The unit wrote to 1-MB cards, which were read into AgLink V5.2.1 (AGRIS Corp., Roswell, GA) software.

[1] Mention of trademarks is for information only. No endorsement implied by USDA-ARS or its cooperators.

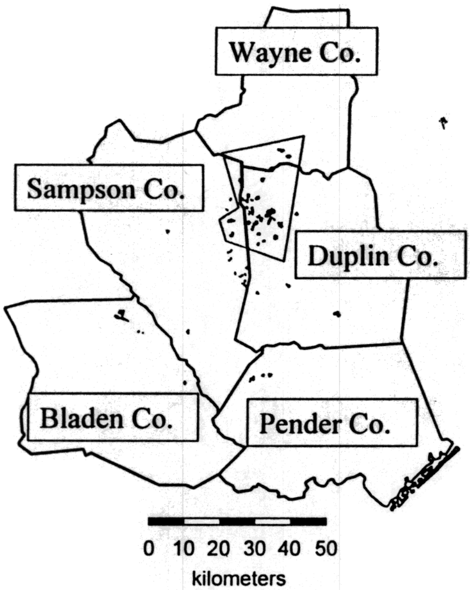

Fig. 1. Location of all corn and wheat on-farm cooperator's fields harvested during the 1997 harvest season. The shaded area encloses fields for Cooperator 1; all other fields are Cooperator 2.

Project personnel set up the monitors, trained the operators in daily monitor-related tasks, and calibrated the monitors using load totals determined with portable truck scales or scale tickets. During harvest, the operators entered field names, crops, and activated the data collection. Project personnel periodically exchanged cards and read data into a personal computer to prepare preliminary yield maps. Data were also transmitted to the server at USDA-ARS Florence via dial-up networking on a regular basis. In Florence, these data were examined for DGPS problems and operator artifacts, such as erroneous crop codes, field names, turns and trips across the field to unload with the header down, etc. Errant passes were straightened, null passes and turns were deleted, and field names and crop codes were corrected as possible. Data from the two combines for the Duplin County cooperator were merged, which required adjacent-pass comparisons to calibrate one of the two combines on some fields. Data from all sources were merged into one comprehensive data set using the AGLink software, then exported to an ASCII format for importing into ARC/Info.

For Duplin County, the soil survey (Goldston et al., 1958)) was available in GIS format. The Duplin County yield data from both cooperators was overlaid in ARC/Info to determine the soil map unit (Table 1) associated with each data point. The resulting ARC/Info table was exported to SAS (SAS Institute, 1990) for summary statistics by soil type. Summary statistics and analyses conducted in SAS include analysis of variance by soil type (for Duplin County data only) and distributions of yield by field, operator, and for the whole data set.

Table 1. Descriptions of soil map units in Duplin County, North Carolina.

Unit	Soil name	Soil Description
AuB	Autryville LS	Loamy, siliceous, thermic Arenic Paleudults
BbA	Bibb SL	Coarse loamy, siliceous, acid, thermic Typic Fluvaquents
BnB	Blanton fS	Loamy, siliceous, thermic Grossarenic Paleudults
FoA	Foreston fS	Coarse loamy, siliceous, acid, thermic Typic Fluvaquents
GoA	Goldsboro LS	Fine loamy, siliceous, thermic Aquic Paleudults
JoA	Johns LS	Fine-loamy over sandy or sandy-skeletal, siliceous, thermic Aquic Hapludults
LnA	Leon S	Sandy, siliceous, thermic Aeric Alaquods
LsB	Lucy LS	Loamy, siliceous, thermic Arenic Kandiudults
McC	Marvyn LS and	Fine-loamy, siliceous, thermic Typic Kanhapludults
	Gritney SL	Clayey, mixed, thermic Aquic Hapludults
NoA	Norfolk LS	Fine-loamy, siliceous, thermic Typic Kandiudults
NoB	Norfolk LS	Fine-loamy, siliceous, thermic Typic Kandiudults
OrB	Orangeburg LS	Fine-loamy, siliceous, thermic Typic Kandiudults
PnA	Pantego L	Fine-loamy, siliceous, thermic Umbric Paleaquults
RaA	Rains LS	Fine-loamy, siliceous, thermic Typic Paleaquults
RuB	Rumford SL	Coarse-loamy, siliceous, thermic Typic Hapludults
ToA	Torhunta fSL	Coarse-loamy, siliceous, acid, thermic Typic Humaquepts
WoA	Woodington LS	Coarse-loamy, siliceous, thermic Typic Paleaquults

RESULTS AND DISCUSSION

Representative Yield Maps

Within the project, 1997 corn yield maps demonstrated wide variation both within and among fields. Three fields for cooperator 1 (Duplin Co.) averaged 5.3 Mg ha^{-1} (Fig. 2). These three fields averaged from 4.3 to 6.2 Mg ha^{-1}, and areas within the fields ranged from <1 to approximately 10 Mg ha^{-1}. Patterns in the yield maps suggest soil type variations consistent with Carolina Bays, including bounding arcs with dramatically reduced yields. In Field 104, the areas south of the Carolina Bays consistently yielded above 7 Mg ha^{-1}, and in field 102, almost all yielded below 7 Mg ha^{-1}. For the same cooperator, six additional fields with essentially the same overall average (Fig. 3) show that the variation is widespread. Wheat yield maps not shown here show similar patterns. In the second year of the project, we hope to find whether corn yield patterns correspond to wheat yield patterns in the same fields.

Representative Distributions of the Yields by Cooperator and Fields

Wheat 97

Cumulative frequency distributions of wheat yield (Fig. 4) showed a difference in variation but no real difference in median yield between cooperators. Frequency distributions by field and cooperator (Fig. 5) show the reason for that result. There are 5 fields for Cooperator 2 in which the median yield is less than the

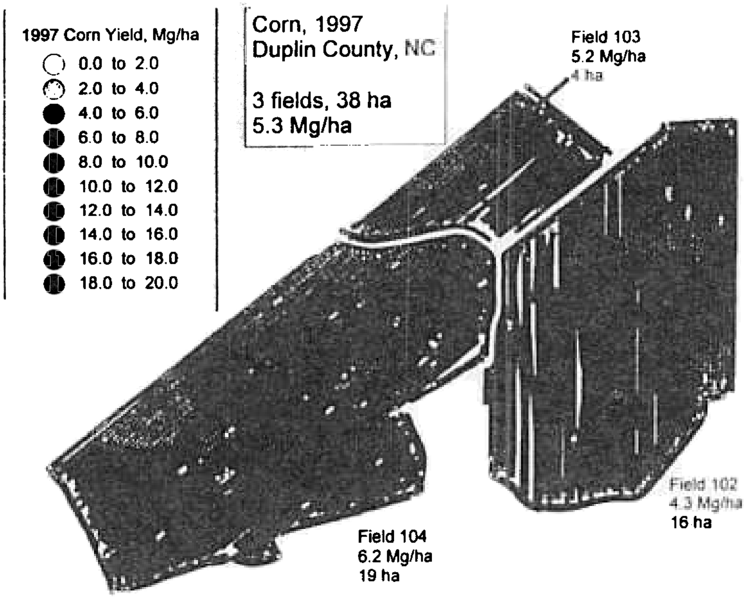

Fig. 2. Yield maps for three representative corn fields in Duplin County, NC.

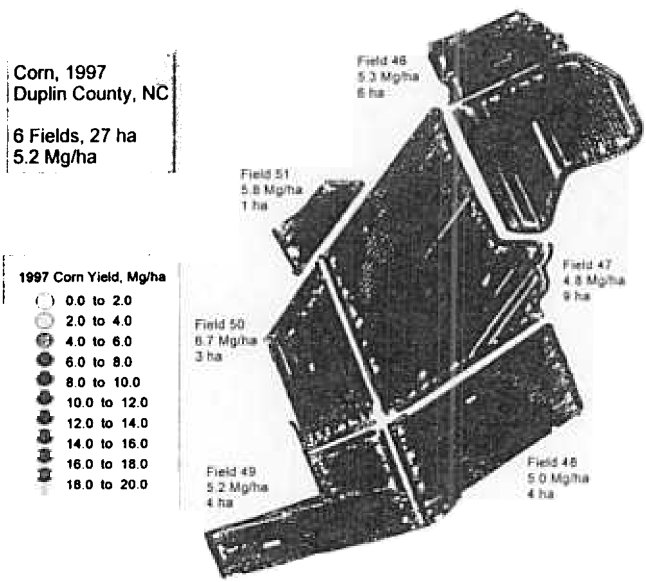

Fig. 3. Yield maps for six representative corn fields in Duplin County, NC.

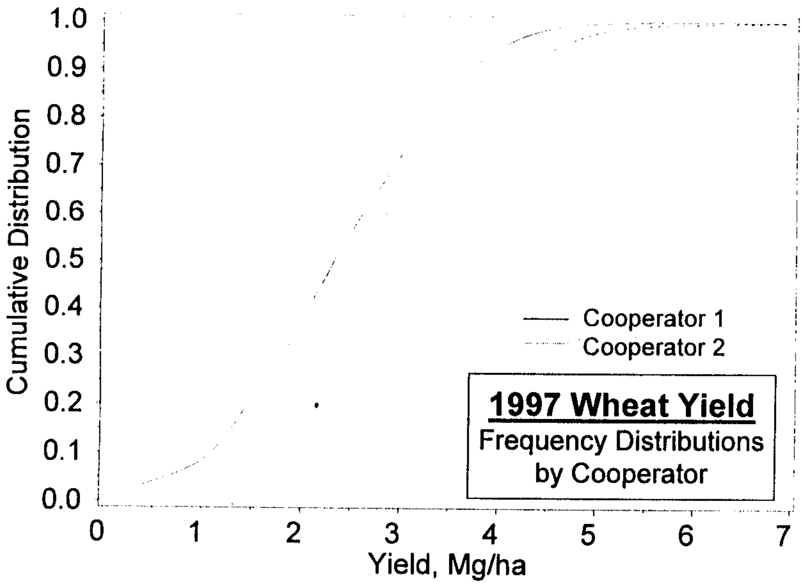

Fig. 4. Cumulative frequency distribution of 1997 wheat yield by cooperator.

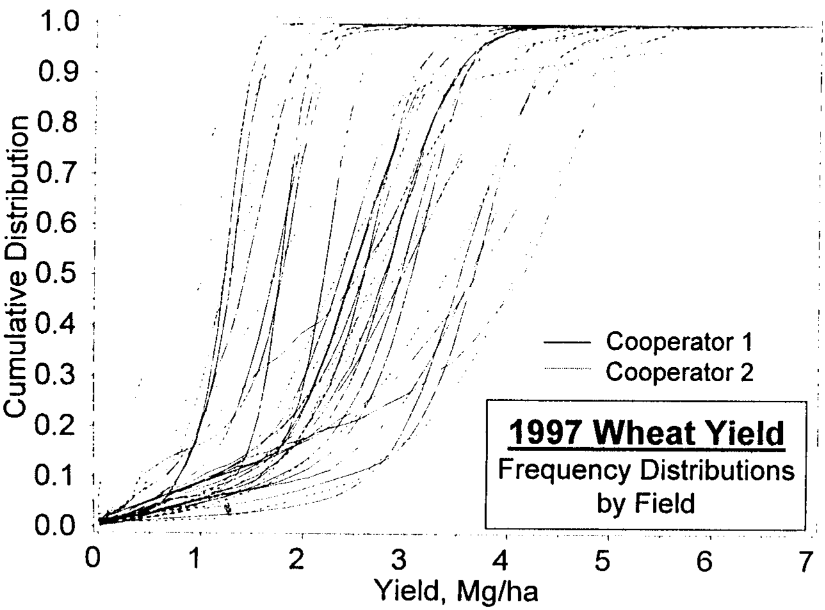

Fig. 5. Cumulative frequency distribution of 1997 wheat yield by field and cooperator.

minimum median yield for all fields of Cooperator 1. Distributions within most fields for Cooperator 2 have longer tails on the upper end, which offsets the five low-yielding fields.

Corn 1997

Similar results occurred for the 1997 corn yield data. The median for Cooperator 1 (Fig. 6) is approximately 0.5 Mg ha^{-1} higher than that for Cooperator 2, but the main difference was in the variation shown. Part of the reason for these differences came from the types of farming operations used by the two cooperators. Cooperator 1 primarily harvested rainfed fields in which he managed the crops, presumably uniformly. On the other hand, Cooperator 2 harvested additional fields for other growers, including several that were irrigated or used as spray fields for swine wastewater. The distributions by fields and cooperators (Fig. 7) supported this observation. The bulk of cooperator 1 fields clustered near the central portion of the graph, while those for Cooperator 2 fell into three groups. There were two fields with median yield less than 1 Mg ha^{-1}, a cluster with medians similar to those for cooperator 1, and five with substantially higher yields, all greater than 8 Mg ha^{-1}.

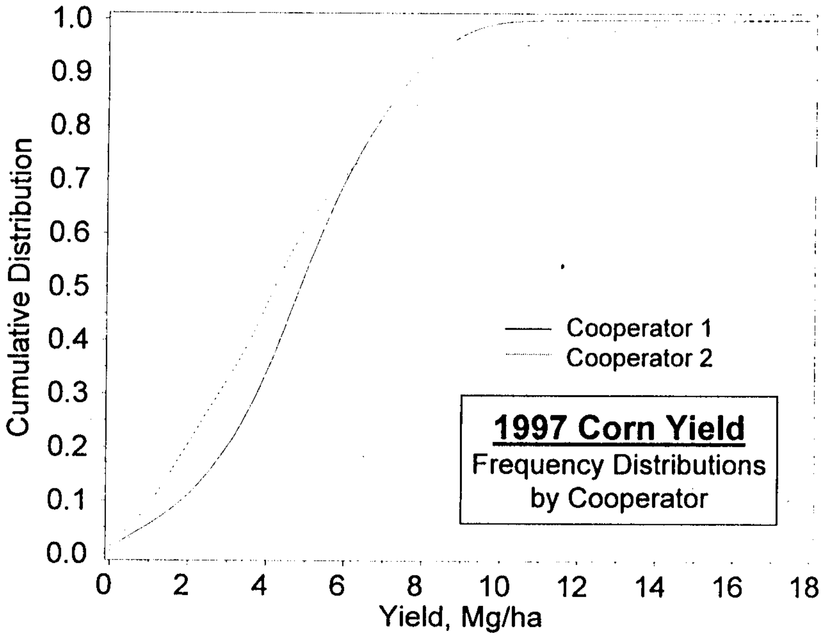

Fig. 6. Cumulative frequency distribution of 1997 corn yield by cooperator.

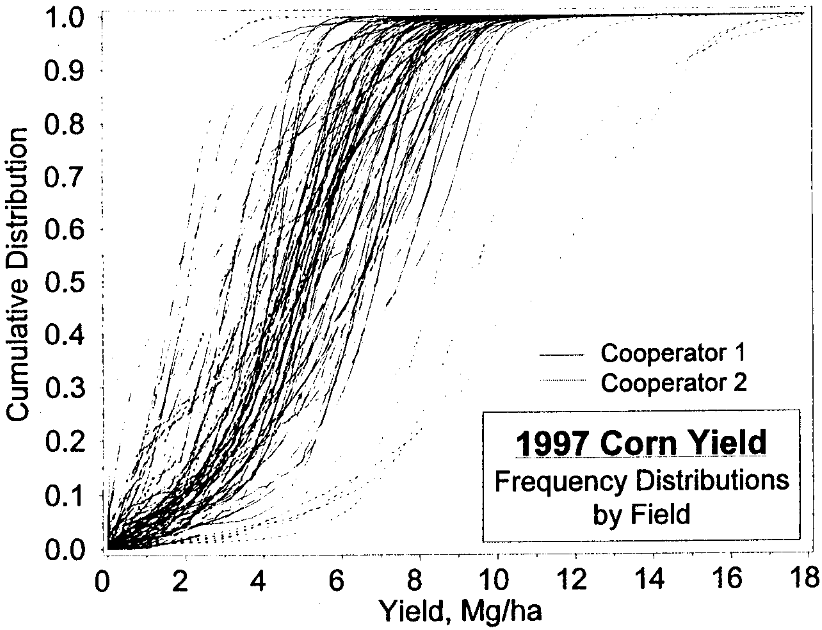

Fig. 7. Cumulative frequency distribution of 1997 corn yield by field and cooperator.

Analysis by Map Unit

The corn and wheat results for each of the soil map units in Duplin County are shown in Table 2. Mean wheat yields ranged from 1.2 to 3.5 Mg ha^{-1}, and mean corn yields ranged from 3.1 to 5.8 Mg ha^{-1}. In general, the lower yields for wheat corresponded with the lower yields for corn. In contrast, the soils with the two highest wheat yields had intermediate corn yields, and vice versa. The yield distribution by soil map unit for wheat (Fig. 8) shows a wide variation in yield distribution, with median yields ranging from <1.0 Mg ha^{-1} for LnA to approximately 3.5 Mg ha^{-1} for ToA. The yield distributions for corn (Fig. 9) showed relatively less variation in the median, with values ranging from approximately 3 Mg ha^{-1} for McC to about twice that for the two Norfolk soils. For the record, the irrigated fields discussed above, in Pender County, did not enter into the analysis by map unit.

Table 2. Means and standard deviations of yields, number of points, and area harvested of soil map units in Duplin County.

	Corn				Wheat			
	Yield	Std	N	Area	Yield	Std	N	Area
Soil	Mg/ha	Mg/ha	-	ha	Mg/ha	Mg/ha	-	ha
AuB	3.88	2.39	8141	9.96	2.16	0.87	17360	17.98
BbA	3.56	2.75	755	0.74	1.60	1.04	152	0.17
FoA	4.72	2.50	20496	23.87	2.57	1.08	20173	25.76
GoA	4.80	1.96	88101	109.36	2.83	1.04	78308	97.38
LnA	none				1.18	1.17	3148	8.39
LsB	3.92	1.80	1222	1.71	1.86	0.67	2487	3.21
McC	3.07	2.23	1209	1.53	1.38	0.62	3442	4.89
NoA	5.79	2.57	58749	74.42	2.18	0.95	44326	54.46
NoB	5.65	2.71	15647	18.96	2.48	0.88	19886	22.22
OrB	none				2.40	0.80	7272	6.95
PnA	3.98	2.31	608	0.65	2.53	0.80	8982	7.01
RaA	4.71	2.01	120560	146.35	2.31	1.02	80770	109.16
RuA	none				2.84	0.92	1887	2.25
RuB	4.42	2.39	727	0.76	none			
ToA	4.30	1.93	7098	17.65	3.53	1.01	3675	14.76
WoA	3.94	2.19	5841	9.65	3.08	1.16	8879	34.65
non-Duplin	4.89	2.82	240588	482.39	2.18	1.32	12308	48.72
Total	4.90	2.51	569742	898.02	2.46	1.06	313055	457.94
LSD(0.05)	0.15				0.07			

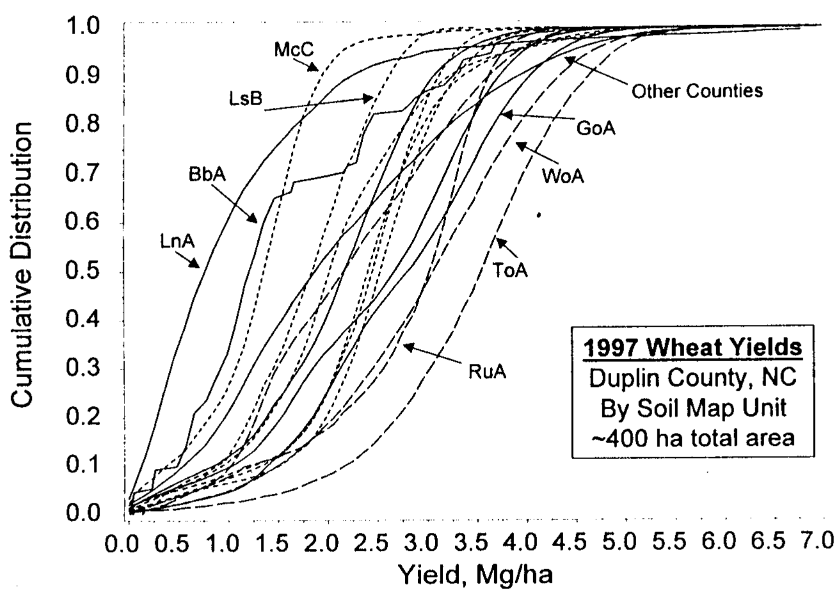

Fig. 8. Cumulative frequency distribution of 1997 wheat yield by soil map unit. The combined curve for all fields outside Duplin County, for which soil information is not available in digital form, is shown for comparison.

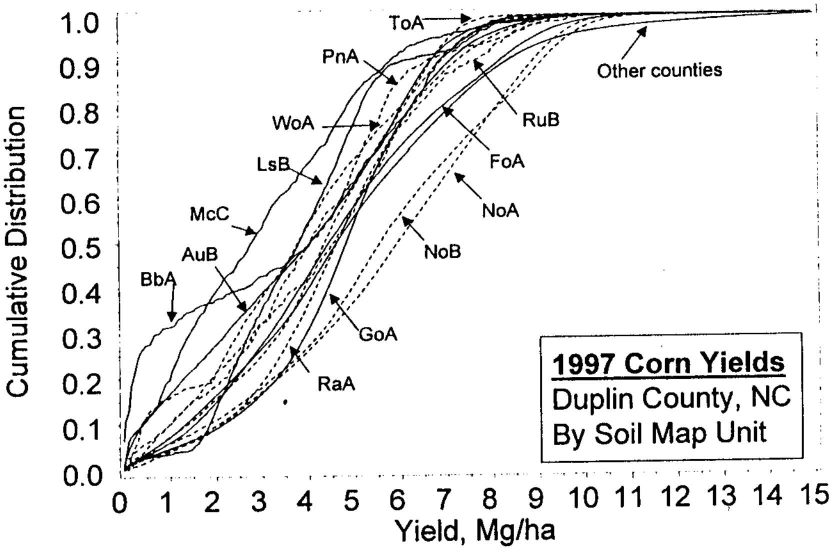

Fig. 9. Cumulative frequency distribution of 1997 corn yield by soil map unit. The combined curve for all fields outside Duplin County, for which soil information is not available in digital form, is shown for comparison.

SUMMARY AND CONCLUSIONS

Preliminary results from this on-farm cooperative research project documented the wide variation in wheat and corn yield during the 1997 season. Variation in yield within and among fields reflected differences in both operators and in soils. Correlation of yields to USDA-NRCS soil map units documented the distinctly different distributions of both wheat and corn yields on different soils. Second-year data should document persistence or variation in yield patterns for each crop. These data will provide a basis for development of model inputs and a dataset to compare with model outputs. They will also serve as a basis for development of site-specific fertilizer recommendations.

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