The Extent of Farm Drainage in the United States

D.B. Jaynes and D.E. James
USDA-ARS-NSTL
Ames, IA

Introduction

Modern production agriculture in much of the central and eastern United States would not be possible without the extensive drainage network that has been built up starting ~1870. While an unqualified success for increasing agricultural production, research over the past quarter century has illustrated the important role drainage plays in determining the quality of surface water. Much of the nitrate that enters the Mississippi river and contributes to hypoxia in the northern Gulf of Mexico comes from tile drainage of agricultural fields in the Midwest. Because of its distributed nature, extended installation history, incomplete maps of subsurface drains, and the lack of a systematic survey in recent years, the current extent of drained cropland in the US is poorly known. In this study, we investigate using the information contained in the NRCS STATSGO soils database in conjunction with the 1992 National Land Cover Dataset (NLCD) compiled by the USGS to estimate the distribution and extent of agricultural drainage across the U.S.

History

Table 1. Drainage census results

Census Year	Drained land (1,000,000 ac)
1920	53.0
1930	44.5
1969	59.5
1974	42.8

In 1920, 1930, 1969, and 1974 on farm drainage data was collected in Censuses of Agriculture. Information from organized drainage projects was also collected during this period in Censuses of Governments. Results of the on-farm drainage enumeration were found to be unsatisfactory as indicated by wild swings in the total area of drainage reported (Table 1). To improve drainage estimates, the 1978 Census of Drainage used state and county SCS personnel to estimate drainage areas for every county. While an improvement over farmer surveys, these estimates were uneven from state to state as indicated by reporting precision spanning 3 orders of magnitude. Starting in 1977 the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS), in cooperation with the Iowa State University Statistical Laboratory started collecting data for the National Resources Inventory (NRI). The NRI is a statistically-based survey that has been designed and implemented using scientific principles to assess conditions and trends of soil, water, and related resources on non-Federal lands in the United States. In 1982 and again in 1992, information on both subsurface and surface drainage was explicitly collected in the NRI and summarized by state and county. In 1987, G.A. Pavelis used land capability class and crop information collected in the 1982 NRI to estimate the extent of drained cropland (Pavelis, 1987). These estimates were published for selected states in the 1987 USDA publication “Farm Drainage in the United States”. Thus, there are 4 estimates of drained cropland from the 70’s, 80’s, and 90’s, but no estimates since. In addition, these surveys used a broad definition of “cropland: or “land in farms”. While appropriate for the goals of the specific surveys, these definitions are overly broad when trying to answer the question of how drainage impacts water quality, because it is drainage from primarily row crops and other annuals that contribute high levels of nutrients to surface waters and not drainage from pastures, hay fields, orchards, or timber (Amatya et al., 1998; Randall et al., 1997; Berstrom, 1987). There are no accurate estimates of drainage of row crop and annual crop production fields currently available.

Methods

We used a GIS approach to estimate the row crop and annual cropland that in drained. Our primary assumption was that row crop and small grains growing on soils that require drainage must have artificial surface or subsurface drainage. Drainage is required for these crops not only to provide for an aerated root zone but to also allow for adequate trafficability during planting. We used the 1992 National Land Cover Database (NLCD) developed by the USGS and USEPA to estimate agricultural land in annual and row crop production (http://landcover.usgs.gov/natllandcover.php). This database was developed from 1992 Landsat thematic mapper imagery and other data. We used the NLCD classifications Row Crops (82), Small Grains (83), and Fallow (84) to indicate cropland (Fig 1). Other possible classifications such as Pasture/Hay (81) or Orchards/Vineyards/Other (61) were not included as our focus was on the water quality impact of drained land growing annual crops. To determine soils requiring drainage, we used the NRCS STATSGO database (http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/). Numerous soil properties and interpretations within this database can be used to indicate the need for drainage. Examples include the land capability class modifier "water", soil drainage class information such as "poorly drained", and the hydrologic class modifier "D". Estimates of percentages of each STATSGO map unit meeting the selected criteria were determined by querying the STATSGO data base. The results were converted to a raster format and, using the NLCD coverage of cropland as a mask, used to estimate the total land area meeting the criteria for each classification. Total area meeting the criteria and the fraction of this area were computed for each county and state and projected for the continental U.S. using GIS.

Results

Percent area meeting the soil and land cover criteria are summarized for the 23 most intensively drained states in Table 2 for several of the soil attributes examined. While there are no absolute criteria to compare these estimates against, the earlier drainage surveys are a useful comparison and their estimates are also listed. Several observations from this table can be made:

- The Pavelis, 1987 estimates agree with the 1978 Census results as this was his intention. Noted exceptions are Indiana and Ohio where the Pavelis, 1987 estimate is substantially greater. (We were unable to reproduce the results from Pavelis, 1987 for land capability class IIw, IIw, IVw using the same 1982 NRI date even though our total land use estimates were very close to those reported in Pavelis, 1987. We were also unable to reproduce Pavelis, 1987estimates of drained lands because of insufficient detail on the method used.)
- The explicit 1982 and 1992 NRI drainage estimates are self consistent with a slight increase in drainage area during the 10 yr.

- In general, the 1982 and 1992 NRI estimates agree with the estimates from the 1978 Census and Pavelis, 1987 for Midwest states but are vastly different for Eastern and Southern states. This is probably a reflection of the different definitions for “agricultural land” used in the surveys and the dominance of annual crop production in the Midwest. For example total “land in farms” used in the 1978 Census totaled 1,026 x 106 ac whereas the NLCD total for “croplands” was 309 x 106 ac. While much of this difference is due to grazing lands, some of the difference is due to the 1978 Census including pastures and timber – land uses prevalent in the South but not of interest in this study. Lower estimates for the NRI surveys for Midwestern states may also reflect the difficulty in identifying lands with subsurface drains where this practice is common.
- The NRI estimates for drained land in Delaware were particularly lower than the estimates from the 1978 Census. This may be due to in part to loss of cropland to urbanization.
- There is a great range in estimates for the STATSGO/NLCD estimates depending on the suite of soil properties or characteristics chosen as indicative of drainage need.
- None of the STATSGO/NLCD estimates agree well with either the 1978 Census or NRI estimates for every state.
- For Midwest states except Nebraska, the STATSGO/NLCD “w” land capability class gives results intermediate between the 1978 Census and the 1992 NRI.
- Using poorly drained soils as an indication of drainage requirement gave estimates close to the “w” land capability class for most Midwestern states, but including “somewhat poorly drained” soils gave better agreement for Indiana, Ohio, and the Eastern and Southern states.
- Using the hydrologic class “D” gave results much closer to the poorly drained estimate than the “w” land capability class.

Discussion

While there is no absolute criteria for comparison because of the different definitions used for drained agricultural land in the historic surveys, it appears that the water, “w”, limitation for land capability classes II, III, and IV combined with the NLCD row crop and small grain land cover classification give a reasonable estimate of the extent of drained lands used for annual-crop production. Pavelis, 1987 also used the “w” land capability class as one of the criteria to estimate drained lands. Spatial distributions for the different estimates are illustrated in Figures 2-5 where percent drained lands for the different estimates are plotted by county. Overall, the spatial pattern of drainage is similar for each estimate. For the 1978 Census, more drainage is identified for Western states as that survey included drainage to remove salts and lower high water tables in irrigated lands. Neither land capability class nor drainage class for the STATSGO/NLCD estimates captured the prevalence of surface drainage used in North Carolina and surrounding states.

Some of the differences between drained land estimates are due to differences in what was considered “agricultural land”. The 1978 Census used the most liberal definition, while the STATSGO/NLCD estimates made in this study were the most restrictive as it focused on drained land used for production of annual crops. Another source of disagreement may be what is considered “drained land”. For example in Iowa, subsurface drains were installed in random or distributed patterns linking a series of wet areas, typically depressions or potholes, to a surface outlet. It is not uncommon for an 80 ac field to have subsurface drains directly draining only about 10-15 ac of the field. In the surveys, it is unclear if the entire 80 ac of this field was considered drained or just the 10-15 ac that are directly drained. In our STATSGO/NLCD approach only the poorly drained soils are counted as drained, but at a 30-m resolution. For the Census of Agriculture it is unclear if the entire 80 ac was counted or just the poorly drained fraction. Thus, to some extent, the different estimates of drained lands are comparing apples to oranges. These differences affect more the absolute estimate of drained acres rather than the spatial distribution across the U.S.

Finally, the approach used here could be refined by using the more recent 2001 NLCD database or substituting SSURGO data for STATSGO data. In addition, higher resolution spatial maps can be easily produced even from the STATSGO data by estimating drained area per map unit rather than aggregating up to county or state levels. An example of the latter is shown in Figure 6 for cropped land having the STATSGO Land capability class (LCC) IIw, IIIw, IVw soil attribute. Using SSURGO data these types of maps could be prepared at the county or watershed scale.

Citations

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Bergstrom, L. 1987. Nitrate leaching and drainage from annual and perennial crops in tile-drained plots and lysimeters. J. Environ. Qual. 16:11-18.

Pavelis, G.A. 1987. Economic survey of farm drainage. *In* G.A. Pavelis (ed.) Farm drainage in the United States: History, status, and prospects. USDA Misc. Publ. 1455. U.S. Gov. Print. Office. Washington, DC.

Randall, G.W., D.R. Huggins, M.P. Russelle, D.J. Fuchs, W.W. Nelson, and J.L. Anderson. 1997. Nitrate losses through subsurface tile drainage in conservation reserve program, alfalfa, and row crop systems. J. Environ. Qual. 26:1240-1247.

	Existing Estimates				STATSGO/NLCD													
STATE NAME	1978 Census	Pavelis, 1987	National Resouce Inventory, 1982	National Resouce Inventory, 1992	STATSGO: land capability classes IIw, IIIw, IVw	STATSGO: poorly and very poorly drained soils	STATSGO: poorly, very poorly, and somewhat poorly drained soils	STATSGO: hydrologic classes A/D, B/D, C/D,D	STATSGO: poorly, very poorly, and somewhat poorly drained soils with hydrologic classes A/D, B/D, C/D, D	STATSGO: poorly and very poorly drained soils with slopes ≤ 2%	STATSGO: poorly and very poorly drained soils with slopes ≤ 5% and watertable < 2'	STATSGO: poorly, very poorly, and somewhat poorly drained soils with hydrologic classes A/D, B/D, C/D, D and %clay < 40	STATSGO: poorly and very poorly drained soils and %clay < 60	STATSGO: watertable < 2'	STATSGO: watertable < 3'	STATSGO: poorly, very poorly, and somewhat poorly drained soils with %clay < 40	STATSGO: watertable < 3' and %clay < 40	STATSGO: prime farmland when drained, protected from flooding, or irrigated and drainged
Midwest	%																	
Illinois	27	27	15	17	23	16	34	17	17	16	16	15	16	32	48	32	31	18
Indiana	29	35	24	30	28	14	29	15	14	14	14	14	14	31	46	29	33	26
Iowa	21	22	17	18	21	17	29	16	16	15	16	15	17	23	44	23	17	15
Michigan	15	15	7	8	10	7	14	7	7	7	7	7	7	10	20	13	14	10
Minnesota	12	12	10	12	15	16	22	15	15	16	16	13	16	21	34	16	14	12
Missouri	9	9	4	5	8	5	11	7	6	4	5	3	4	9	13	6	8	6
Nebraska	2	2	0	0	5	1	3	4	2	1	1	1	1	14	27	2	3	1
North Dakota	5	5	8	8	7	9	15	11	8	9	9	5	9	10	46	10	6	2
Ohio	19	28	23	26	22	12	25	15	14	12	12	9	12	21	33	19	24	22
Wisconsin	6	6	3	4	5	4	7	4	4	4	4	3	4	5	17	6	7	4
South																		
Arkansas	21	21	3	4	15	10	16	13	13	10	10	6	5	17	21	9	12	9
Louisiana	24	24	14	16	13	8	16	13	13	8	8	7	5	15	20	10	11	0
Mississippi	19	19	3	3	9	7	12	9	9	7	7	3	2	13	15	5	7	2
Texas	3	3	1	1	1	0	2	6	1	0	0	0	0	8	14	0	0	0
East																		
Delaware	35	35	9	9	12	9	10	10	10	9	9	10	9	24	31	9	15	5
Florida	18	18	6	7	4	4	5	4	4	4	4	4	4	5	8	5	5	0
Georgia	4	4	1	1	2	3	4	3	3	3	3	3	3	7	13	4	4	0
Maryland	19	19	5	5	5	4	5	4	4	4	4	4	4	6	11	4	7	3
New York	1	3	3	3	2	1	2	1	1	0	0	0	0	0	4	1	3	1
North Carolina	17	17	8	9	4	5	6	5	5	5	5	5	5	8	13	6	7	2
South Carolina	9	9	4	4	4	4	5	4	4	4	4	3	4	8	14	5	6	0
Tennessee	4	4	1	1	3	2	3	2	2	2	2	1	1	3	7	2	5	0

Table 2. Percent of total state area estimated to be drained

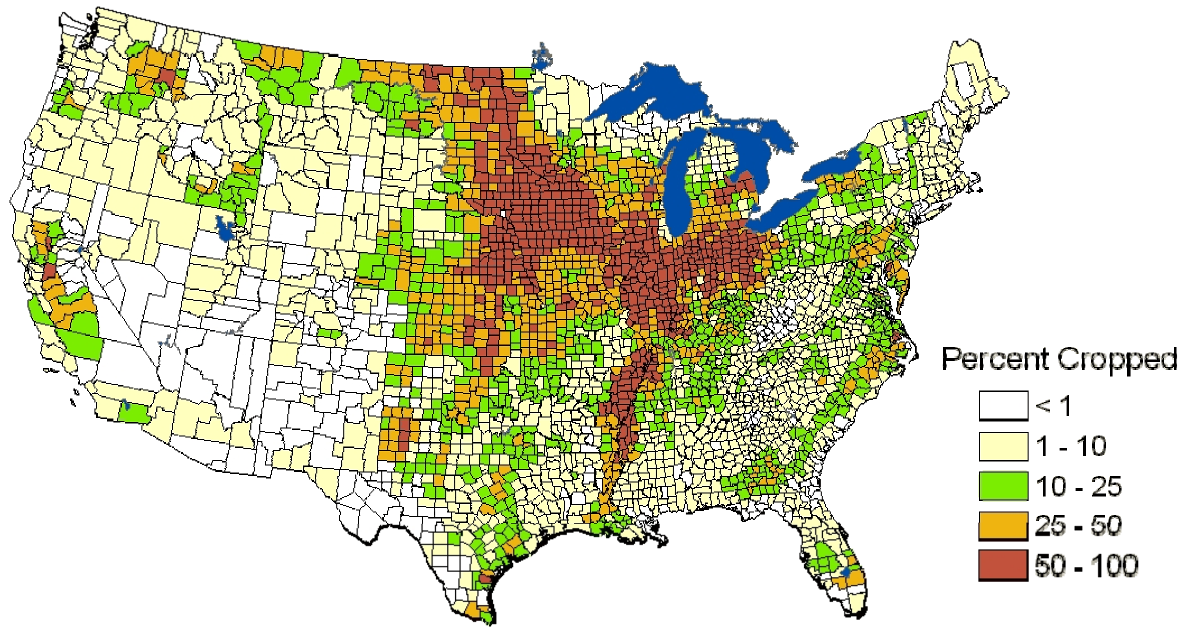

Figure1. Row crops, small grains, and fallow land as defined by NLCD

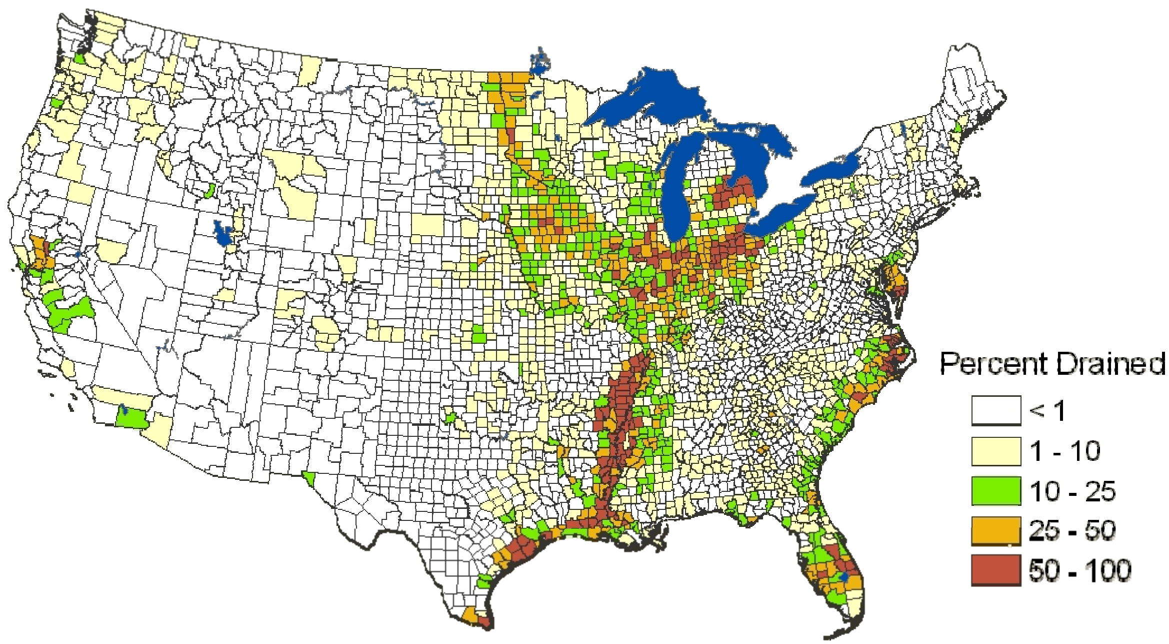

Figure 2. Percent of total county area estimated to be drained cropland by 1978 Census of Agriculture.

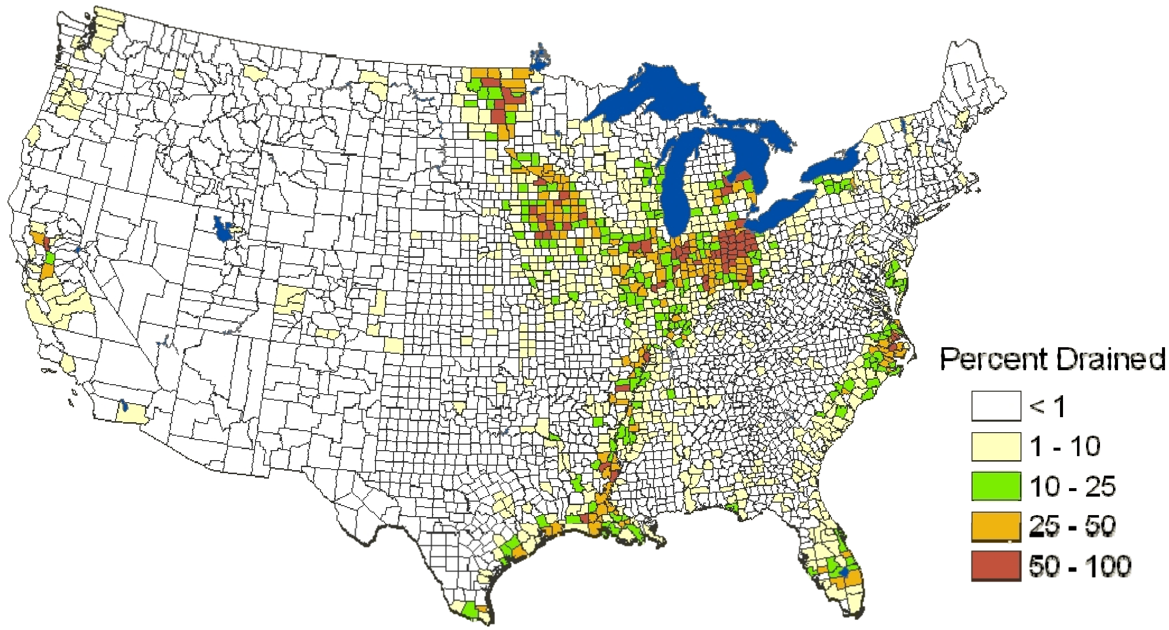

Figure 3. Percent of total county area estimated to be drained by 1992 NRI survey.

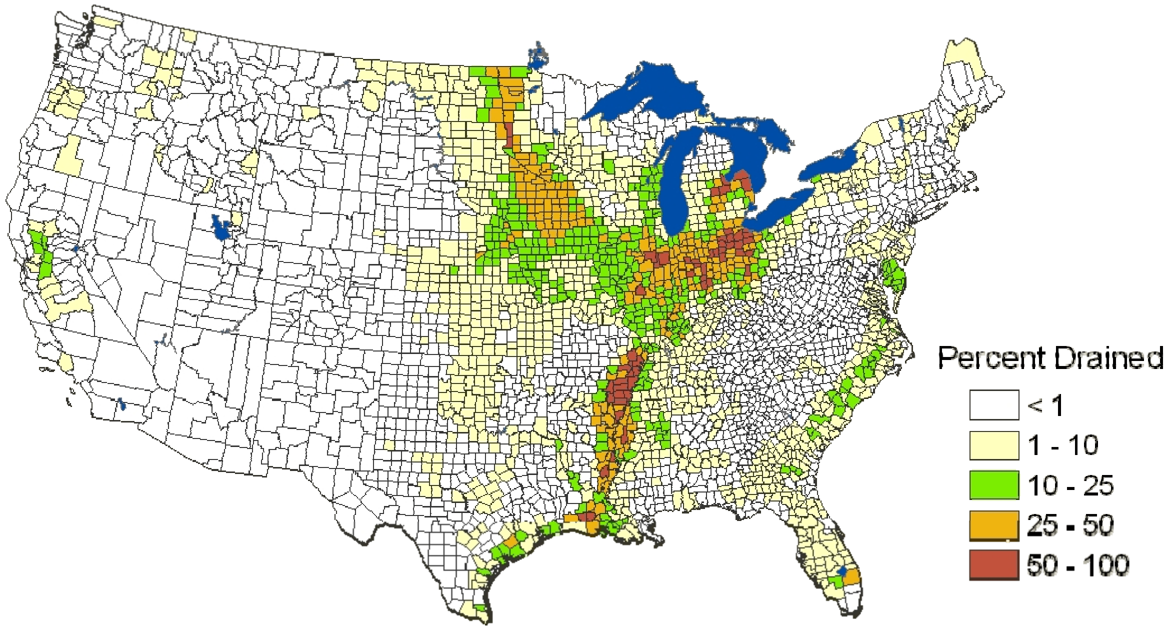

Figure 4. Percent of total county area estimated to be drained annual cropland by STATSGO/NLCD land capability class IIw, IIIw, IVw.

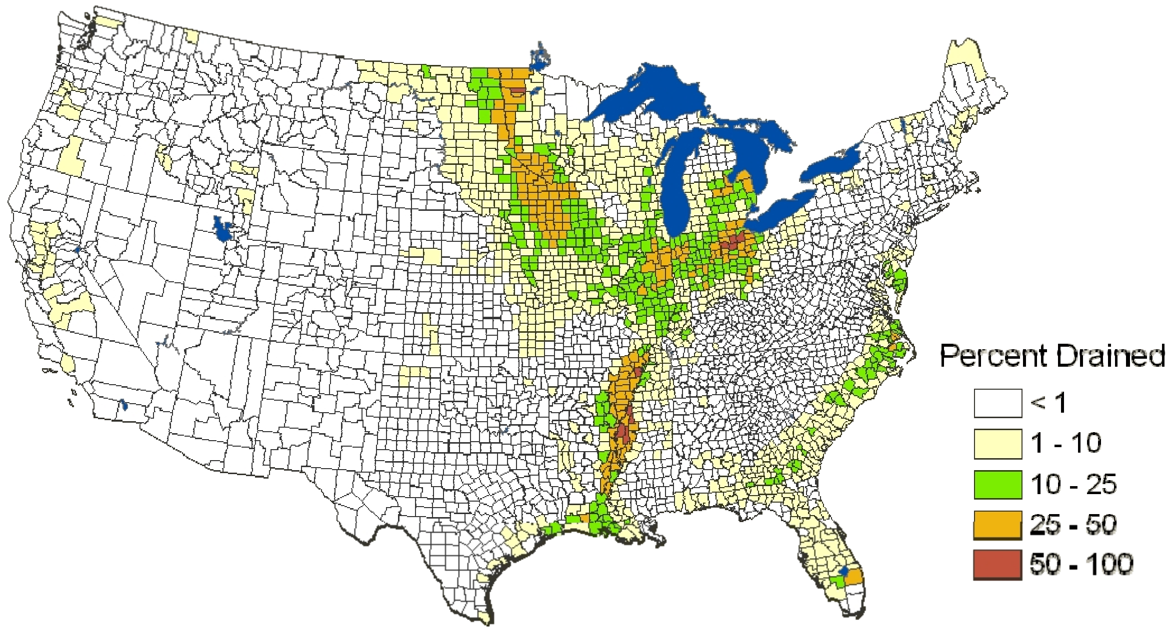

Figure 5. Percent of total county area estimated to be drained by STATSGO/NLCD poorly drained.

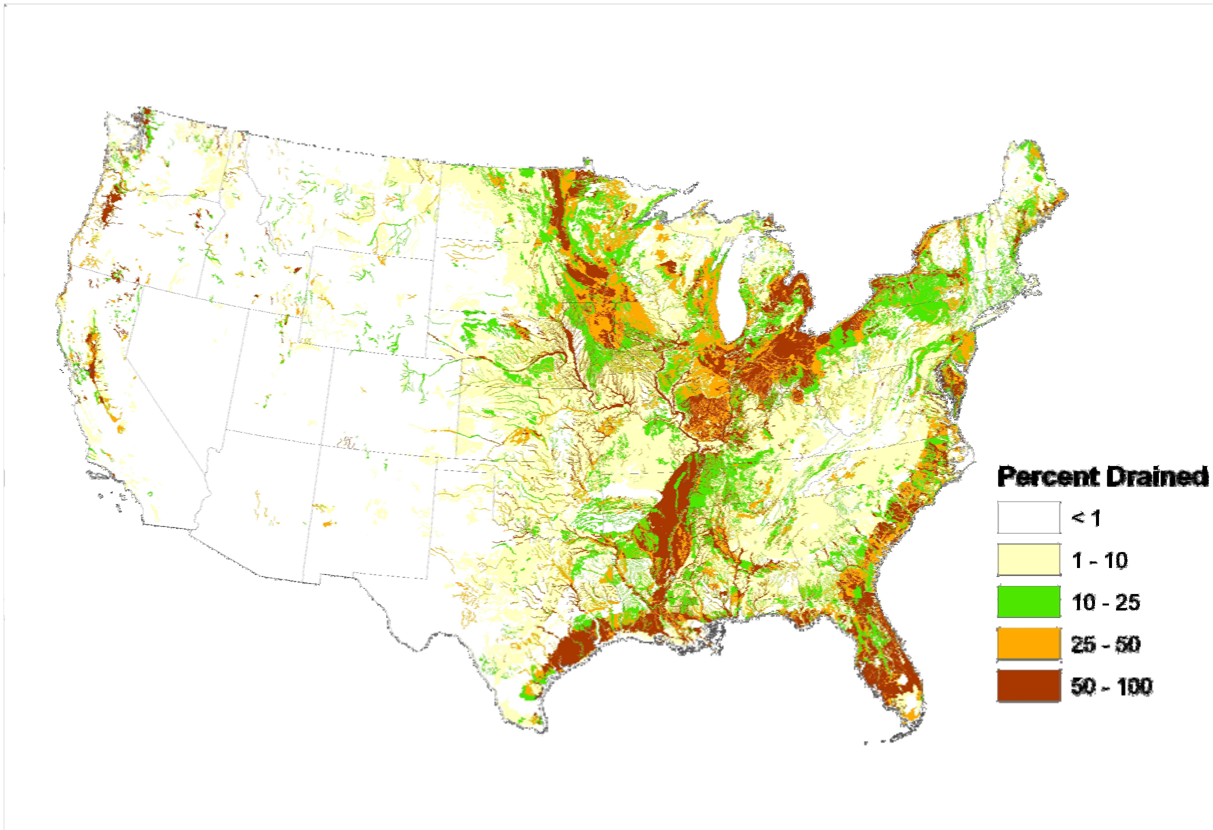

Figure 6. Percent of STATSGO map unit drained.