

Analysis of Monitoring Station Density of the North Carolina Environment and Climate Observing System (NC ECONet)

Souleymane Fall

December 2003

BACKGROUND

The North Carolina Environment and Climate Observing Network (NC ECONET) combines the automated weather network currently operated by the North Carolina State Climate Office with other stations maintained by the National Weather Service, the Federal Aviation Administration, and the US Natural Resources Conservation Service.

The NC ECONET stations provide real time information for emergency situations such as tornadoes, hurricanes or winter storms. Data for these stations are also provided to government's agencies for energy planning and natural resources management. In addition, data are available to the general public, for a variety of uses. The NC ECONET stations can also play a crucial role in the fight against bioterrorism.

Consequently, it is essential to have a good distribution of these stations throughout North Carolina.

OBJECTIVES

The objectives of this project are to characterize the distribution of NC ECONET stations with respect to elevation zones and to identify the areas in North Carolina where additional observing stations must be installed, for the best data set.

The following criteria were used:

- Technical:
 - The distance between two stations should not exceed 50 km.
 - This distance is not uniform: it will vary according to the change in elevation (every 200 meters), given that climatic conditions such as temperature vary with respect to altitude.
 - The network has 8 different types of stations, but only AGNET¹, ASOS² and AWOS³ stations, which have the most complete set of sensors, will be taken

¹ Agricultural Weather Network

into account. The study will be conducted considering first these three sub-networks; then the same procedure will be followed, but only with AGNET and ASOS stations; finally the same analysis will be performed considering only AGNET stations, which constitute the backbone of the NC ECONET.

- Geographic: Each county should have at least one station.

DATA

The data for this project have been obtained from NCSU Libraries and the North Carolina State Climate Office. They consist of shapefiles and a digital elevation model (DEM):

- econet_nc.shp
- nc_counties
- ncdem1000_ft

METHOD

The steps used to achieve the objective are shown in the chart below (Figure 1):

² Automated Surface Observing System

³ Automated Weather Observing System

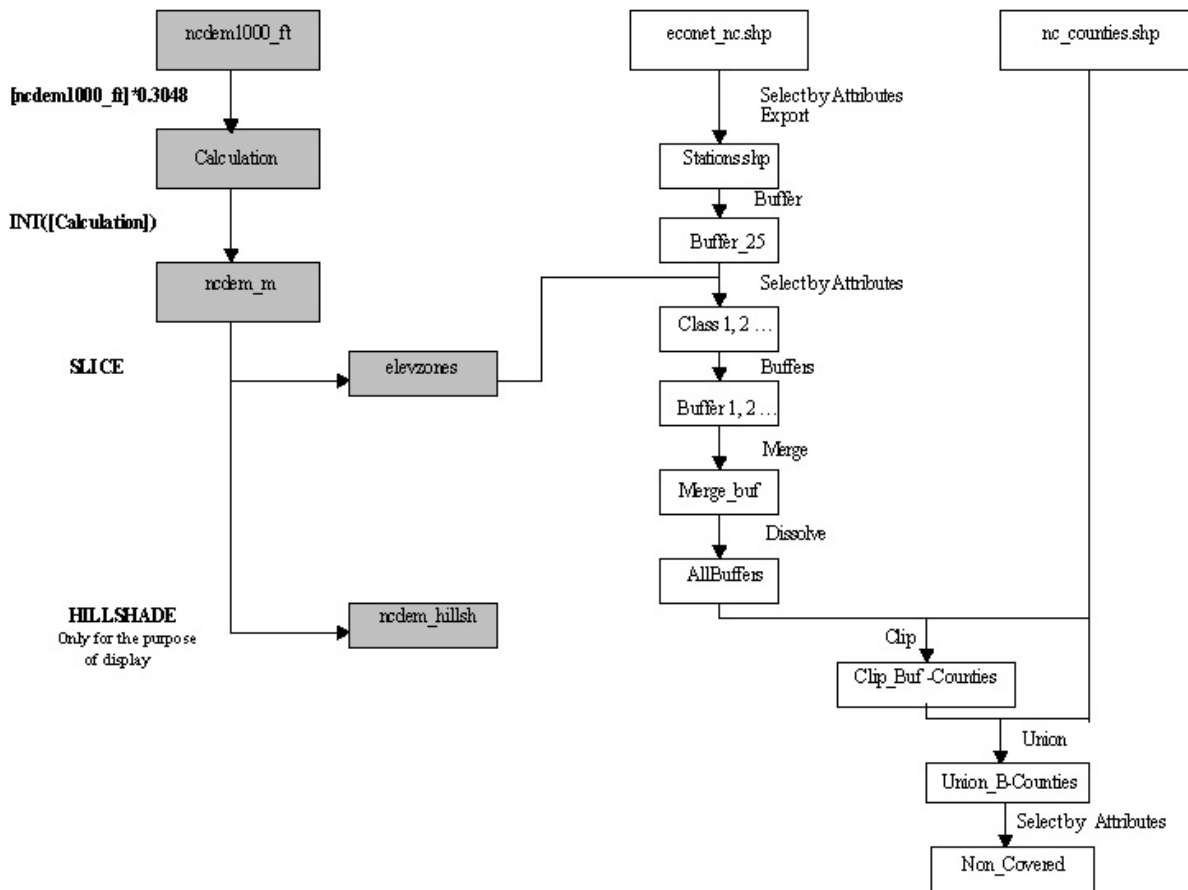


Figure 1: Flowchart of the methods used in the density analysis

In summary, ArcGIS 8.1 and its extension Spatial Analyst were used.

A subset of the targeted stations is created. Using ArcGIS's Spatial Analyst, the DEM, originally in feet, is converted to meters. A text file specifying elevation zones with intervals of 200 meters is used to reclassify the DEM into elevation zones. The elevation zones, along with the location of stations, are shown in Figure 2.

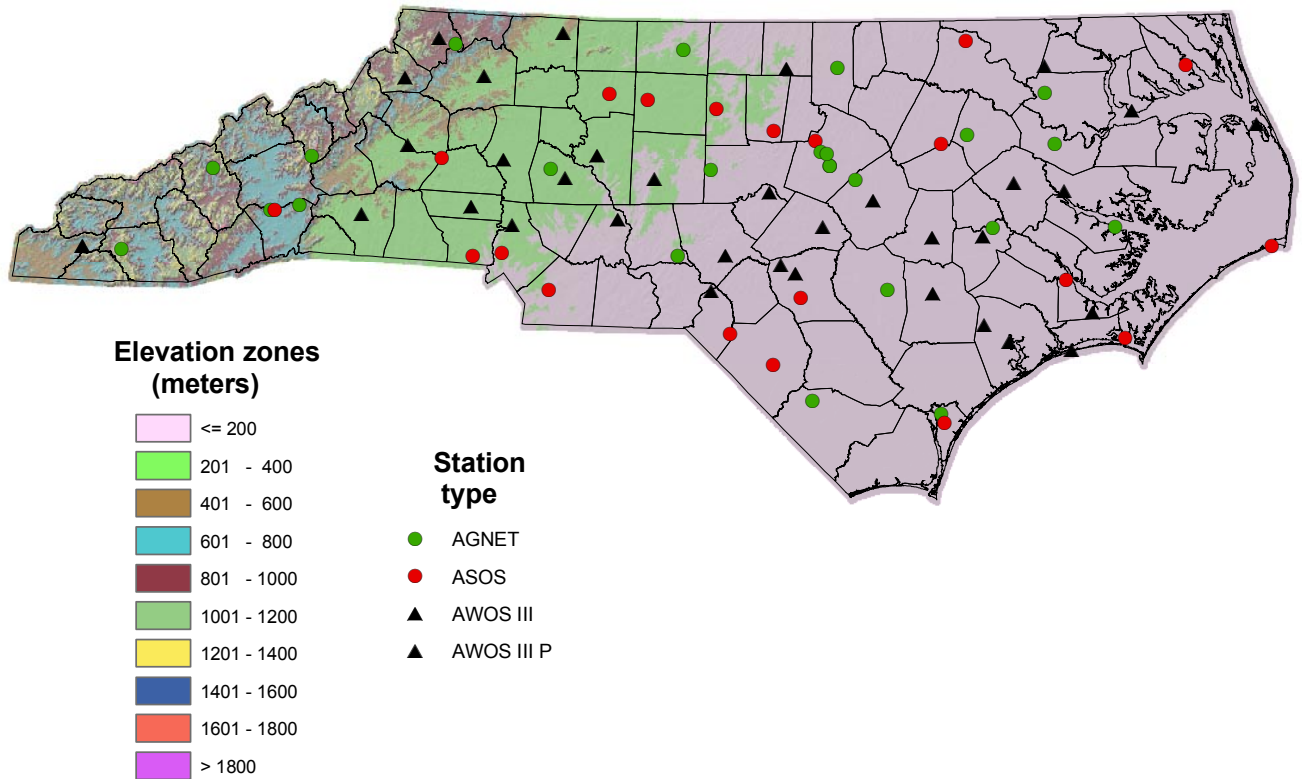


Figure 2: Elevation zones and stations used in density analysis: an elevation zone layer (interval 200 meters), with a transparency set at 50%, is displayed on top of a Hillshade layer.

A first buffer of 25 km is created around stations without dissolving barriers. This new layer, made transparent at 50%, is displayed on top of the elevations layer, to determine the number of elevation zones in each buffer area. Then the stations are classified with respect to the number of elevation zones in their buffer area. This number of zones will determine the actual buffer distance around each set of stations, based on the following equation:

$$\text{Buffer Distance} = 25 \text{ km} - (\text{S} \times 1 \text{ km}) \dots\dots\dots (1)$$

Where **S** is the number of slices (elevation zones in a buffer area). For example, if in a buffer area there are 4 zones, the buffer distance will be: 25 km – 4 km = 21 km.

The different buffer layers are then merged and their boundaries dissolved to get one uniform layer. To identify the counties that are totally or partly covered by stations, this buffer layer is used to clip the NC counties layer. The resulting layer is grouped with the NC counties layer. This new layer represents, for each county:

- Areas that are covered by NC ECONET stations
- Areas that are not covered.

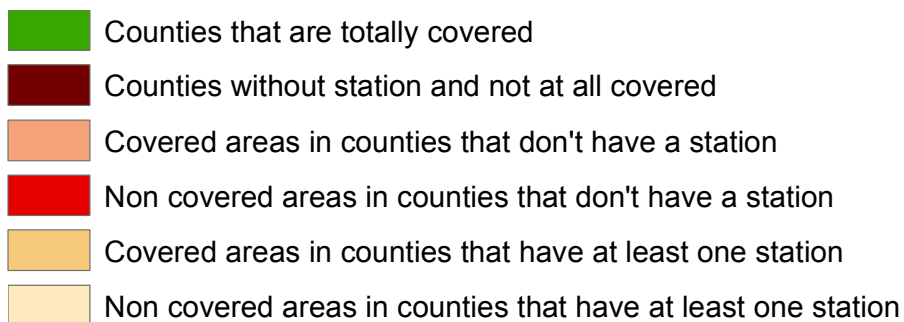
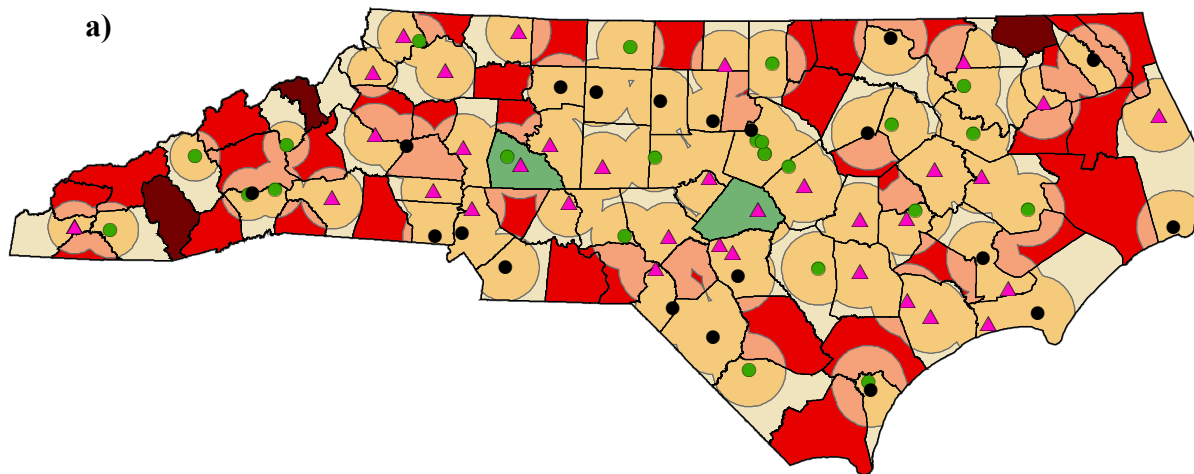
The buffer areas are selected, and then the selection is switched: the areas out of the buffer zone are now selected and exported as a new layer.

It's now possible to group the counties into categories (hint: zoom as large as necessary and use the Identify tool). Then using Select by Attributes, each group will be selected, exported as a shapefile, and given a proper symbology.

All new areas are computed using a pre-logic VBA code in the Field Calculator, and then combined with the total area of counties to compute the percentage of covered and non covered areas for each county. The resulting tables are joined with the Counties attribute table, and the counties are classified based on the percentage of coverage.

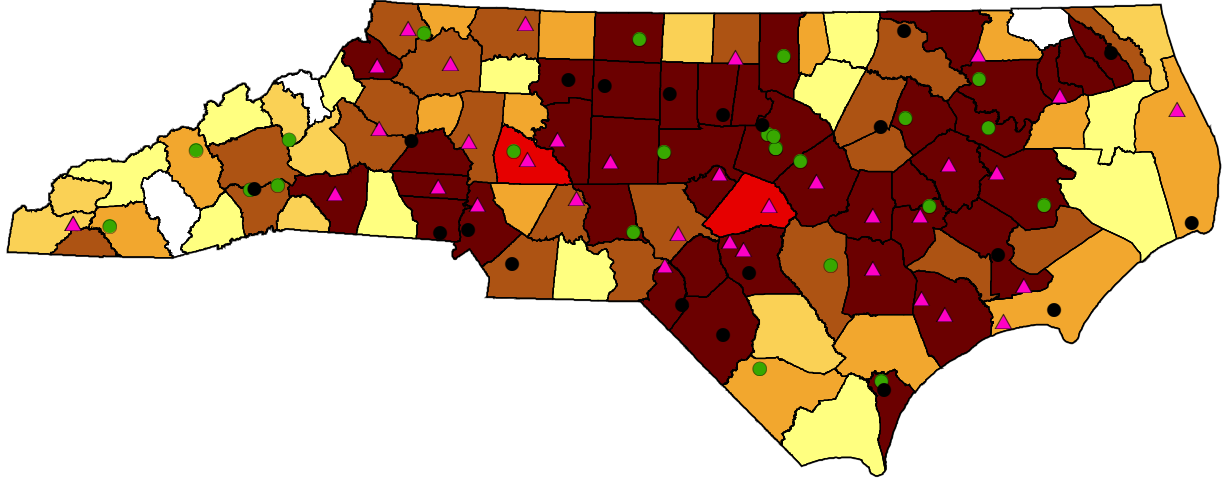
RESULTS

The degree of coverage of counties in North Carolina by AGNET, ASOS, and AWOS sensors is shown in Figure 3. Based on the coverage of these 3 networks, there are 2 counties that are completely covered and 3 counties that are not covered at all (Table 1a and 1b).



Stations





b)

Coverage (%)

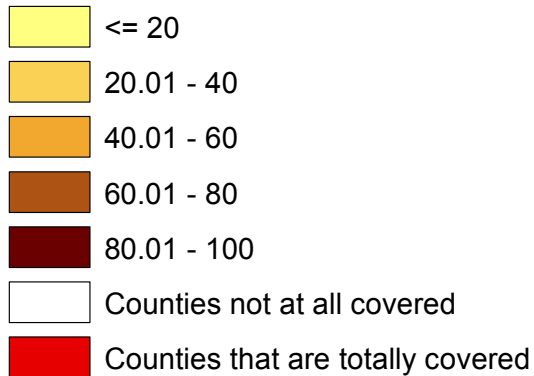


Figure 3: Coverage map when all 3 networks (AWOS, ASOS and AGNET) are included:

a) spatial coverage; b) percentage of area covered.

Figure 4 shows the degree of coverage for AGNET and ASOS stations. These 2 networks are the only sensor suites that record a standard set of hourly measurements including precipitation amounts. In this analysis, there are zero counties that are completely covered and 10 counties that are not at all covered (Tables 2a and 2b).

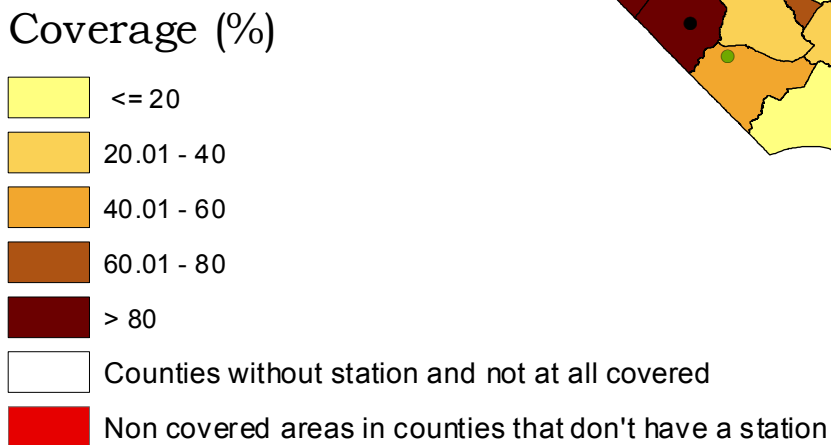
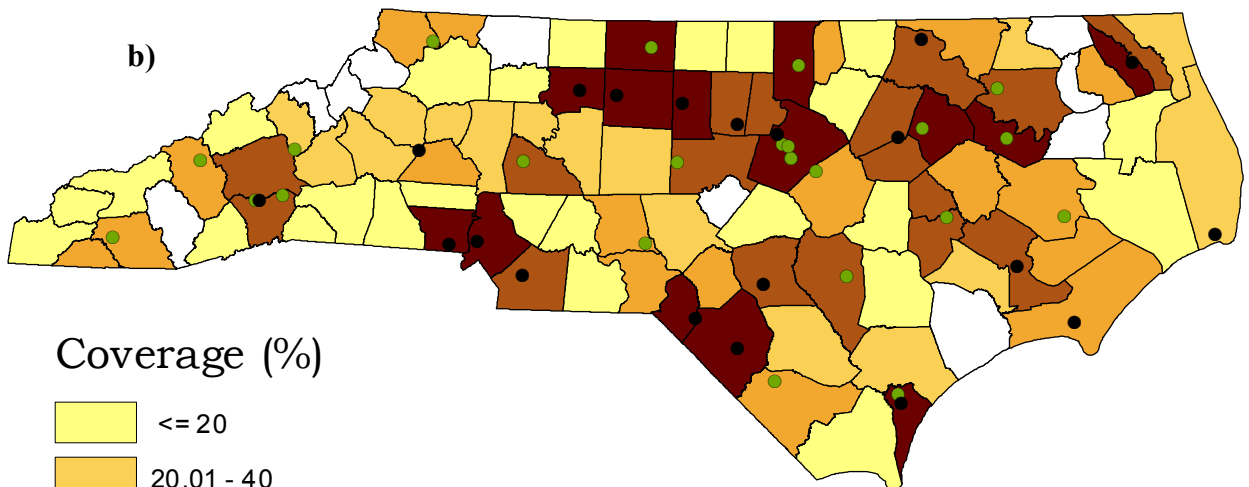
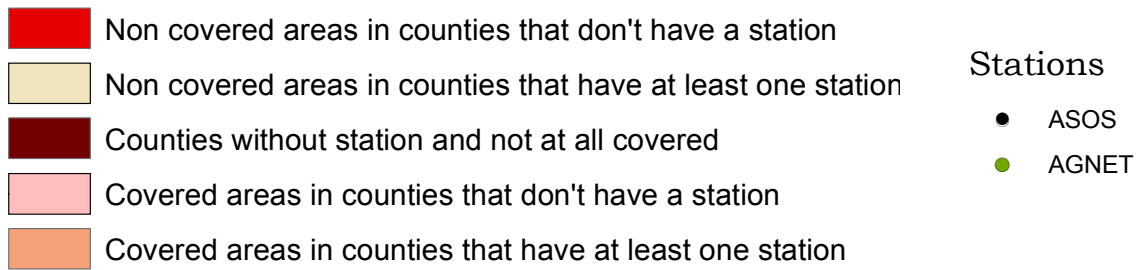
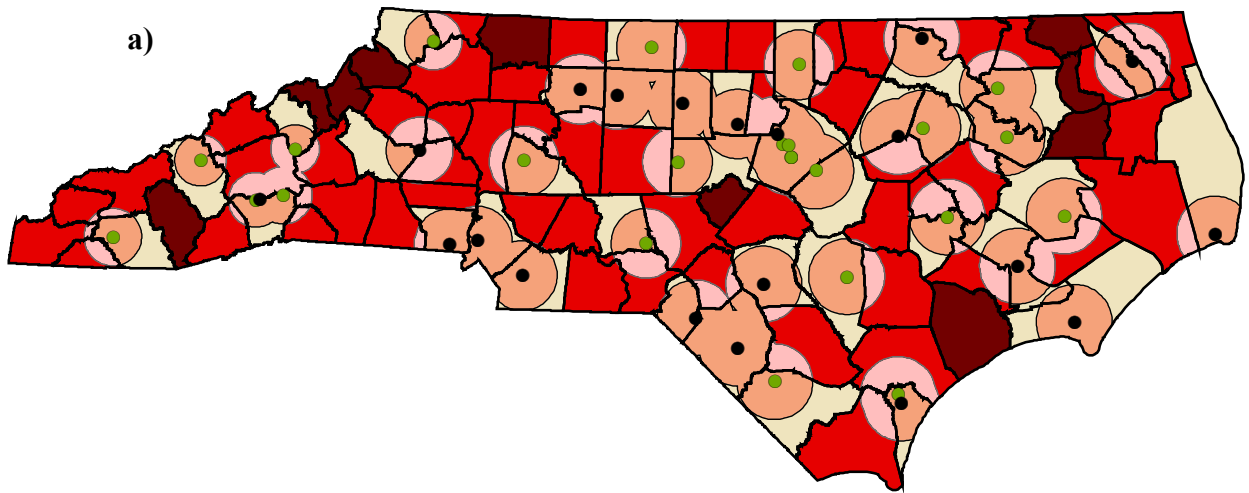
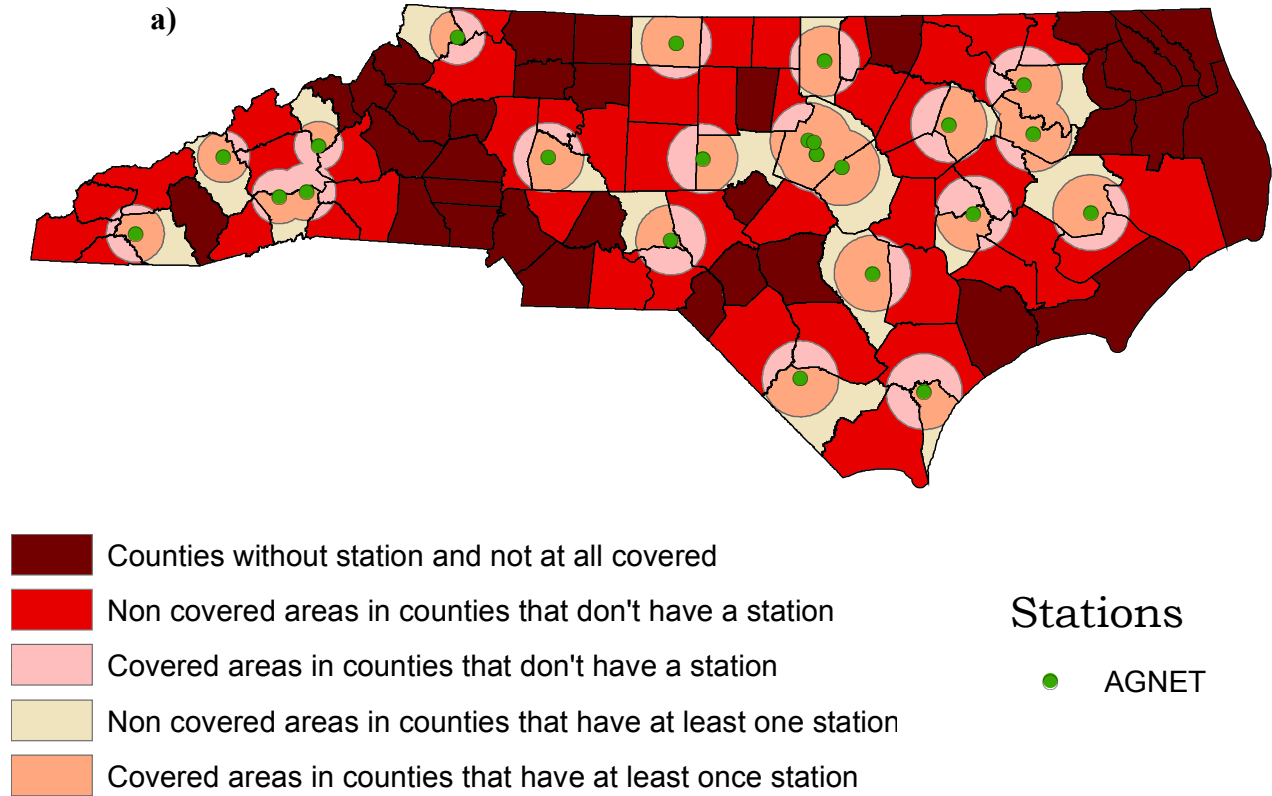


Figure 4: Coverage map of AGNET and ASOS stations.
a) spatial coverage; b) percentage of area covered.

Coverage by only the AGNET stations is given in Figure 5. The AGNET sensor suite is the only station that measures soil temperature and soil moisture. In this analysis, no county is totally covered and 35 counties are not at all covered (Tables 3a and 3b).



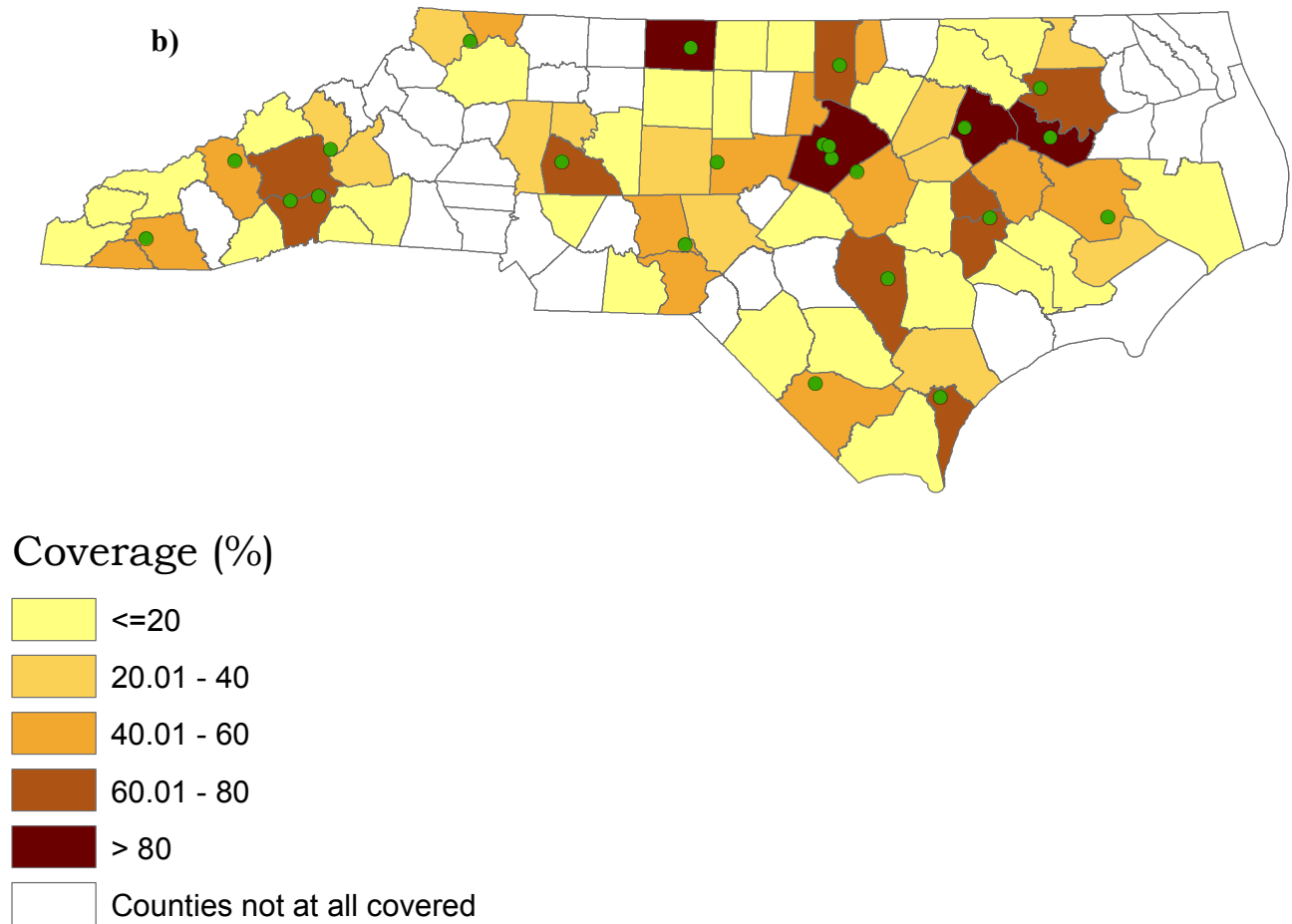


Figure 5: Coverage by AGNET stations.
a) spatial coverage; b) percentage of area covered.

CONCLUSION

On the whole, we can distinguish 4 groups of counties:

- Counties that have at least 1 station and are totally covered
- Counties that have at least 1 station but are not totally covered
- Counties that don't have a station and are not covered by stations of neighboring counties
- Counties that don't have a station but are partially covered by stations of neighboring counties

Western North Carolina, which is a mountainous region with many elevation zones, needs more coverage.

APPENDIX

TABLES OF COUNTIES, STATION NAMES AND DEGREE OF COVERAGE

**Table 1a: AWOS, ASOS and AGNET: degree of coverage for counties that have at least one station.
Counties that are totally covered are in bold**

County name	Station type	Station name	Coverage (%)
Alamance	ASOS	Burlington Alamance RGL Airport	95.72
Ashe	AWOS AGNET	Jefferson Upper Mountain Research Station	76.46
Beaufort	AWOS AGNET	Warren Field Airport Aurora Pamlico Aquaculture Field Laboratory	87.61
Bertie	AGNET	Peanut Belt Research Station	84.37
Burke	AWOS	Morganton/Lenoir Airport	63.56
Carteret	AWOS ASOS	Swansboro4 Beaufort Smithfield	54.77
Chatham	AGNET	Silver City Airport	99.29
Cherokee	AWOS	Andrews	35.78
Chowan	AWOS	Edenton	81.31
Columbus	AGNET	Border Belt Tobacco Research station	48.23
Craven	AWOS ASOS	Cherry Point MCAS Craven County Regional Airport	83.31
Cumberland	AWOS AWOS AWOS	Pope AFB Simmons Army Field Fayetteville Regional Airport	94.60
Dare	AWOS ASOS	Dare County Regional Weather Service Building	59
Davidson	AWOS	Davidson County Airport	98.06
Duplin	AWOS	Duplin County Airport	89.79
Edgecombe	AGNET	Rocky Upper Coastal Plain Research Station	88.53
Forsyth	ASOS	Smith Reynolds Airport	96.67
Gaston	ASOS	Gastonia Municipal Airport	95.42
Granville	AGNET	Oxford Tobacco Research Station	81.70

County name	Station type	Station name	Coverage (%)
Guilford	ASOS	Greensboro Regional Airport	95.16
Halifax	ASOS	Halifax County Airport	65.50
Harnett	AWOS	Harnett County Airport	100
Haywood	AGNET	Mountain Research Station	50.07
Henderson	ASOS	Asheville Regional Airport	72.22
Hertford	AWOS	Tri County Airport	59.81
Iredell	AWOS	Statesville Municipal Airport	74.85
Johnston	AWOS AGNET	Smithfield Johns Central Crops Research Station	92.94
Lee	AWOS	Sanford	96.16
Lenoir	AWOS AGNET	Kinston/Stalling AFB Cunningham Research Station	94.33
Lincoln	AWOS	Lincolnton	84.64
Macon	AGNET	Winespring	51.75
Martin	AGNET	Highway Patrol Troop A Communication Station	93.57
Mecklenburg	AWOS ASOS	Concord Regional Airport Douglass International Airport	98.08
Montgomery	AGNET	Sandhills Research Station	88.35
Moore	AWOS	S.P. Automatic Weather Observing/Reporting System	79.39
Nash	ASOS	Rocky Mount-Wilson Airport	68.93
New Hanover	ASOS AGNET	New Hanover County Airport Horticultural Crops Research Station	82.20
Onslow	AWOS AWOS	New River MCAS Automatic Weather Observing/Reporting System	90.16

County name	Station type	Station name	Coverage (%)
Orange	ASOS	Chapel Hill-Williams Airport	93.22
Pasquotank	ASOS	Coast Guard Air	89.09
Person	AWOS	Roxboro Person	76.47
Pitt	AWOS	Pitt/Greenville Airport	98.22
Randolph	AWOS	Ashboro Municipal	87.09
Robeson	ASOS	Lumberton Municipal Airport	97.41
Rockingham	AGNET	Upper Piedmont Research Station	84.62
Rowan	AWOS AGNET	Salisbury Rowan Piedmont Research Station	100
Rutherford	AWOS	Rutherfordton	83.99
Sampson	AGNET	Horticultural Crops Research Station	67.39
Scotland	AWOS ASOS	Mackall US Army Field Laurinburg-Maxton Airport	98.85
Stanly	AWOS	Albemarle Stanly	67.90
Surry	AWOS	Mount Airy/Surry County Airport	62.40
Union	ASOS	Monroe	74.83
Wake	ASOS AGNET AGNET AGNET	Raleigh-Durham Airport Reedy Creek Field Laboratory Turfgrass Field Laboratory Lake Wheeler Rd Field Laboratory	90.47
Watauga	AWOS	Boone Watauga CT	80.88
Wayne	AWOS	Seymour Johnson Air Force Base	88.23
Wilkes	AWOS	Wilkesboro	72.09
Yancey	AGNET	Mount Mitchell State Park	35.85

Table 1b: AWOS, ASOS and AGNET: degree of coverage of counties that don't have a station (by stations of neighboring counties). Counties that not at all covered are in bold.

NAME	COVERAGE (%)	NAME	COVERAGE (%)
Alexander	46.02	Hyde	13.32
Alleghany	43.14	Jackson	0
Anson	0.49	Jones	62.97
Avery	1.04	Madison	9.66
Bladen	25.53	McDowell	35.35
Brunswick	19.13	Mitchell	0
Buncombe	60.47	Northampton	80.70
Cabarrus	47.11	Pamlico	65.93
Caldwell	70.59	Pender	44.36
Camden	68.96	Perquimans	81.21
Caswell	26.69	Polk	32.39
Catawba	99.51	Richmond	67.76
Clay	72.66	Stokes	42.76
Cleveland	5.98	Swain	7.23
Currituck	31.88	Transylvania	7.51
Davie	45.85	Tyrrell	9.09
Durham	89.79	Vance	47.87
Franklin	5.07	Warren	14.65
Gates	0	Washington	56.46
Graham	34.09	Wilson	72.02
Greene	80.68	Yadkin	3.71
Hoke	96.17		

Table 2a: ASOS and AGNET: degree of coverage for counties that have at least one station.

County name	Station type	Station name	Coverage (%)
Alamance	ASOS	Burlington Alamance RGL Airport	95.72
Ashe	AGNET	Upper Mountain Research Station	41.64
Beaufort	AGNET	Aurora Pamlico Aquaculture Field Laboratory	56.98
Bertie	AGNET	Peanut Belt Research Station	63.84
Burke	AWOS	Morganton/Lenoir Airport	24.01
Carteret	ASOS	Beaufort Smithfield	41.64
Chatham	AGNET	Silver City Airport	72.17
Columbus	AGNET	Border Belt Tobacco Research station	48.23
Craven	ASOS	Craven County Regional Airport	73.93
Cumberland	ASOS	Fayetteville Regional Airport	77.80
Dare	ASOS	Weather Service Building	22.32
Edgecombe	AGNET	Rocky Upper Coastal Plain Research Station	86.78
Forsyth	ASOS	Smith Reynolds Airport	96.67
Gaston	ASOS	Gastonia Municipal Airport	87.22
Granville	AGNET	Oxford Tobacco Research Station	81.69
Guilford	ASOS	Greensboro Regional Airport	95.16
Halifax	ASOS	Halifax County Airport	63.89
Haywood	AGNET	Mountain Research Station	50.07
Henderson	ASOS	Asheville Regional Airport	72.22
Johnston	AGNET	Central Crops Research Station	50.97
Lenoir	AGNET	Cunningham Research Station	69.07
Macon	AGNET	Winespring	51.75
Martin	AGNET	Highway Patrol Troop A Communication Station	92.64
Mecklenburg	ASOS	Douglass International Airport	81.24
Montgomery	AGNET	Sandhills Research Station	46.93
Nash	ASOS	Rocky Mount-Wilson Airport	68.93
New Hanover	ASOS	New Hanover County Airport	82.20
	AGNET	Horticultural Crops Research Station	
Orange	ASOS	Chapel Hill-Williams Airport	67.62
Pasquotank	ASOS	Coast Guard Air	89.09
Robeson	ASOS	Lumberton Municipal Airport	97.41
Rockingham	AGNET	Upper Piedmont Research Station	84.62
Rowan	AGNET	Piedmont Research Station	75.24
Sampson	AGNET	Horticultural Crops Research Station	63.09
Scotland	ASOS	Laurinburg-Maxton Airport	89.81
Union	ASOS	Monroe	74.83
Wake	ASOS	Raleigh-Durham Airport	88.33
	AGNET	Reedy Creek Field Laboratory	
	AGNET	Turfgrass Field Laboratory	
	AGNET	Lake Wheeler Rd Field Laboratory	
Yancey	AGNET	Mount Mitchell State Park	35.85

Table 2b: ASOS and AGNET: degree of coverage of counties that don't have a station (by stations of neighboring counties). Counties that not at all covered are in bold.

NAME	COVERAGE (%)	NAME	COVERAGE (%)
Alexander	25.84	Lee	0
Alleghany	46.32	Lincoln	3.88
Anson	0.49	Madison	9.66
Avery	0	McDowell	21.43
Bladen	25.53	Mitchell	0
Brunswick	19.13	Moore	31.54
Buncombe	60.47	Northampton	50.19
Cabarrus	2.49	Onslow	0
Caldwell	30.19	Pamlico	57.91
Camden	68.96	Pender	35.95
Caswell	15.37	Perquimans	45.00
Catawba	59.66	Person	10.40
Cherokee	5.33	Pitt	41.37
Chowan	0	Polk	14.19
Clay	41.79	Randolph	33.71
Cleveland	7.29	Richmond	41.46
Currituck	25.04	Rutherford	8.57
Davidson	22.89	Stanly	0.91
Davie	29.66	Stokes	18.42
Duplin	19.91	Surry	0
Durham	75.89	Swain	7.23
Franklin	5.07	Transylvania	7.51
Gates	0	Tyrrell	1.54
Graham	4.20	Vance	47.87
Greene	75.63	Warren	14.65
Harnett	2.75	Washington	0
Hertford	22.90	Watauga	0
Hoke	44.01	Wayne	3.36
Hyde	13.32	Wilkes	19.84
Iredell	22.15	Wilson	71.83
Jackson	0	Yadkin	3.12
Jones	39.81		

Table 3a: AGNET: degree of coverage for counties that have at least one station.

COUNTY NAME	STATION NAME	COVERAGE (%)
Ashe	Upper Mountain Research Station	37.96
Beaufort	Aurora Pamlico Aquaculture Field Laboratory	56.98
Bertie	Peanut Belt Research Station	63.84
Chatham	Silver City Airport	54.42
Columbus	Border Belt Tobacco Research station	48.23
Edgecombe	Rocky Upper Coastal Plain Research Station	86.78
Granville	Oxford Tobacco Research Station	79.94
Haywood	Mountain Research Station	50.07
Henderson	Asheville Regional Airport	72.18
Johnston	Central Crops Research Station	50.97
Lenoir	Cunningham Research Station	69.06
Macon	Winespring	51.75
Martin	Highway Patrol Troop A Communication Station	92.64
Montgomery	Sandhills Research Station	46.93
New Hanover	Horticultural Crops Research Station	73.87
Rockingham	Upper Piedmont Research Station	80.92
Rowan	Piedmont Research Station	75.24
Sampson	Horticultural Crops Research Station	61.21
Wake	Reedy Creek Field Laboratory Turfgrass Field Laboratory Lake Wheeler Rd Field Laboratory	85.23
Yancey	Mount Mitchell State Park	35.85

Table 3b: AGNET: degree of coverage of counties that don't have a station (by stations of neighboring counties). Counties that not at all covered are in bold.

NAME	COVERAGE (%)	NAME	COVERAGE (%)
Alamance	10.11	Jackson	0
Alleghany	41.38	Jones	5.91
Alexander	0	Lee	0
Anson	0.49	Lincoln	0
Avery	0	Madison	9.66
Bladen	18.68	McDowell	21.43
Brunswick	15.89	Mecklenburg	0
Buncombe	60.47	Mitchell	0
Burke	0	Moore	31.54
Cabarrus	1.49	Nash	35.65
Caldwell	0	Northampton	16.63
Camden	0	Onslow	0
Carteret	0	Orange	0
Caswell	14.74	Pamlico	33.16
Catawba	0	Pasquotank	0
Cherokee	5.33	Pender	35.58
Chowan	0	Perquimans	0
Clay	41.79	Person	10.40
Cleveland	0	Pitt	41.37
Craven	11.06	Polk	14.19
Cumberland	0	Randolph	31.61
Currituck	0	Richmond	40.04
Dare	0	Robeson	14.08
Davidson	5.55	Rutherford	8.57
Davie	29.19	Scotland	0
Duplin	19.91	Stanly	0
Durham	45.80	Stokes	0
Forsyth	0	Surry	0
Franklin	5.07	Swain	7.23
Gaston	0	Transylvania	7.51
Gates	0	Tyrrell	0
Graham	4.20	Union	0
Greene	75.63	Vance	47.87
Guilford	10.97	Warren	0
Halifax	14.06	Washington	0
Harnett	2.75	Watauga	0
Hertford	22.90	Wayne	3.36
Hoke	0	Wilkes	17.54
Hyde	5.62	Wilson	33.29
Iredell	22.16	Yadkin	0

ACKNOWLEDGEMENTS

I gratefully acknowledge the reviewers of this study, Dr Sethu Raman, State Climatologist for North Carolina, and Ryan Boyles, Associate State Climatologist, for their comments and suggestions.