

Working Group for Land Cover

Report to the Statewide Mapping Advisory Committee

April 16, 2019

Summary

The Working Group for Land Cover, reporting to the Statewide Mapping Advisory Committee of the North Carolina Geographic Information Coordinating Council, finds numerous business needs for land cover data.

From a survey of land cover data users in local, state, and federal government agencies, regional organizations, universities, and private service providers, 15 business needs were evident, in rank order:

1. Apply land cover data to land use planning
2. Monitor changes in impervious surface that may affect stormwater flow and/or billing
2. Identify areas where forest cover has changed that may affect water quality
4. Monitor riparian buffers where forest cover is expected to be sustained
5. Identify areas that are clear cut or change from forested or cultivated to developed
6. Analyze water resources for watershed characterization
7. Identify areas where wetland cover has changed to inform floodplain management
8. Identify areas that are floodplains, small and isolated wetlands, longleaf pine forests, and rock outcrops to help identify priority lands for conservation
9. Predict wetland areas or stream locations using models
10. Monitor properties over time that qualify for “present use value” in county tax appraisal
11. Estimate the areas within property boundaries that are forested or cultivated for property tax appraisal purposes
12. Identify and/or analyze vegetation species related to wildlife habitat
13. Monitor terrestrial plant communities
14. Identify and/or analyze tree type for urban forestry planning
15. Assess timber condition and value in areas of interest

The priority requirements for land cover data identified by the working group based on a survey of stakeholders:

- Ground resolution of 1-meter or better in a raster product
- Reliable distinction between what is classified as impervious surface, tree cover, farm fields, and wet areas at a minimum
- Frequency of at least annual classification to detect land cover change

The results suggest a bi-modal ground resolution requirement. By organization type, local government respondents favored 6- or 12-inch resolution with a few choosing 1-meter resolution. Most federal government and university respondents chose between 1 and 10 meters. State government and regional organization respondents indicated a wide range from 6-inch to 30-meter resolution.

Some business needs require more detailed classes, especially related to wildlife habitat, but with less frequency. A shared need among survey respondents may be described as a timely resource to identify changes in land cover, especially from forest and/or agriculture to developed land, serving a variety of purposes and generating benefits.

Classified land cover data can be scoped for specific business needs in terms of resolution, classes, extent and currency. The most common requirements for land cover data for the most business needs are NLCD level-2 classification, statewide, annual, produced within 12 months, and easily accessible as a raster dataset. The bi-modal ground resolution requirements, 6-inch versus 1-meter, have implications for source data (e.g., orthoimagery), classification methods, disk storage space, processing time, and cost. A dataset could be re-classified to simpler classes, resampled to pixel sizes larger than 6-inches or 1-meter, and/or extracted for areas of interest.

In practical terms, frequency and geographic extent may depend on data specifications and methods. While statewide land cover is preferred by survey respondents, there are business needs that could be served by targeted land cover classification for areas of interest from one or more statewide and or regionwide imagery sources. Also, the Working Group recognizes that satisfying some needs—for example, water quality planning in river basins that span multiple states—highlights the value of national land cover data or at least state adoption of national land cover classes.

Recommendations

The Working Group for Land Cover recommends that the Statewide Mapping Advisory Committee recognize significant business needs for land cover data, and pursue research on sources of imagery to be classified, tools and techniques, and strategies for targeting land cover classification and products to satisfy business needs identified in this report. Also, the Working Group recommends that the State of North Carolina not “go it alone” and collaborate with national efforts including GAP/LANDFIRE, NOAA’s Office of Coastal Management land cover mapping, and US EPA land cover mapping.

Background

"Land cover" refers to the vegetative or non-vegetative characteristics of a portion of the Earth's surface. Land cover does not represent how land is used. The separate concept of "land use" describes some human activity on the surface. The concept of land cover is best understood when applied to natural surfaces where no activity has occurred (e.g., unharvested forest land). Some land cover classes may imply use, for example, cultivated land cover implies farming, but the concepts of land cover and land use need to be classified differently.

The type of land cover present is determined directly by observation. This observation may use satellite imagery or aerial photography for certain levels of classification detail and positional accuracy. For very detailed levels of mapping, however, on-site inspection may be required.

Land use types may also be determined through observation by deducing human activity or disturbance based on the appearance of the landscape. As in the case of land cover, land use classes may also be determined, in many cases from satellite imagery or aerial photographs. For detailed land use information, on-site analysis is often required. In many cases, supplemental information gathered from business licenses or questionnaires is needed to reliably assign a land use class since the use is not always apparent through observation.

Available land cover datasets are either statewide low-resolution (30-meter) representations or higher-resolution classifications of one land cover type (e.g., tree cover), or higher-resolution local government products limited to selected jurisdictions. The State of North Carolina developed a land cover classification scheme in 1994 and created a statewide land cover product in 1996 with a grant to CGIA from the US Environmental Protection Agency. Since 1996, statewide land cover was published by the US Geological Survey (USGS) as National Land Cover Data based on satellite imagery captured in 2001, 2006, and 2011. A product based on 2016 imagery is in progress. The land cover classification scheme used by USGS is similar to the North Carolina version with a few differences. See Appendix A for the classification schemes. A single-class product is tree cover based on classification of 1-meter leaf-on 2016 imagery by the NC Department of Agriculture & Consumer Services.

Approach

The Statewide Mapping Advisory Committee of the NC Geographic Information Coordinating Council identified land cover as a geospatial dataset needing attention. The committee recognized the infrequency of land cover products, the expansion of available imagery sources at different ground resolutions since 1996, and changes in computer technology that may make land cover products more practical and affordable. What was not clear to the committee was the current business needs for land cover and requirements for ground resolution, geographic extent, frequency, and classification details. To answer questions about land cover, the committee chartered a Working Group for Land Cover in late 2017.

To evaluate business needs for land cover classification and products, the approach of the working group was to research, define, and clarify business needs from members of the statewide GIS community. The primary questions for the working group:

- What are business needs among federal, state, regional, local and private entities?
- What are shared needs?
- What are the most compelling needs for adding value to public services and generate public benefits?
- Are there common land cover products that would meet most of the business needs?

The working group surveyed the GIS community in North Carolina to gather information for each business need (e.g., water quality modeling, land conservation planning, and determining land area in agriculture for tax assessment purposes). A total of 72 respondents answered questions for their business needs, including:

- What is the minimum ground resolution required for classified land cover?
- How many land cover classes are required?
 - o What are the classes?
 - o Which classes are essential?
- What are the temporal requirements?
 - o What is the time span between date of capture of remotely sensed data and completion of products—ideal span and tolerable span?
 - o What is the minimum frequency required if change analysis is required?
- What is the geographic extent?
 - o Is statewide extent required?
 - o Are there specific locations that take priority if statewide extent is not practical or affordable?
- What are the potential benefits (save time and do more, better inform decisions, achieve more confidence in models and analysis, avoid costs, etc.)?

Findings

The Working Group for Land Cover distributed a survey about business needs to the working group, the Statewide Mapping Advisory Committee, the Local Government Committee, the State Government GIS Users Committee, the Federal Interagency Committee and selected contacts in universities, regional councils of government, and local governments between January and March 2018. Additional responses were obtained at the NC GIS Conference in February 2019. The 12-question survey took an average of 6 minutes to complete. A total of 77 respondents provided a reasonable amount of data to summarize and analyze.

From contact information (questions 1 and 2), respondents represented state government (28), local government (21), regional government (12), federal government (7), university (7), and private (4). Respondents with a title including “GIS” or “IT” or “mapping” numbered 40. Respondents with a title with an environmental, natural resource, or science type numbered

17. Titles for others indicated 24 were planners, modelers, engineers, image analysts, professors, or project managers.

The results for questions 3-11 are summarized by question with comments on the responses by organization type where relevant.

Question 3. Which of the following best describes your role?	Local/Reg	State	Nat/Uni	TOTAL	Percent
Classification of land cover	9	5	8	22	28.6
Analysis and mapping	16	12	9	37	48.1
Deriving or developing data from land cover	15	13	9	37	48.1
Modeling	7	12	11	30	39.0
Land use or other planning	23	16	4	43	55.8
Visual monitoring	10	9	3	22	28.6
General interest	16	7	5	28	36.4
Total respondents: 79					

The roles selected in Question 3, in rank order, were:

1. Land use or other planning using land cover
2. Analysis and mapping of classified land cover
3. Deriving or developing geospatial data using land cover as a source
4. General interest in land cover
5. Modeling using land cover
6. Visual monitoring of land cover in areas of interest
7. Classification of land cover from imagery sources

Many respondents indicated multiple roles related to land cover. Other roles using land cover not included in the available choices were to crosswalk federal and state land cover classes, create cartographic products from land cover, analyze wooded versus cleared land for use-based property taxation, measure impervious surfaces, teach raster analysis, and do fire inspections. Across organization types (local or regional, state, national or university), roles were multiple and varied as shown in the table above.

Of the 79 respondents, five (three local government and two state government) did not answer questions after Question 3. Most of the remaining questions had 74 responses as a representative sample of data users.

Question 4. What business needs apply to your organization?	TOTAL	Percent
Identify areas where forest cover has changed that may affect water quality	37	50.0
Monitor riparian buffers where forest cover is expected to not change	33	44.6
Monitor terrestrial plan communities	14	18.9
Identify areas where wetland cover has changed to inform floodplain management	28	37.8
Monitor changes in impervious surface that may affect stormwater flow and/or stormwater billing	37	50.0
Predict wetland areas or stream locations using models	22	29.7
Analyze water resources for watershed characterization	30	40.5
Identify and/or analyze vegetation species related to wildlife habitat	14	18.9
Identify and/or analyze tree type for urban forestry planning	13	17.6
Assess timber condition and value in areas of interest	9	12.2
Estimate the areas within property boundaries that are forested or cultivated for tax appraisal purposes	19	25.7
Monitor properties over time that qualify for "present use value" in county tax appraisal	20	27.0
Apply land cover data to land use planning	40	54.1
Identify areas that are floodplains, small and isolated wetlands, longleaf pine forests, and rock outcrops to help identify priority lands for conservation	27	36.5
Identify areas that are clear cut or change from forested or cultivated to developed	31	41.9
Other business needs	17	23.0
Total responses: 74		

The multiple choices for Question 4 were identified by the working group as most likely to describe business needs. The business needs in rank order:

1. Apply land cover data to land use planning
2. Monitor changes in impervious surface that may affect stormwater flow and/or billing
3. Identify areas where forest cover has changed that may affect water quality
4. Monitor riparian buffers where forest cover is expected to be sustained
5. Identify areas that are clear cut or change from forested or cultivated to developed
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9. Predict wetland areas or stream locations using models

10. Monitor properties over time that qualify for “present use value” in county tax appraisal
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Many respondents indicated multiple business needs. Only 7 of 74 respondents to this question indicated only one business need from the list given. Other business uses for land cover were described by respondents:

- Change in agricultural and forest lands over time
- Enhance map products and applications
- Estimate field boundaries for research
- Evaluate state owned property subject to billing for stormwater fees
- Identify general change in land cover over time
- Help partition precipitation into the hydrological classes of runoff and infiltration; this information is applied in a model to determine the relative vulnerability of public water sources to contamination
- If tree species classification is sufficiently detailed, land cover could be used to aid in risk and targeting analysis for invasive insect pests
- Identify impervious areas where new developments have occurred
- Analyze land cover change for hazards, sediment models and landslide risk
- Model the relationship of land over to soil types
- Monitor possible ground cover changes
- Analyze riparian buffers that have changed over time
- Utilize land cover data to develop meteorological parameters used in atmospheric dispersion models

The Working Group discussed several examples of business uses in detail. The Division of Water Resources (DWR) issues stormwater permits for developments over five acres in area. If permits are effective, negative impacts on water quality are mitigated. Note that land cover classified using 30-meter resolution would translate to about 135 raster cells in a 4,047-square meter (5-acre) area, making for a coarse representation of land cover for the size of the area.

DWR also uses land cover data in water quality models in large areas to assess the impact of land cover on water quality. The smallest drainage area is 2,000 acres. Even in large study areas, the National Land Cover Data at 30-meter resolution introduces error, especially on the edge of land cover classes. The smaller the area of interest, the greater the error in model results. Similar limitations of 30-meter resolution data occur for Department of Environmental Quality biologists who use land cover in models and analyses.

The Wildlife Resources Commission assists local governments with land use planning with the goal of conserving wildlife habitat. For a representation of wildlife habitat, the land cover data published by the GAP Analysis Program (30-meter resolution based on 2011 National Land Cover Data (NLCD) and other sources) is very useful and need not be updated on a regular basis. Habitat is not created and does not tend to change from one habitat to another. The change is conversion from habitat to developed land. Land cover change that identifies those habitat areas that have changed land cover would be most valuable on an annual basis. Other datasets that are useful to WRC are headwater streams under development by DWR, wetlands, NC Natural Heritage Program data, and data from the Nature Conservancy (e.g., areas with prescribed burning).

The City of New Bern is an example of a local government where planning efforts may not cover the entire city. Annual change analysis would be useful in areas experiencing land development and urban change. Land cover before and after change can be informative, but it must be at a high resolution to be meaningful for sub-city areas.

The City of Durham relies on high-resolution (6-inch) land cover mapping to calculate impervious surface by property that is part of the formula for stormwater billing. Accurate and fair stormwater billing requires accurate representations of impervious surface. The city refreshes its data regularly, classifying land cover from imagery captured three time per year and supported by field data collection.

For many planning purposes in Durham, a 5-meter generalized land cover product is valuable. Where type of vegetation is important to classify, 1-meter land cover is appropriate. For any land cover product, timeliness of land cover classification is essential considering timing of planning and permitting needs in the city.

Federal business uses of land cover include the US Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA). EPA supports its online EnviroAtlas with 1-meter resolution land cover data in 25 selected communities nationally, including the City of Durham. See an example in Figure 1. Land cover is applied in maps and metrics for 85 ecosystem services in EnviroAtlas.

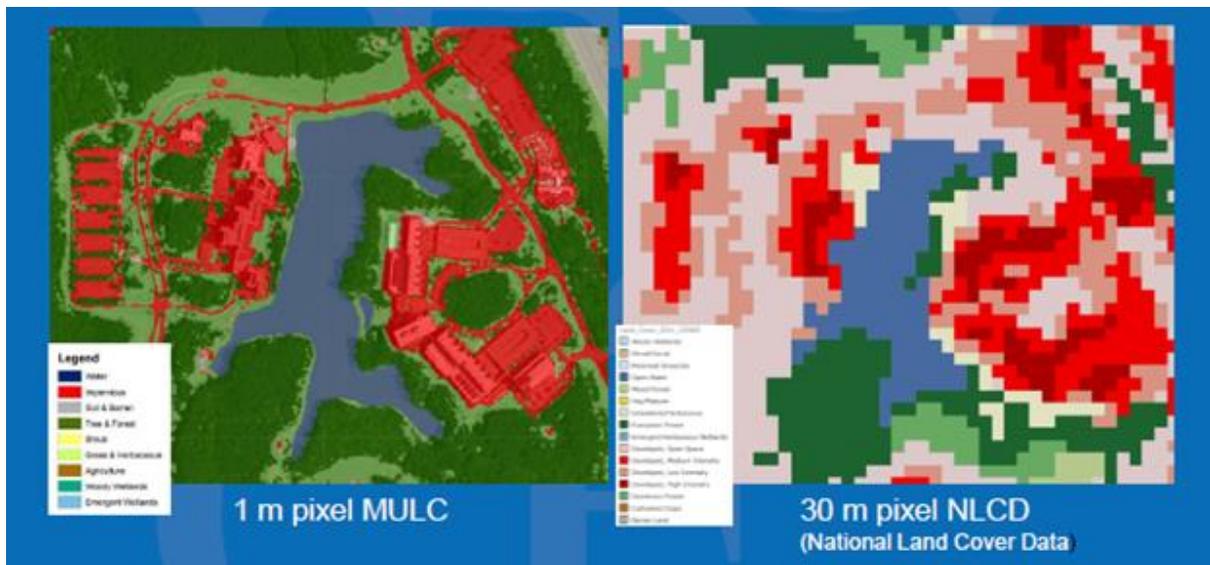


Figure 1. Land Cover Comparison

Images show 1-meter and 30-meter resolution land cover data for the EPA RTP campus. Left: US EPA EnviroAtlas MULC (Meter-scale Urban Land Cover) transparent over imagery. Right: NLCD (National Land Cover Dataset).

NOAA’s Office for Coastal Management is another source of classified land cover. In addition to the 30-meter resolution Coastal Change Analysis Program (C-CAP) land cover data in coastal regions that the agency has maintained for years, NOAA is transitioning to 1-meter resolution products with six classes of land cover to support coastal management and planning. NOAA has products under development for the coastal half of North Carolina. High-resolution products have restrictive licensing. The C-CAP classes are described in Appendix A.

Question 5. What is the Ideal Ground Resolution?	Local/Reg	State	Nat/Uni	TOTAL	Percent
6-inch	11	5	1	17	25.0
1-foot	6	3	2	11	16.2
1-meter	6	7	5	18	26.5
3-meter	5	4	3	12	17.6
5-meter	0	2	1	3	4.4
10-meter	0	2	2	4	5.9
15-meter	1	0	0	1	1.5
30-meter	0	2	0	2	2.9
Total responses: 68					

Ground resolution of 1 square meter or smaller was ideal for 68 percent of the respondents (Question 5). Another 18 percent chose 3 square meters. Only 10 percent chose 10-meter or larger cell sizes for land cover. The questionnaire did not inquire about the smallest object on the ground that needs to be mapped, for which business needs, but 1-meter resolution was selected as ideal by 27 percent of the respondents, and resolutions as tight as 6-12 inches were

chosen by 41 percent of the respondents. In rank order, the preferences for ideal ground resolution were:

- 1-meter
- 6-inch
- 1-foot
- 3-meter
- 10-meter
- 30-meter
- 5-meter
- 15-meter

The results suggest a bi-modal ground resolution requirement. By organization type, local government respondents favored 6- or 12-inch resolution with a few choosing 1-meter resolution. Most federal government and university respondents chose between 1 and 10 meters. State government and regional organization respondents indicated a wide range from 6-inch to 30-meter resolution. See the table and Figure 2.

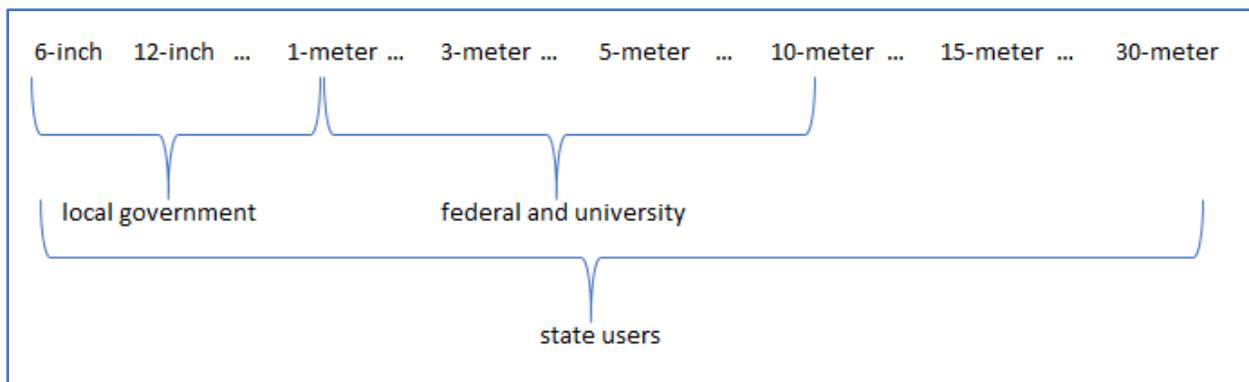


Figure 2. Ideal Ground Resolution by Respondents' Organization Type

Other responses: 250 square meters can be useful for some purposes; the resolution depends on the land cover class and how used; for example, tree cover may be best represented at a resolution of 1 meter, but impervious surface may be best at 30 centimeters (11.8 inches). Also, there may be a trade-off between resolution and frequency to consider; less than the ideal resolution may be practical on a more frequent basis. Analysis by local government can range from a neighborhood to a four-county area.

Do the survey results suggest a priority land cover product? With the exception of highly detailed representation of impervious surface for storm water billing purposes, most business needs would be served by 1-meter resolution. Regarding ground resolution (pixel size) of source imagery to be classified, a small pixel size (e.g., 6-inch) can be resampled to a larger pixel size (e.g., 1-meter, 3-meter, 10-meter, etc.). For land cover classification, a pixel size smaller than 1-meter may introduce more error and more cost to product. For example, a large tree branch may indicate a hard surface in a grassy location where the grass cover is uninterrupted on the ground. The 6-inch resolution is likely to introduce "noise" that complicates the

classification and increases the time (and cost) spent supervising and intervening in a semi-automated process of classification.

Question 6. What is the Minimum Ground Resolution?	Local/Reg	State	Nat/Uni	TOTAL	Percent
6-inch	2	0	0	2	2.7
1-foot	5	1	1	7	9.5
1-meter	8	8	2	18	24.3
3-meter	6	3	2	11	14.9
5-meter	2	4	1	7	9.5
10-meter	5	3	5	13	17.6
15-meter	0	1	1	2	2.7
30-meter	2	7	5	14	18.9
Total responses: 74					

If not ideal, what is the minimum resolution for business needs? Of 72 respondents to Question 6, 24 percent selected 1-meter resolution, and another 9 percent chose 1-foot. Interestingly, 20 percent settled for 30-meter resolution, a familiar cell size for federal land cover products. One response to Question 6 summarized the general concept: as ground resolution (pixel size) increases, the quality of the representation of what is on the ground decreases. By organization type, local government business needs tended to favor 1-foot to 1-meter resolution, while other organization types were mixed in choosing minimum resolutions:

Question 7. What land cover classes would best meet your needs?	TOTAL	Percent
USGS National Land Cover Data, Level 1: water, developed, barren, forest, shrubland, herbaceous, cultivated, wetland	5	6.8
USGS National Land Cover Data, Level 2: open water, developed (open space), developed (low intensity), developed (medium intensity), developed (high intensity), barren land, deciduous forest, evergreen forest, mixed forest, shrub/scrub, grassland/herbaceous, pasture/hay, cultivated crops, woody wetlands, emergent herbaceous wetlands.	49	66.2
More detailed than Level 2 classes	10	13.5
I need only forest cover	1	1.4
I need only impervious cover	1	1.4
Other classification scheme:	8	10.8
Total responses: 74		

The USGS Level 2 classes were favored by 66 percent of respondents. Some state and federal government respondents indicated a need for more detail than the USGS National Land Cover Data Level 2, but all organization types had some business needs satisfied by Level 2.

Other responses to Question 7:

- Include the US National Vegetation Classification (USNVC) for natural and cultural plant communities as implemented in GAP Analysis/LandFire (hosted by NC State University)

- Emphasis that “impervious surface” should be a land cover class, preferably integrated at USGS level 2
- A mix of USGS levels 1 and 2, but with more detailed classes for wetlands

Discussion: Survey results indicated satisfaction with the NLCD Level 2 classification scheme. If necessary, a simpler scheme would meet most business needs. First, the NLCD scheme has four categories of developed land:

- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity

Classification of those development types in NLCD was based on estimates of percent impervious surface in each 30-meter pixel. Using a higher resolution of 1-meter, pixels may be classified as impervious surface (instead of 22, 23, and 24), in the grassland class (21) or some other class.

Second, NOAA uses a “trees” class instead of three classes:

- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest

In fact, the mixed forest class (43) does not make sense at 1-meter resolution where a class of deciduous or evergreen would apply in a single pixel (not both).

Third, relating to agriculture, distinguishing between two classes may be quite time consuming and NLCD Level 2 classes for agriculture may be candidates for combining into an agriculture class:

- 81 Pasture/Hay
- 82 Cultivated Crops

Similarly, wetland classes may be candidates to combine into one class:

- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

EPA’s experience with classification of land cover indicates that distinguishing between bare ground and grass in leaf-off conditions can be challenging.

Alternatively, NLCD Level 2 classes may be collapsed to classes such as those in the NOAA classification of land cover using 1-meter ground resolution. NOAA uses six land classes plus a water class in its transition to a 1-meter product:

- Developed
- Agricultural
- Rangeland (grassland, herbaceous, scrub, shrub)
- Forest Land
- Barren Land
- Wetlands

The Working Group recognized the trade-off between class detail and time/cost in classifying land cover from imagery.

Question 8. Does Your Need Require Change Detection?	Local/Reg	State	Nat/Uni	TOTAL	Percent
Yes, latest and 4 or 5 years prior	16	15	7	38	55.9
Yes, annual change	10	5	2	17	25.0
No, latest land cover is sufficient	6	5	2	13	19.1
Total responses: 68					

Respondents to Question 8 indicated that land cover change analysis is valuable for most business needs. Excepting federal respondents, all organization types had some business needs for annual land cover. Land cover over a 4 to 5-year cycle was indicated as useful in all organization types.

Other responses to Question 8 indicated that the latest land cover is essential, and land cover over a cycle of 4 to 6 years would be useful.

Discussion: Most business needs such as modeling and land use planning would benefit from classified land cover data every four years, but many would benefit from annual data for regular change detection. No matter if all the NLCD Level 2 classes are applied, or a simplified set of classes, the primary concern in change detection is change from non-developed to developed land.

Land cover data captured in multiple years would not be the only indicator of change. For some business needs, such as water quality analysis, creating data for locations of stormwater permits as they are issued would indicate areas of change that would inform business processes sooner than a classified land cover could be produced. Analysis of changes in tax parcels from the previous year (e.g., parcels under a size threshold representing likely residential development, and/or parcels with building value over a dollar threshold) can indicate patterns of development.

Question 9. What Ground Condition?	Local/Reg	State	Nat/Uni	TOTAL	Percent
Leaf-off	18	13	2	33	44.6
Leaf-on	4	0	0	4	5.4
Both leaf-on and leaf-off	10	10	10	30	40.5
Either leaf-on or leaf-off	1	4	2	7	9.5
Total responses: 74					

Respondents to Question 9 were split between choosing leaf-off (46 percent) or both leaf-off and leaf-on (41 percent) as ground conditions for source imagery to be classified as land cover. All organization types had respondents advocating for leaf-off conditions or both leaf-off and leaf-on conditions:

Question 10. What is the Geographic Extent of Business Need?	Local/Reg	State	Nat/Uni	TOTAL	Percent
Statewide	0	25	3	28	45.9
My county only	14	0	1	15	24.6
My county and neighboring counties	8	0	2	10	16.4
My municipality	0	0	0	0	0.0
A project area of interest	0	2	2	4	6.6
National or coastal region	0	0	4	4	6.6
Total responses: 61					

Respondents to Question 10 favored statewide coverage (46 percent), county (25 percent) or multi-county (16 percent). Responses tended to differ by organization type, with federal respondents needing national data for consistency, state government business needs being served best by statewide land cover, local governments needing their own jurisdictions as well as neighboring counties, regional governments needing groups of counties or statewide, and universities needs tending toward project areas of interest that vary over time:

Other responses indicated interest in specific counties for regional analysis, national land cover data, state data that fits a national classification scheme, NC coastal areas as a priority, and land cover classification in areas extending beyond state boundaries relating to 8-digit hydrologic units.

Question 11. What Time Lag Between Capture and Publication Can You Tolerate?	Local/Reg	State	Nat/Uni	TOTAL	Percent
12 months	20	16	6	42	63.6
6 months	6	5	3	14	21.2
1 month	1	0	0	1	1.5
Other specific time lag	2	3	4	9	13.6
Total responses: 66					

Respondents heavily favored 12 months (64 percent). Other responses to Question 11 suggested that 24-month lag or longer can be tolerable, depending on the business need. Land cover can be used several years hence, but in general, the sooner data are published the better. Some respondents would be grateful for a new land cover product on any timetable compared to what is available now in terms of vintage and resolution.

Question 12. Please share additional comments and suggestions related to your business need for land cover data.

Responses to Question 12 added more insight into business needs for land cover data:

- a. Creating one land cover product for a large user base may dilute the solution opportunities for an increasing number of end-users.
- b. Data needs to be available online for agency staff use because many work from home offices and do not have internal state government connections to state servers
- c. The State of North Carolina should not go it alone—integrate with national level efforts, especially GAP/Landfire (headquartered at NCSU).
- d. Metadata availability will be vital.
- e. Land cover data outside of North Carolina boundaries are needed for modeling watersheds in river basins that flow into the state.
- f. Of great importance is land cover data that can be applied in models related to subdivision development, large scale home building tracts and mixed-use development areas.
- g. US EPA has had a wide variety of land cover requirements for various programs.
- h. A valuable dataset would indicate land cover pixels that have changed from forest to some other class (and other class to forest) over 10 year-periods.
- i. While leaf-off alone or leaf-off and leaf-on imagery appear to be most useful for land cover classification, leaf-on imagery alone could still be useful.
- j. For some local governments, paying for a land cover product is not practical.
- k. One county described success in purchasing color infrared orthoimagery in conjunction with Statewide Orthoimagery and classifying land cover to create an informative product for the county.
- l. A suggestion is to deliver land cover data along with Statewide Orthoimagery (one-fourth of the state each year).
- m. Land cover is useful for analyzing water quality, agricultural lands, and biodiversity and for habitat mapping.
- n. Land cover is not applied to transportation planning, design, and construction.
- o. Lead regional organizations may be willing and able to contribute in-kind assistance but, as receipt-supported entities, would not have funds available for sharing costs.

Summary of Priority Business Needs

What are the priority business needs and requirements for land cover data? Many of the compelling business needs for land cover require a ground resolution of 1-meter or better; reliable distinction between what is classified as impervious surface, tree cover, farm fields, and wet areas; and frequency of at least annual classification to detect land cover change. Some business needs require more detailed classes, especially related to wildlife habitat, but with less frequency.

A shared need among survey respondents may be described as a timely resource to identify changes in land cover, especially from forest and/or agriculture to developed, serving a variety of purposes and generating benefits.

Classified land cover data can be scoped for specific business needs in terms of resolution and classes. The most valuable land cover dataset for the most business needs may be statewide, NLCD level-2 classification, 1-meter ground resolution, annual, produced within 12 months, and easily accessible as a raster dataset. That dataset could be re-classified to simpler classes, resampled to pixel sizes larger than 1-meter, and extracted for areas of interest.

In practical terms, frequency and geographic extent may be related in terms of how often land cover is classified and where. While statewide land cover is preferred by survey respondents, there are business needs that could be served by targeted land cover classification for areas of interest from one or more statewide and or regionwide imagery sources.

Satisfying the needs of water quality planning in river basins that span multiple states highlights the value of national land cover classification.

Recommendations

The Working Group for Land Cover recommends that the Statewide Mapping Advisory Committee recognize significant business needs for land cover data, and pursue research on sources of imagery to be classified, tools and techniques, and strategies for targeting land cover classification and products to satisfy business needs identified in this report.

The Working Group recommends that the State of North Carolina not “go it alone” and collaborate with national efforts including GAP Analysis/Landfire, NOAA land cover mapping, and US EPA land cover mapping. Complementary data development efforts in North Carolina have emerged from the NC Department of Agriculture & Consumer Services (forest cover classification from NAIP imagery), and US Fish and Wildlife Service (tree canopy data development from NAIP imagery).

Next Steps

Findings about business needs lead to questions about source imagery, classification techniques, requirements, business cases, and a standard for future land cover data development. Topics for further research and analysis:

1. What are sources of imagery that would be suitable for the priority business needs? For example, can statewide orthoimagery be produced in an additional color infrared dataset for land cover classification? Can classification of LiDAR serve as alternative or a supplement to land cover classification?
2. What classification techniques would be suitable?
3. What can we learn from municipalities and counties with experience classifying land cover at high ground resolution?
4. Can the priority requirements (ground resolution, classes, extent, frequency) all be satisfied by a source and a classification technique? Are there practical trade-offs among the priority requirements?
5. Which organizations have the strongest business cases for land cover products? Is there funding for those cases?
6. What are practical methods for targeting areas for priority land cover classification where land cover change is most evident or likely? For example:
 - a. Building permits
 - If locations reach a density threshold
 - What is currency/frequency of publication of building permits and in what format(s)?
 - b. Road construction
 - If new road segments, what is threshold for centerline length or total of all segments with the same name/route?
 - What is currency/frequency of update of local roads in the statewide roads dataset?
 - c. Military installations
 - Select buffer area and update frequently?
 - d. Streams or other sensitive natural resources as prime areas to monitor
 - Select buffer areas and update frequently?
 - Parcel ownership trends?
7. What are relative costs for classifying different imagery sources, at different ground resolutions, with different classification schemes?

Acknowledgements

The Chair of the Land Cover Working Group would like to thank members of the group and their colleagues and counterparts who responded to the land cover survey and/or otherwise advised the group about business needs for land cover data.

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Appendix A

Land Cover Classification Schemes

1. North Carolina

The North Carolina land cover classification scheme from 1994 has seven first-level classes and several detailed classes for some. This was applied to the 1996 statewide land cover dataset.

- 1 Heavily Developed or Disturbed Land
- 2 Cultivated Land
- 3 Herbaceous Cover and Shrubland
 - 31 Herbaceous Cover
 - 32 Shrubland
- 4 Forest Land
 - 41 Broadleaf Deciduous Forest Land
 - 42 Needleleaf Coniferous Forest Land
 - 43 Non-Deciduous Broadleaf
 - 44 Mixed Deciduous-Coniferous Forest Land
 - 48 Orchards and Tree Farms
 - 49 Other Forest Land
- 5 Water Bodies
 - 51 Coastal/Marine Water Bodies
 - 52 Inland Water Bodies
 - 54 Linear Drainage
 - 59 Other Water Bodies
- 6 Bare Land
 - 61 Beaches, Bare Coastal Land, and Upland Sand Areas
 - 62 Riverbanks and Bars
 - 63 Exposed Rock
 - 64 Other Barren Land
- 9 Other Unclassified Land Cover

Note: the North Carolina classification scheme did not classify wetlands, yielding to the vegetation covering wet areas, and intending to produce a separate wetlands dataset that was not realized. The land cover product has a ground resolution of 30 meters.

2. US Geological Survey

The USGS National Land Cover Data Level One classes are somewhat different, with more detailed classes for developed land, two wetland classes, and fewer detailed classes for forest land, water bodies, and bare land. The land cover product has a ground resolution of 30 meters.

- 11 Open Water
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land (Rock/Sand/Clay)
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 52 Shrub/Scrub
- 71 Grassland/Herbaceous
- 81 Pasture/Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

3. GAP/LANDFIRE National Terrestrial Ecosystems

Another national land cover mapping product from 2011 satellite imagery (30-meter resolution) is available from the USGS Gap Analysis Program located in NC State University. Gap Analysis is the science of answering the question: How well are we protecting common plants and animals? The mission of the Gap Analysis Program (GAP) is to develop the data and tools that support that science.

A new GAP dataset is in progress as described on the GAP/LANDFIRE [website](#): “In conjunction with changes within the Federal Geographic Data Committee, National Geospatial Data Asset (FGDC NGDA) Biodiversity and Ecosystems Theme, the theme’s leadership proposed and had accepted a formal name change for GAP’s National Land Cover Dataset. The new name, GAP/LANDFIRE National Terrestrial Ecosystems, conveys the ecological richness of the map legend and the ongoing collaboration between the National GAP and LANDFIRE Programs.” The Working Group for Land Cover will review forthcoming GAP/LANDFIRE National Terrestrial Ecosystems data. For more information on classification, see the U.S. National Vegetation Classification (<http://usnvc.org/>)

4. NOAA High-Resolution Land Cover

The High-Resolution Land Cover Classification Scheme used in NOAA's Coastal Change Analysis Program (C-CAP) has classes targeted as indicators of coastal ecosystems. There are 25 classes in the full set:

Unclassified

- Unclassified (1)

Developed Land

- Impervious (2)
- Developed, Open Space (5)

Agricultural Land

- Cultivated Crops (6)
- Pasture/Hay (7)

Grassland

- Grassland/Herbaceous (8)

Forest Land

- Deciduous Forest (9)
- Evergreen Forest (10)
- Mixed Forest (11)

Scrub Land

- Scrub/Shrub (12)

Barren Land

- Unconsolidated Shore (19)
- Barren Land (20)
- Tundra (24)
- Perennial Ice/Snow (25)

Palustrine Wetlands

- Palustrine Forest Wetland (13)
- Palustrine Scrub/Shrub Wetland (14)
- Palustrine Emergent Wetland (Persistent) (15)

Estuarine Wetlands

- Estuarine Forested Wetland (16)
- Estuarine Scrub/Shrub Wetland (17)
- Estuarine Emergent Wetland (18)

Water and Submerged Lands

- Open Water (21)
- Palustrine Aquatic Bed (22)
- Estuarine Aquatic Bed (23)

Note: For the 1-meter land cover product, these may be grouped in six categories: Impervious, Bare, Grass, Shrub, Forest, and Water.