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High-resolution Land Use Change Data in CAST-21

Background

To understand the land use differences between CAST-19 and proposed CAST-21, it is necessary to understand how the land use data for CAST-19 was created. This is a high-level summary of information available in more detail in Section 5 of the Phase 6 land use documentation. To create the 2013-2025 CAST land use, the original 2013 high-resolution land use data were integrated with surveyed estimates of agricultural acres from the Census of Agriculture (interpolated annually between 2012 and 2017 and extrapolated statistically to 2025), estimated feeding space, and modeled urban growth forecasts from 2013-2025 derived from state-sponsored population and employment projections. Census estimates of agricultural acres often differ from mapped agricultural acres and all data have some level of uncertainty associated with it. Therefore, a reconciliation process was needed that adjusts all land uses to maintain the fixed area of each land-river segment. The overall magnitude of adjustment is determined by the acreage difference between mapped and Census-estimated agricultural acres. The reconciliation process is referred to as the "true-up" and generally involves adjusting the combined mapped, surveyed, and modeled land use acres for each year (2013-2025) at the land-river segment scale proportional to the adjustable portion of each land use which is a function of the relative accuracy[1] and extent for each land use. For example, if mapped forests compose 1,000 acres in a land river segment and are 97% accurate, they can potentially be adjusted by 30 acres. Likewise, if mapped impervious surfaces are 95% accurate and cover 100 acres, they can potentially be adjusted by 5 acres. The acres of cropland and pasture reported in the Census of Agriculture are also adjusted in this process based on their extents and reporting standard error rates. Using this process, land uses with the highest accuracy and lowest extent (e.g., impervious surfaces) have the lowest adjustment potential whereas land uses with the lowest accuracy and highest extent (e.g., turf grass, pasture, cropland) have the greatest adjustment potential. Following the "true-up" process, estimated feeding space is incorporated and taken out of cropland, reported or estimated construction acres and reported or estimated timber harvest acres are integrated directly into the land use data. Where not reported, construction acres for any given year equal 1.29 * (estimated change in developed land for the subsequent year). Construction acres are taken proportionally from developed land uses. Where not reported, timber harvest acres equal 1.5% of forest acres and are subtracted from forest acres.

When the CAST-19 land use data are examined as change over time at county scales, some issues emerge. In some counties, developed land uses increase as farmland declines despite declines in population and employment and little observational evidence of urban growth in the high-resolution data. In other counties, impervious surfaces increase (due to modeled urban growth) while turf grass decreases (despite modeled increases) resulting from the true-up process. Large fluctuations in forest cover can occur at the county scale despite the high accuracy of

[1] The mapped land use accuracies were assessed based on the statewide land cover accuracy statistics produced for the original 2013 land cover data produced for each state. Turf grass was given the same accuracies as the Census of Agriculture except in Virginia where it was explicitly assessed.

mapped forest cover because forest encompasses the majority of some counties. The creation of the high-resolution land use change data provides, for the first time, a contrasting perspective of land use patterns and trends in the watershed.

High-resolution Land Use Change Data

Under a 2018, six-year Cooperative Agreement between the USEPA and the Chesapeake Conservancy, high-resolution land cover, land use, and land use change datasets are being developed for all 206 counties within, intersecting, and adjacent to the Chesapeake Bay watershed. The data produced under this agreement include land use change data representing change from 2013/14 to 2017/18. These data were produced directly from the imagery as an independent product from the "wall-to-wall" (aka complete coverage) static land use datasets for 2013/14 to 2017/18. The creation of this new land use change product was also independent from the original 2013/14 land use data and therefore is not impacted by the methodology and data used to produce the original 2013/14 land use. The land use change data are assumed to represent cumulative changes over the four period. This is a reasonable assumption because changes detectable in the imagery such as the development of new structures and regrowth of trees often takes multiple years to progress to a point where change can be detected in the imagery. To create the land use data in CAST for the years 2014-2017, the annualized changes in mapped land uses over the 2013-2017 period are added to the original 2013/14 land use data that informs all versions of CAST.

CAST-21 is the first version of CAST to ingest high-resolution land use change data. These data have been reviewed by county and state organizations, non-governmental organizations, and technical staff from the University of Vermont, Chesapeake Conservancy, and USGS. A concerted effort was made to facilitate local review of the data including the creation of an online review tool and the automated production of land use change matrices (aka "pivot tables") for every county and incorporated city in the watershed: http://cicapps.org/obj1lu/. Probably no other dataset in the history of the Chesapeake Bay Program has received the level of scrutiny and review as these data. The intensive review process has led to noticeable improvements and corrections to the data over the past several months. A formal accuracy assessment of these data will be initiated in the fall of 2021.

Comparing Changes in Land Use between CAST-19 and CAST-21 from 2013 to 2017

Table 1 (below) represents a comparison between land use change from 2013 to 2017 as depicted in CAST-19 and CAST-21 for the 197 full-counties in CAST broken down by major jurisdiction with units in acres. The extent of this area is greater than that of the Bay watershed but the relative differences between CAST-19 and CAST-21 are similar for the watershed as for the 197-county area. The left-hand table reflects changes in land use in CAST-19 from 2013-2017. The middle table reflects changes in land use in CAST-21 from 2013-2017. The right-hand table reflects differences between the changes represented in CAST-19 and CAST-21. For example, focusing on Delaware one can see that in CAST-19, 1,431 acres of new development and 14,724 acres of new agriculture were estimated to have occurred from 2013-2017 with corresponding decreases of natural lands (forest and wetlands) by 7,524 acres and mixed open (e.g., herbaceous/barren lands not receiving fertilizer, most of which are undergoing succession) by 8,621 acres. In contrast, the mapped high-resolution land use change data reflected in CAST-21 (middle table)

indicate that development in Delaware increased by 11,180 acres with corresponding declines in all other land uses. Throughout the 197-county area, total differences in development between CAST-19 and CAST-21 shown in the far-right table are minor (4,770 acres). These differences become more pronounced at the state level and even more at the scale of individual counties. Changes to natural lands, agriculture, and mixed open are very different between CAST-19 and CAST-21. Examining the high-resolution imagery and land use change product via the online tool, http://cicapps.org/obj1lu/, large declines in agricultural lands reported in the Census of Agriculture are not visible. This may be because Census-estimated agricultural acres reflect land in production whereas the high-resolution land use represents agricultural lands as low vegetation in large parcels that have been mapped as cropland or pasture in the USDA's Cropland Data Layer, USGS' National Land Cover Database, or local land use datasets. However, this explanation of difference is not always applicable because the Census sometimes reports more land in agriculture in a county than can possibly exist according to the high-resolution land use data. Differences in changes in natural and mixed open lands between CAST-19 and CAST-21 mostly stem from the complete mapping of all forest clearings in the high-resolution imagery. Forest clearings are not reported in the Census of Agriculture and clearings unassociated with development are not modeled as a component of urban growth. Forests may be cleared for timber, development, and sometimes (but rarely) for agriculture. The ultimate use of lands that were forested in 2013/14 and cleared by 2017/18 is not always evident and therefore cleared forests are classed as "mixed open" in CAST-21. The high-resolution land use change data detect some forest regrowth but not very much because it generally takes longer than four years for trees to mature on cleared or low-shrub land. Therefore, it should be noted that most of the declines in natural lands in CAST-21 are transient and will appear again as forest in the 2021/22 data or in the 2025/26 data, assuming the CBP extends the high-resolution monitoring period. A similar logic and interpretation of the CAST-19 land change data is not possible because much of the change over time in CAST-19 is an artifact of the true-up process.

Table 1. Comparison of changes in land use from 2013-2017 between CAST-19 and CAST-21.

2013 to 2017

CAST 2019

2013-2017	DEV	NAT	AG	MO
Delaware	1,431	(7,534)	14,724	(8,621)
District of Columbia	64	(64)	-	(0)
Maryland	18,027	(2,077)	(9,693)	(6,257)
New York	28,305	132,912	(163,996)	2,779
Pennsylvania	36,453	49,781	(81,583)	(4,650)
Virginia	31,407	(65,551)	46,699	(12,555)
West Virginia	1,099	(17,751)	20,116	(3,464)
Total	**116,785**	**89,716**	**(173,733)**	**(32,769)**

CAST 2021

2013-2017	DEV	NAT	AG	MO
Delaware	11,180	(4,473)	(2,567)	(4,140)
District of Columbia	78	(34)	-	(44)
Maryland	24,974	(11,361)	(8,068)	(5,545)
New York	7,622	(6,154)	(3,103)	1,636
Pennsylvania	34,619	(79,060)	(6,278)	50,720
Virginia	38,974	(242,427)	(1,920)	205,374
West Virginia	4,108	(11,677)	(386)	7,955
Total	**121,555**	**(355,187)**	**(22,324)**	**255,956**

CAST 2021 - CAST 2019

2013-2017	DEV	NAT	AG	MO
Delaware	9,750	3,061	(17,292)	4,481
District of Columbia	14	29	-	(44)
Maryland	6,947	(9,284)	1,625	712
New York	(20,683)	(139,066)	160,892	(1,143)
Pennsylvania	(1,834)	(128,841)	75,305	55,370
Virginia	7,567	(176,876)	(48,619)	217,929
West Virginia	3,009	6,074	(20,502)	11,419
Total	**4,770**	**(444,903)**	**151,409**	**288,724**

Land Use Change from 2017 to 2025

Note: Updates to the urban growth forecasts are not pending a WQGIT decision because updating these forecasts for every milestone period with new and more accurate data for such things as population estimates and sewer service areas is already Water Quality GIT policy (and has occurred for previous Milestone updates).

For the years post-2017, no high-resolution land use data yet exist and therefore land use conditions must be inferred from models and statistical techniques. For CAST-19, trends reported in the Census of Agriculture were extrapolated annually from 2017 through 2025 and these were reconciled (via the "true-up" process) with modeled increases in urban development and associated conversions of farmland and forest. For CAST-21, extrapolated trends from the Census of Agriculture and the "true-up" process will be eliminated and therefore the only changes in land use that occur post-2017 in CAST-21 will be those associated with modeled urban development. Urban growth in both CAST-19 and CAST-21 is modeled using the CBP Partnership's Chesapeake Bay Land Change Model (CBLCM). This model was used to inform the Phase III WIPs and CAST-17 and updated with the most recent data for CAST-19. The model has been reviewed twice by STAC in 2008 and 2010 and revised according to STAC recommendations. For the CBLCM, urban growth is driven by expected growth in population and/or employment with data provided by state-sponsored projections. In the process of updating the population and employment projections for each milestone period, additional updates are made to protected lands, sewer service areas, and MS4 areas, and the base-year land use (if needed).

For CAST-21, updates to the urban growth forecasts included updates to the population and employment projections for Maryland, Delaware, and the Baltimore Metropolitan Council counties. In addition, county-level population estimates were updated from the Census Bureau's 2018 data release to their 2020 data release. The 2020 population estimates enabled a first-time (for CAST-21) adjustment of projected population values to conform to the Census' estimated population values. For example, if the 2020 population projections for a particular county were 5% higher than the Census' 2020 population estimates, the projections for all future years for that county were adjusted down by 5%. The Census Bureau conducts population estimates separately from the Decennial Census, but they are still more accurate than projections.

Another first for CAST-21 is a reduction in the forecast period, from 12 years (2013-2025) in CAST-19 to 8 years (2017-2025) in CAST-21. Reducing the duration of the forecast reduces the potential magnitude of error and resets the baseline for the forecasts from 2013 to 2017. To update the baseline land use, the 2016 National Land Cover Dataset (NLCD) was combined with the high-resolution developed footprint (all impervious surfaces, turf grass, and trees over turf grass) mapped for 2017/18. For CAST-19, the 2013 baseline was established using the 2011 National Land Cover Dataset combined with the high-resolution impervious footprint mapped for 2013/14. This high-resolution data is integrated into the coarser, 30-meter resolution NLCD to ensure future development is not simulated in already developed areas (infill and redevelopment are estimated separately).

Comparing Changes in Land Use between CAST-19 and CAST-21 from 2017 to 2025

Table 2 (below) represents a comparison between land use change from 2017 to 2025 as depicted in CAST-19 and CAST-21 for the 197 full-counties in CAST broken down by major jurisdiction with units in acres. This table, configured similarly to Table 1, shows that CAST-21 indicates less development, a decrease in forest, and less of a decrease in agriculture and mixed open land compared to CAST-19 for the period 2017 to 2025. Less development in CAST-21 stems from adjusting the projections in all jurisdictions to align with the recently released 2020 population estimates from the Census Bureau. Less of a decline in agriculture and the decline in forest stem mainly from eliminating the future extrapolation of agriculture in CAST-21 and associated "true-up" process. Further differences may be explained by the additional exclusion of developed lands in 2017/18 which might alter the deflection patterns of growth to remaining undeveloped, unprotected farms and forest lands in the CBLCM.

Table 2. Comparison of changes in land use from 2017-2025 between CAST-19 and CAST-21.

CAST 2019

2017 to 2025	DEV	NAT	AG	MO
Delaware	20,394	(3,853)	(17,002)	461
District of Columbia	127	(127)	-	0
Maryland	26,596	6,369	(48,917)	15,952
New York	15,195	99,070	(134,192)	19,927
Pennsylvania	47,285	27,278	(99,366)	24,804
Virginia	93,684	(49,541)	(46,525)	2,382
West Virginia	5,114	(2,161)	(3,262)	310
Total	**208,395**	**77,035**	**(349,264)**	**63,834**

CAST 2021

2017-2025	DEV	NAT	AG	MO
Delaware	19,292	(3,622)	(16,127)	457
District of Columbia	115	(115)	-	0
Maryland	15,865	(8,434)	(8,282)	851
New York	295	(21)	(280)	6
Pennsylvania	16,112	(4,195)	(12,324)	407
Virginia	86,804	(48,684)	(40,443)	2,323
West Virginia	4,724	(1,415)	(3,440)	131
Total	**143,207**	**(66,486)**	**(80,897)**	**4,176**

CAST 2021 - CAST 2019

2017-2025	DEV	NAT	AG	MO
Delaware	(1,102)	230	875	(4)
District of Columbia	(12)	12	-	0
Maryland	(10,731)	(14,804)	40,635	(15,101)
New York	(14,900)	(99,091)	133,911	(19,921)
Pennsylvania	(31,173)	(31,473)	87,042	(24,397)
Virginia	(6,880)	857	6,082	(59)
West Virginia	(390)	747	(178)	(178)
Total	**(65,188)**	**(143,521)**	**268,367**	**(59,659)**