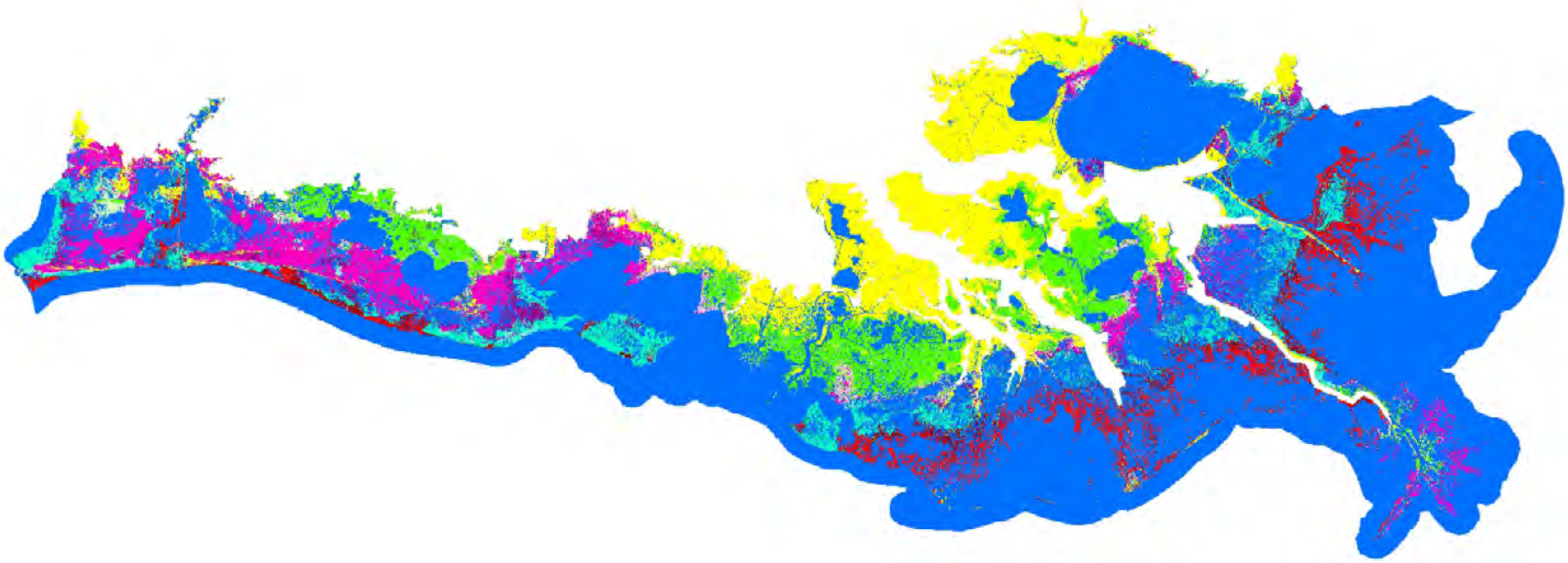
Prepared in cooperation with Bureau of Ocean Energy Management

Delineation of Marsh Types and Marsh-Type Change in Coastal Louisiana for 2007 and 2013



Scientific Investigations Report 2017–5044

U.S. Department of the Interior
U.S. Geological Survey

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By Stephen B. Hartley, Brady R. Couvillion, and Nicholas M. Enwright

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RYAN ZINKE, Secretary

U.S. Geological Survey
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U.S. Geological Survey, Reston, Virginia: 2017

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as

°F = (1.8 × °C) + 32.

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as

°C = (°F – 32) / 1.8.

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Abbreviations

CCAP	Coastal Change Analysis Program
DEM	digital elevation model
DT	decision-tree
lidar	light detection and ranging
NAIP	National Agriculture Imagery Program
NLCD	National Land Cover Database
NWI	National Wetlands Inventory
TM	Thematic Mapper
USGS	U.S. Geological Survey

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Abstract

The Bureau of Ocean Energy Management researchers often require detailed information regarding emergent marsh vegetation types (such as fresh, intermediate, brackish, and saline) for modeling habitat capacities and mitigation. In response, the U.S. Geological Survey in cooperation with the Bureau of Ocean Energy Management produced a detailed change classification of emergent marsh vegetation types in coastal Louisiana from 2007 and 2013. This study incorporates two existing vegetation surveys and independent variables such as Landsat Thematic Mapper multispectral satellite imagery, high-resolution airborne imagery from 2007 and 2013, bare-earth digital elevation models based on airborne light detection and ranging, alternative contemporary land-cover classifications, and other spatially explicit variables. An image classification based on image objects was created from 2007 and 2013 National Agriculture Imagery Program color-infrared aerial photography. The final products consisted of two 10-meter raster datasets. Each image object from the 2007 and 2013 spatial datasets was assigned a vegetation classification by using a simple majority filter. In addition to those spatial datasets, we also conducted a change analysis between the datasets to produce a 10-meter change raster product. This analysis identified how much change has taken place and where change has occurred. The spatial data products show dynamic areas where marsh loss is occurring or where marsh type is changing. This information can be used to assist and advance conservation efforts for priority natural resources.

Introduction

Detailed information on the extent and distribution of emergent marsh vegetation types throughout coastal Louisiana has been historically available (O'Neil, 1949; Chabreck and others, 1968; Chabreck and Linscombe, 1978, 1988, 1997; Linscombe and Chabreck, n.d.; Sasser and others, 2008, 2014). These existing maps showing marsh vegetation types in coastal Louisiana have been used to document temporal changes in vegetation types and land-water relationships in coastal Louisiana and to refine the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) datasets. These datasets were limited because of their coarseness and have proven insufficient for large-scale targeted conservation planning efforts conducted by natural resource managers and coastal researchers. Although these datasets provide useful historical information, technological limitations prevented these and other mapping efforts from providing sufficiently detailed calculations of areal changes and shifts in marsh vegetation types. To help meet these needs, the U.S. Geological Survey (USGS) in cooperation with the Bureau of Ocean Energy Management produced a detailed classification of marsh vegetation types indicative of salinity zones for 2007 and 2013 by using advanced geographic information system datasets that were created by using Landsat Thematic Mapper (TM), digital color-infrared aerial imagery, and lidar data at a spatial scale of 10 meters (m) (Hartley and others, 2017). Additionally, we conducted a change analysis to determine how marsh types have changed from 2007 and 2013. The ability to understand past dynamics and anticipate future trends in vegetation change and related land loss in the coastal region of Louisiana is vital to ongoing and future efforts to conserve the region's critical wetland ecosystem. Our analysis provides Federal and State agencies, as well as researchers and interested parties in the private sector, with current (2017) and large-scale detailed information which could be used to base future decisions in the interest of preserving the coastal marshes of Louisiana.

Methodology

Habitat types were classified by using decision-tree (DT) classification analyses and rulesets produced by using Rulequest See5 in combination with ERDAS IMAGINE 2010, National Land Cover Database (NLCD) Mapping Tool version 2.087, Esri ArcMap version 10.2, and Trimble eCognition version 9.2 software packages. See5 has been used to produce broad land-cover classifications, including NLCD (Homer and others, 2007; Enwright and others, 2014, 2015) and Coastal

Change Analysis Program (CCAP). DT classification analyses use dependent variables (such as ground reference data) and a suite of predictor variables (such as independent spatial variables) to develop multivariate classification trees for classifying a target area. Seven Landsat TM scenes cover the study area (fig. 1). DT classification analyses were developed for each Landsat TM scene.

Building upon earlier efforts of Sasser and others (2008, 2014), this study involved classification of land cover in coastal Louisiana by using reference data from approximately 8,500 sample points collected via helicopter surveys during each survey year. CCAP data from 2006 and 2010 served as additional reference data for non-wetland classes. A change-vector analysis was conducted to exclude areas of change between the 2010 CCAP data and the 2013 imagery used for this analysis. Areas which were determined to have undergone a change between 2010 and 2013 were excluded from potential selection as reference data for non-wetland classes.

Independent variables included multitemporal satellite-based imagery from 2007 and 2013, a bare-earth digital elevation model (DEM; National Elevation Dataset 1/9-arc-second [3-m] elevation data) based on airborne lidar, and other contemporary land-cover classifications (such as 2007 and 2013 vegetation-type maps). All available cloud-free Landsat TM (table 1) satellite imagery from 2007 and 2013 was included to capture phenological conditions among coastal marsh plant species, such as green-up and senescence phases. Imagery was downloaded from the USGS Global Visualization

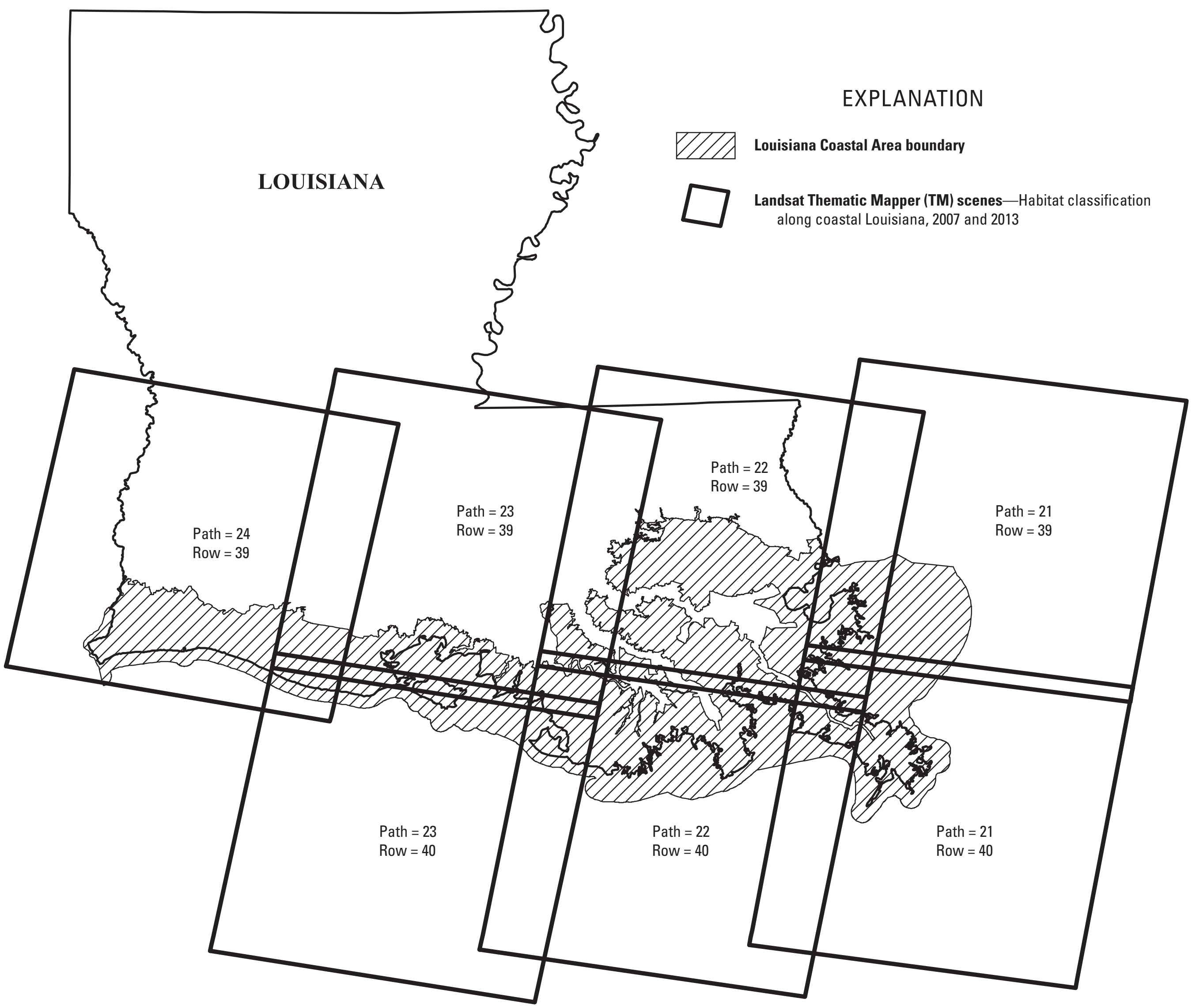

Figure 1. Landsat Thematic Mapper (TM) scenes for habitat classification along coastal Louisiana, 2007 and 2013. Also included is the Louisiana Coastal Area boundary (hatched area).

Table 1. Satellite imagery acquisition dates by Landsat Thematic Mapper (TM) scene for coastal Louisiana, 2007 and 2013.

[Water levels are from one gage in that area of the coast but may not be representative of all areas in the imagery footprint. MSL, mean sea level; m, meters; mm, month; dd, day; yyyy, year; *, portions of this image contained clouds, and pixels in that region were replaced by values from 9–29–2007 and 7–11–2007 after undergoing linear normalization to provide values as comparable as possible to the 8–12–2007 image]

Path 21 (mm–dd–yyyy)	Water level (MSL) (m) Station ID 8760922	Path 22 (mm–dd–yyyy)	Water level (MSL) (m) Station ID 8761724	Path 23 (mm–dd–yyyy)	Water level (MSL) (m) Station ID 8764227	Path 24 (mm–dd–yyyy)	Water level (MSL) (m) Station ID 8768094
11–22–2006	-0.493	10–28–2006	-0.351	11–20–2006	-0.546	2–12–2006	-0.965
1–25–2007	-0.029	4–6–2007	0.007	9–20–2007	0.019	4–20–2007	0.065
3–16–2008	0.010	8–12–2007*	0.138	2–27–2008	-0.197	2–18–2008	-0.238
10–26–2008	0.060	10–1–2008	0.045	4–15–2008	0.012	11–16–2008	-0.742
Path 21 (mm–dd–yyyy)	**Water level (MSL) (m) Station ID 8760922**	**Path 22 (mm–dd–yyyy)**	**Water level (MSL) (m) Station ID 8761724**	**Path 23 (mm–dd–yyyy)**	**Water level (MSL) (m) Station ID 8764227**	**Path 24 (mm–dd–yyyy)**	**Water level (MSL) (m) Station ID 8768094**
10–24–2013	0.043	12–18–2013	-0.367	2–27–2014	-0.460	4–20–2013	0.177
1–12–2014	0.011	1–19–2014	-0.296	9–23–2014	-0.002	12–16–2013	-0.368
5–4–2014	0.328	4–9–2014	-0.177	10–25–2014	-0.257	10–16–2014	0.071
11–28–2014	-0.160	11–19–2014	-0.082	11–26–2014	-0.285	11–1–2014	-0.425

Viewer (http://glovis.usgs.gov/) with the Standard Terrain Correction (level 1T); level 1T correction provides systematic radiometric and geometric accuracy by incorporating ground-control points while employing a DEM for topographic accuracy. No further geometric correction was applied, except for subpixel shifts to ensure pixel alignment among all Landsat TM scenes. All satellite multispectral imagery was processed in terms of top-of-atmosphere reflectance units. Additionally, the modified normalized-difference water index (Xu, 2006) and the normalized-difference vegetation index (Rouse and others, 1974) were calculated and used as independent variables in the DT analyses. For all Landsat TM imagery, a Tasseled-Cap Transformation (Crist and Cicone, 1984) of Landsat TM bands 1–5 and 7 was applied to include additional information on brightness, greenness, and wetness as independent variables.

Schmidt and others (2004) found elevation to be the greatest determining factor for mapping coastal vegetation. Inundation frequency, in part a function of elevation, was found to influence the occurrence of marsh communities in coastal Louisiana (Couvillion and Beck, 2013); therefore, to best leverage high-resolution (3-m) airborne lidar bare-earth DEMs when available in the study area, all datasets used in the DT analyses were resampled to 10 m from their native resolutions.

Trimble eCognition version 9.2 was used to generate image objects by parish from the 2007 and 2013 National Agriculture Imagery Program (NAIP) color-infrared aerial photography. The image objects were created at a parish extent because the original NAIP imagery was mosaicked to the parish boundaries. This also allowed for better data processing and handling because creation of image objects can result in large vector files not easily handled within ArcMap. The final 10-m classification was produced by using a script in ArcMap to determine the majority DT-based class for each image object.

Land cover was delineated within the study area into sixteen classes: (1) High Intensity Developed, (2) Medium Intensity Developed, (3) Low Intensity Developed, (4) Developed Open Space, (5) Cultivated, (6) Pasture/Hay, (7) Upland Forest, (8) Palustrine Forested, (9) Palustrine Scrub/Shrub, (10) Palustrine Emergent Wetland [Fresh Marsh], (11) Palustrine Emergent Wetland [Intermediate Marsh], (12) Estuarine Scrub/Shrub Wetland, (13) Estuarine Emergent Wetland [Brackish Marsh], (14) Estuarine Emergent Wetland [Saline Marsh], (15) Unconsolidated Shore, and (16) Water. CCAP data were used as training data for classes 1, 2, 3, 4, 5, 6, 7, and 9. The study area covers approximately 36,125 square kilometers (km^2). The extent was defined by the Louisiana Coastal Area boundary (fig. 1) (Louisiana Coastal Wetlands Planning, Protection and Restoration Act Program, n.d.). The classification was then simplified into the final six classes for the change analysis: (1) Fresh Marsh, (2) Intermediate Marsh, (3) Brackish Marsh, (4) Saline Marsh, (5) Other [non-marsh], and (6) Water.

Processing methods for the classified 2007 satellite imagery consisted of first resampling the spatial resolution from 30 m to 10 m. Next, we merged a 2008 water mask derived from the 2008 NWI water layer onto the resampled image because this represented the best water layer available and was within an acceptable time frame. The final 10-m classification was produced by using a script in ArcMap to determine the majority DT-based class for each image object by parish. Each parish file was then merged into a composite to compose the entire coastal Louisiana zone. The final composite of the image was then reclassified from 16 categories to 6 (table 2) to enable a simplified crosswalk matrix during the change-analysis process.

Processing methods for the classified 2013 imagery was similar to those of the 2007 dataset. The spatial resolution of the imagery was resampled from 30 m to 10 m. Next, we created mask layers from the urban categories from the 2007 and 2013 classified imagery. The 2007 urban mask was then merged into the classified 2013 imagery to keep all urban areas classified in 2007 to be carried forward into 2013. We then merged the 2013 urban areas back into the 2013 imagery so that those areas classified in 2013 would get the proper urban class on the basis of the 2013 imagery. We also merged the 2008 water mask onto the 2013 imagery to allow for water classified in 2008 to continue to be classified as water in 2013. We did this because we believed that the majority of water would not revert back to any land category.

The final 10-m classification was produced by using a majority filter script in ArcMap to determine the majority DT-based class for each image object by parish. Just like the 2007 classified imagery, each parish file was then merged into a composite. The final image was then reclassified from 16 categories to 6.

A pixel-by-pixel change analysis was conducted on the final two datasets (that is, the 2007 and 2013 six-category classification) to determine the final change-analysis matrix (table 3).

Table 2. Crosswalk matrix of land-cover classes between the original 16 categories and simplified 6 categories.

Value	16 Class names	Value	6 Class names
1	High Intensity Developed	5	Other
2	Medium Intensity Developed	5	Other
3	Low Intensity Developed	5	Other
4	Developed Open Space - Grassland	5	Other
5	Cultivated	5	Other
6	Pasture/Hay	5	Other
7	Upland Forest	5	Other
8	Palustrine Forested Wetland	5	Other
9	Palustrine Scrub/Shrub Wetland	5	Other
10	Palustrine Emergent Wetland - F	1	Fresh Marsh
11	Palustrine Emergent Wetland - I	2	Intermediate Marsh
12	Estuarine Scrub/Shrub Wetland	5	Other
13	Estuarine Emergent Wetland - B	3	Brackish Marsh
14	Estuarine Emergent Wetland - S	4	Saline Marsh
15	Unconsolidated Shore	6	Water
16	Water	6	Water

Table 3. Change-analysis matrix of the 2007 and 2013 six-category classification of land-cover categories. Numbers represent acres of change. Highlighted diagonal cells represent areas of no change.

		2013					
		Fresh Marsh	Intermediate Marsh	Brackish Marsh	Saline Marsh	Other	Water
2007	Fresh Marsh	549,603	46,030	5,376	651	51,463	29,411
	Intermediate Marsh	69,700	458,436	106,538	3,763	21,377	32,072
	Brackish Marsh	5,819	42,408	332,039	20,648	7,891	22,870
	Saline Marsh	1,410	5,001	88,789	290,020	5,075	38,135
	Other	11,037	3,674	1,796	729	996,378	2,781
	Water	19,864	22,149	20,583	15,446	10,876	5,585,351

Results

Approximately 9,043 km^2 of marsh were classified in the four marsh-type classification in 2007 and approximately 8,587 km^2 for the 2013 survey. The percentage of all marsh types calculated during the 2007 study was about 25.04 percent and for the 2013 time period was 23.77 percent. Coverage of fresh marsh remained constant at about 7 percent during the 2007 and 2013 study periods. Intermediate marsh coverage was 7.75 percent during the 2007 survey and 6.47 percent during the 2013 survey. Brackish marsh shifted from 4.84 percent during the 2007 survey to 6.22 percent during the 2013 survey. Coverage of saline (saltwater) marsh was 4.80 percent during the 2007 survey and 3.71 percent during the 2013 survey.

Discussion

This study provides a more objective and repeatable method for classifying marsh types of coastal Louisiana and greater level of thematic detail than previously available. The most appropriate use of this classification is for understanding general distribution and overall changes in areal coverage of emergent marshes at the landscape level. Similar to CCAP and NLCD, this marsh-type classification might warrant a 4- to 5-year update cycle. The seamless classification produced by this work can be used to help develop and refine conservation efforts for priority natural resources. Moreover, these data may improve projections of landscape change and serve as a baseline for monitoring future changes resulting from chronic and episodic stressors (Sasser and others, 2008, 2014).

Marsh types calculated during this study for coastal Louisiana suggested a 1.27-percent decline in the available marsh between the two time periods. The general trend across coastal Louisiana was a shift to increasingly saltier marsh types. Fresh marsh remained almost the same, with only a small decrease from 7.65 to 7.37 percent during the 2007 and 2013 study periods. Intermediate marsh followed the same pattern, with brackish marsh showing a reverse (increasing) pattern. Changes in saline (saltwater) marsh were minimal but trending to less saline marsh.

For the two snapshots we analyzed (that is, 2007 and 2013), the total marsh acreage decreased. With the loss of marsh and resultant changes in hydrology, it is likely that changes in marsh type may show greater variation in the future, even if given only minor changes in precipitation levels.

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