Continued Evolution of the Lower Mississippi: Changes to Fluvial Islands Over Five Decades (1965 to 2015)

Universiteit Leiden

Paul F. Hudson, LUC The Hague, Leiden University, The Netherlands (p.f.hudson@luc.leidenuniv.nl)

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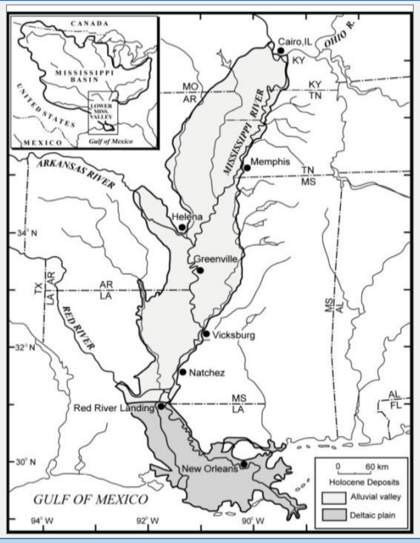
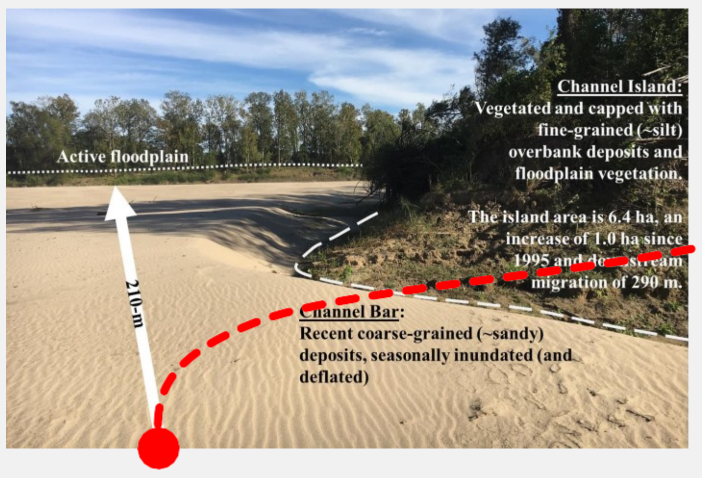
The lower Mississippi continues to adjust to upstream human impacts and channel engineering. Fluvial islands (vegetated sandy bars > 1 ha) are a key mode of riverine adjustment along the Lower Mississippi, and have substantially increased in number and size over the past five decades, from 112 in 1965 to 295 by 2015, which can largely be attributed to groyne construction. This study examines the morphologic evolution of fluvial islands from Cairo, IL to the downstream-most island at about Bonnet Carre Spillway (~5 km upstream of New Orleans). The analysis utilizes lidar DEMs, historic air photos, and adjacent hydrologic (stage) data. Additionally, changes to island vegetation were examined by comparison of the Normalized Difference Vegetation Index (NDVI) calculated from analysis of Landsat imagery for 1996 with 2014.

While each island is somewhat unique and influenced by local scale factors, there are clear geomorphic differences between new islands and older islands. New islands (did not exist in 1965) do not have appreciable natural levees and the island high point is at about flood stage. Older islands that are stable and larger have formed natural levees, which are higher than average flood stage and often higher than the adjacent floodplain surface. The downstream slope of new islands is an order of magnitude higher than old islands, at 0.0028 m/m and 0.0009 m/m, respectively.

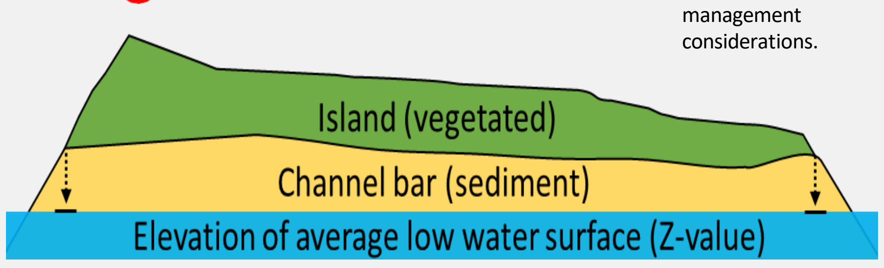
This is likely attributed to the downstream growth of islands, increasing in length and aggradation on the downstream flank. Additionally, between 1996 and 2014 island vegetation matured, with the area of moderate vegetation decreasing at the expense of an increase in denser vegetation. A comparison of the NDVI for the same islands in 1996 and 2014 between Vicksburg and Red River Landing reveals an increase in vegetation health and density. While the area of islands classified as sandy (NDVI 0.1-0.2) and scrubby (NDVI 0.2-0.3) vegetation did not substantially change between 1996 and 2014, the amount of dense vegetation (NDVI > 0.5) considerably increased (from 3.2 km2 to 9.8 km2) as the amount of moderate vegetation (NDVI 0.3-0.5) decreased (15.1 km2 to 8.4 km2). The increase in vegetation density can be attributed to the increased amount of time since island formation was initiated, and a maturation of the island surface with its geomorphic development. The change to fluvial islands over the past five decades represents continued geomorphic evolution of the Lower Mississippi. This is of interest because, although it occurs during a period in which sediment supply has dramatically decreased, with the influence of channel engineering there remains sufficient coarse sediment to drive fluvial landform evolution along the Lower Mississippi.



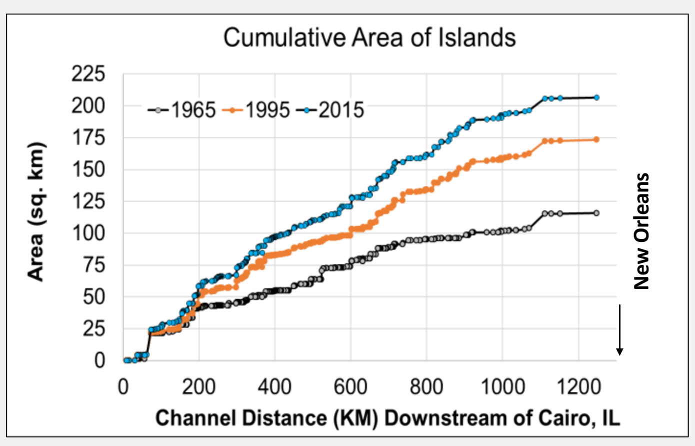
Background:
The Lower Mississippi River continues to exhibit non-equilibrium change, a state of adjustment in response to engineering imposed on the channel for flood control and navigation.



Here we see the significance of dikes (groynes), which were intensively constructed in the 1970s and 1980s. Dikes trap coarse sediment and eventually result in formation of vegetated islands, which then contribute to the riparian habitat. Thus, the development of islands was an unintended consequence that requires further management considerations.



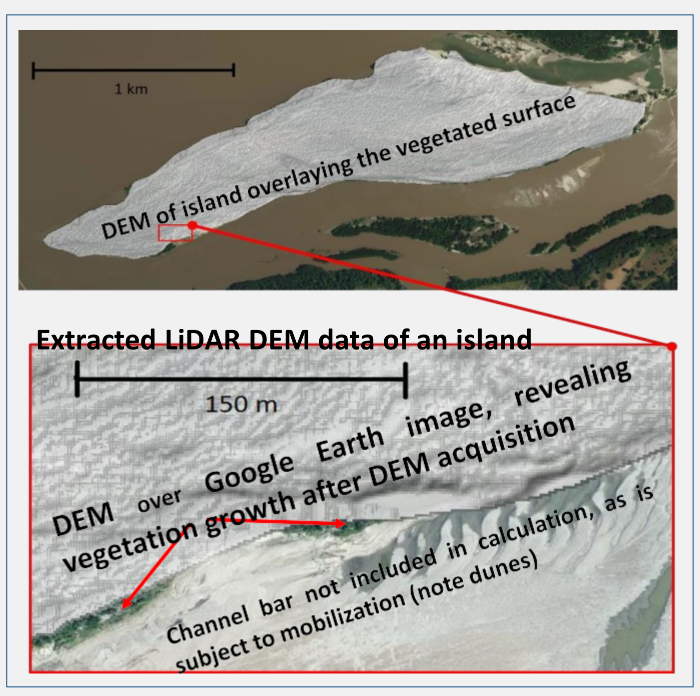
Vegetated island atop sedimentary bar and low water surface (z-value) for calculating island volume

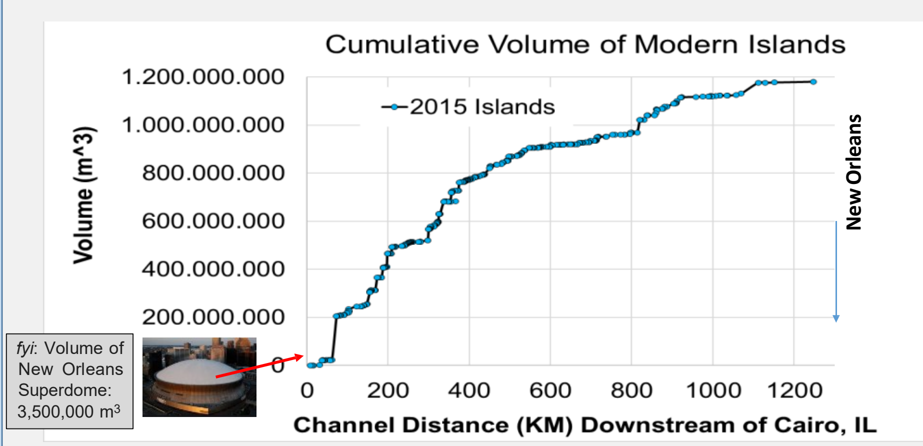


LARGE INCREASE IN ISLANDS: 1965 - 2015:

The number of islands (> 1 ha) increased from 112 in 1965, 206 in 1995, 295 in 2015. The average size of islands *decreased* from 101 ha (hectare) to 63 ha, but this is only because so many new (small) islands developed so rapidly within the dike fields. The total area of islands (within the river channel) increased from 118 km² in 1965, 169 km² in 1995, to 206 km² in 2015.

So how much sediment is that? The total volume of sediment stored within the islands is equal to 1,180,000,000 m³. Is that a lot of sediment? For context it is enough sediment to fill New Orleans Super DOme at 3,500,000 m³, 337 times!





Volume of sediment stored within vegetated islands (fill-up AJax stadium…. 337 times!)

DATA AND METHODS

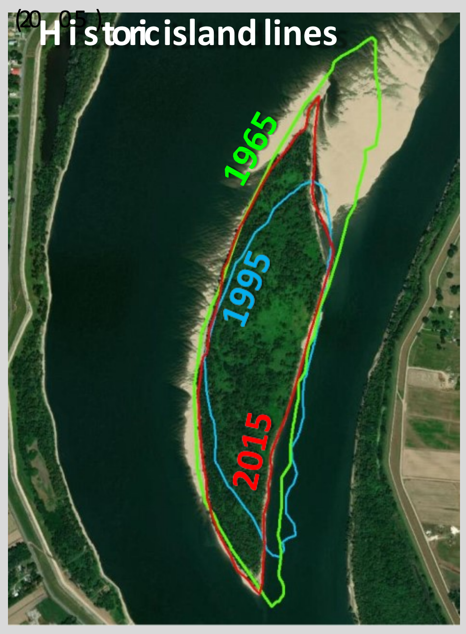
Research utilizes a GISc framework to analyze LiDAR DEMs and satellite imagery.

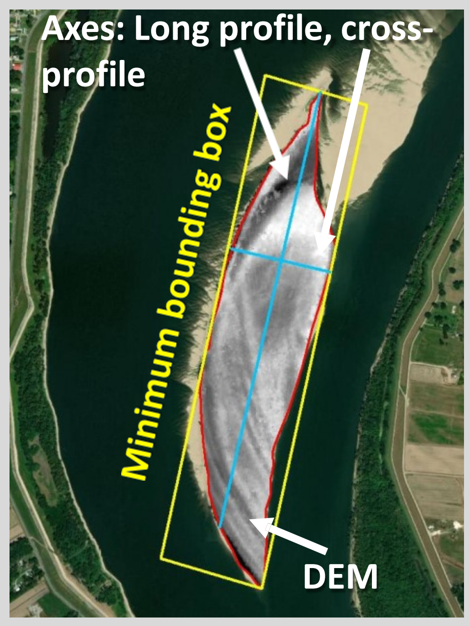
In a nutshell: A database of islands in the Mississippi River channel for three time periods (1965, 1995, 2015) was used to identify islands in which to sample. Using LiDAR data (2002-2008) topographic profiles of old and new islands were sampled with the 3D Analyst tool in ArcGIS. Changes in vegetation were assessed for 1996 and 2014

Primary Data Sources

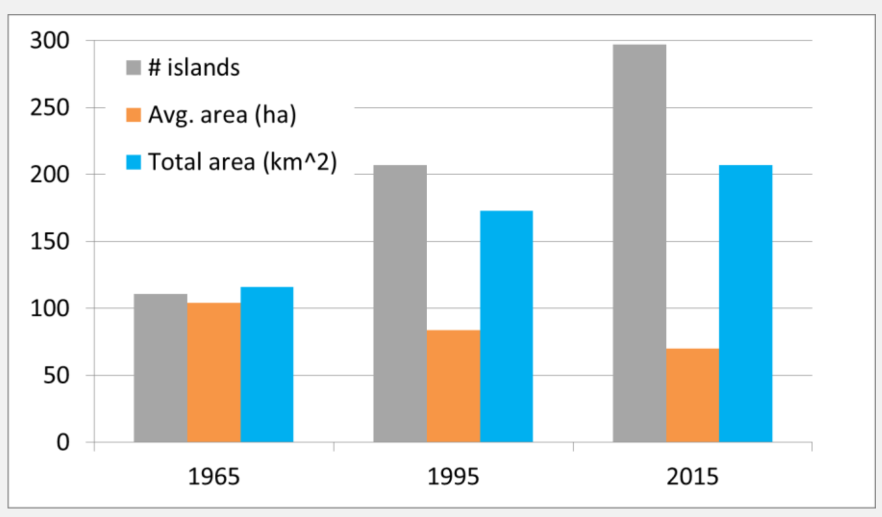
Data type	Years	Source, distribution	Scale / resolution
Satellite Imagery	1996 (3 July, Landsat 5) and 2014 (5 July, Landsat 8)	LandSat (USGS GloVis)	30 m
LiDAR DEM	2000 – 2012	LSU CADS, state geospatial data sites	5m, 2.5 m (x-y), ~0.2 m (z)
Island database for Lower Mississippi River (Hudson et al., 2019)	1965, 1995, 2015	Hudson et al., 2019 (ESRI shapefiles)	

The Normalized Difference Vegetation Index (NDVI) is a robust method to assess vegetation health levels using satellite imagery. The procedures uses a difference formula for the Near Infrared (NIR) and visible Red spectral bands (see NASA, 2000). Five discreet classes were created, which consisted of water, sand, shrubs/soil, moderate vegetation, and dense vegetation. The thresholds were manually set at 0, 0.2, 0.3, and 0.5, respectively, as loosely based on Takeushi et al.





Changes in the frequency and area of islands between 1965 and 2015.



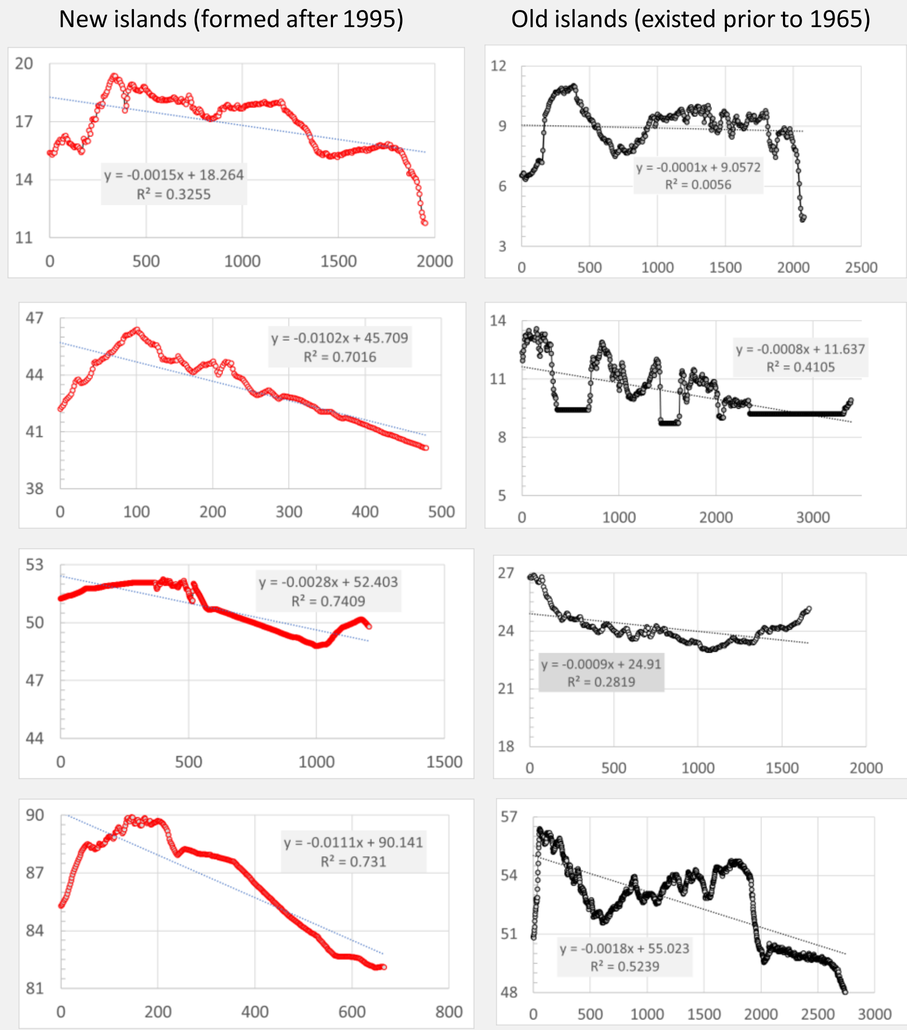
Long-profiles of islands from LiDAR DEM (2002-2008)

A comparison of long-profiles of new and old islands reveals the morphologic adjustment of islands. New islands have slope profiles that are nearly three-fold that of old islands. Overall, slope profiles of new islands are more variable, with several having negative slope. Old islands also have greater relief than new islands, being 7.12 m, and include a greater variety of habitat (e.g., lakes, wetlands…).

Relief (m) of islands		Height difference (m) between islands and floodplain		Downstream slope (m/m) along island axis	
New islands	Old islands	New islands	Old islands	New islands	Old islands
4.5	7.1	-1.4	+0.7	0.0028	0.0009

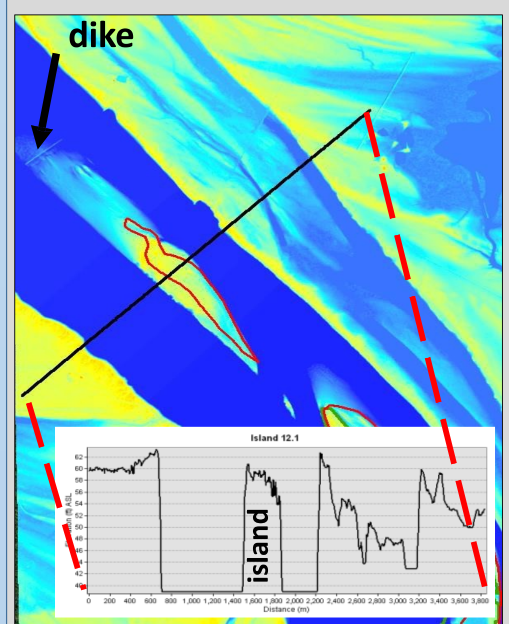
new islands formed after 1995, old islands existed prior to 1965.

New islands (formed after 1995) | Old islands (existed prior to 1965)

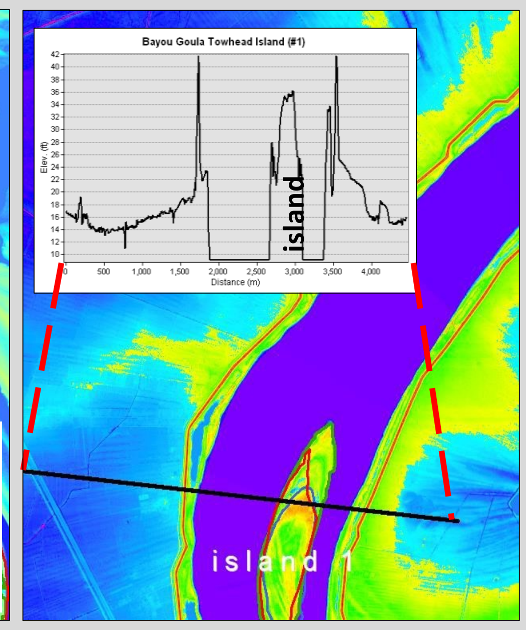


ISLAND EVOLUTION

While each island is somewhat unique and influenced by local-scale factors, there are clear differences between recently formed islands and older islands. New islands (did not exist in 1965) do not have appreciable natural levees and the high point is in the center of the island, which is usually lower than the adjacent floodplain. Older islands that are stable (and usually larger) have well developed natural levees that can be higher than the adjacent floodplain.



New island: note presence of upstream dike, and that island is lower than the floodplain surface.

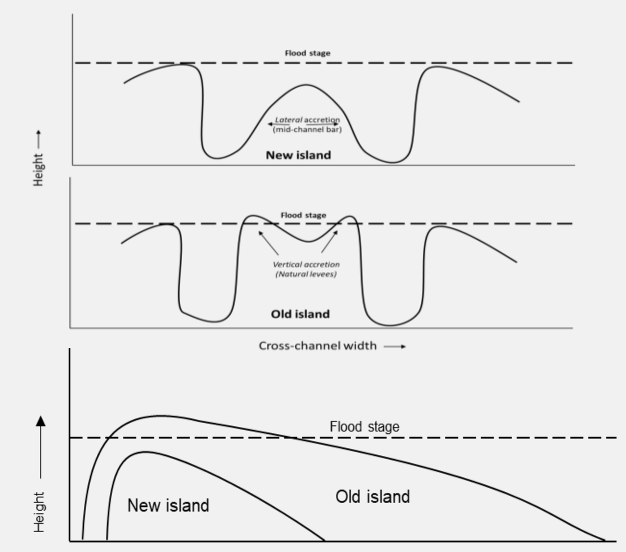


Old island (Bayou Goula Towhead Island, u/s New Orleans…same as in methods box): note accretion higher than floodplain!

Cross-sectional (A) and longitudinal (B) topographic profiles of new and old islands, illustrating the evolution of the surfaces in relation to flood stage. While initial bar accretion occurs downstream, the trapping of overbank sedimentary deposits and associated vertical accretion by vegetation results in old islands having lower downstream slope gradients than new islands.

(A)Cross-sectional topographic profile of new and old islands.

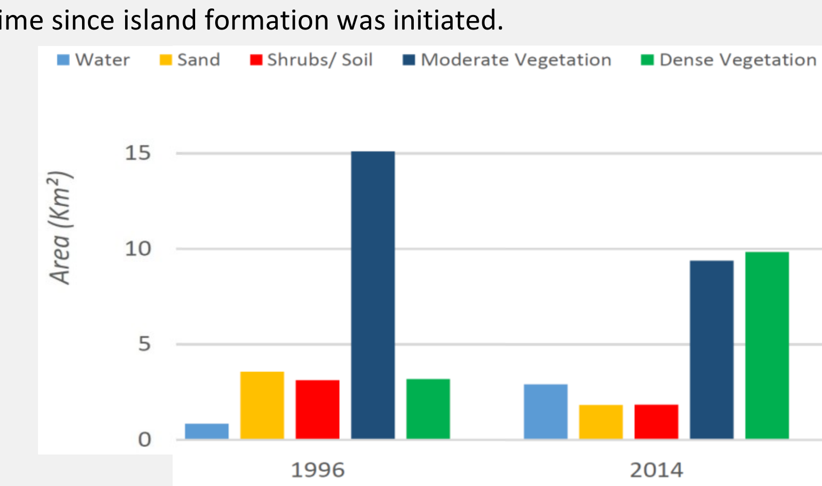
(B)Longitudinal topographic profile (downstream) of new and old islands.

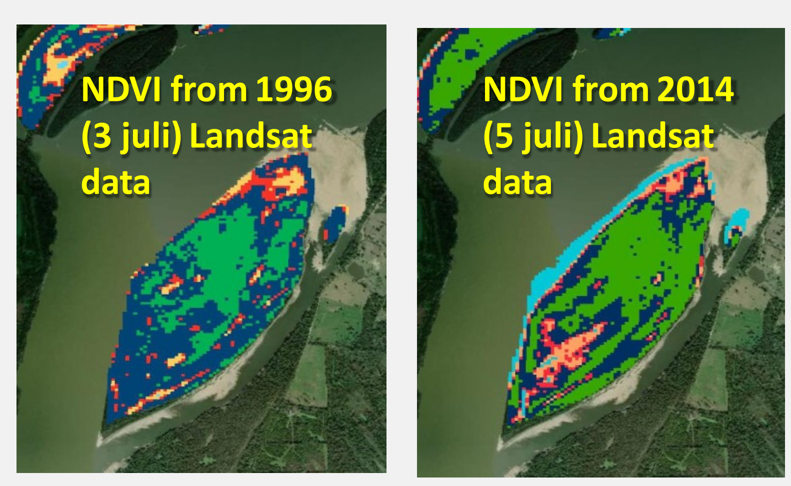


Model of Island Evolution

Vegetation Adjustment: 1996 – 2014

A comparison of the Normalized Difference Vegetation Index (NDVI) calculated from Landsat data for 1996 with 2014 revealed adjustments to the characteristics of islands, as related to vegetation health. Using NDVI thresholds of 0.1, 0.2, 0.3, 0.4 and > 0.5 for water, sand, scrub/soil, moderate vegetation, and dense vegetation for islands between Red River Landing, LA and Vicksburg, MS it can be seen that the density of vegetation increased overall, especially in comparison to moderate vegetation. Of note is that both images are three years after a major flood on the Lower Mississippi. Thus, the increased in vegetation density can be seen as revealing that a three year period is sufficient for vegetation to recover from a large flood. The increase in vegetation density can be attributed to the increased amount of time since island formation was initiated.





Sources:
Hudson, P.F., Van der Hout, E. and Verdaasdonk, M. 2019. (Re)Development of fluvial islands along the lower Mississippi River over five decades, 1965–2015. Geomorphology 331, 78-91. doi:org/10.1016/j.geomorph.2018.11.005 NASA. (2000). Normalized Difference Vegetation Index (NDVI). [Online]. Available at: https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_2.php
Takeuchi, W., & Yasuoka, Y. (2005). Development of normalized vegetation, soil and water indices derived from satellite remote sensing data. Journal of the Japan society of photogrammetry and remote sensing, 43(6), 7-19.