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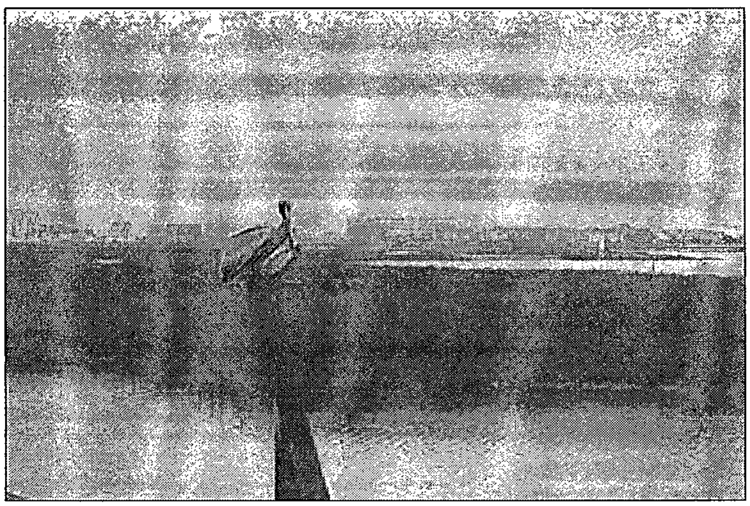
Research Description and Rationale

The Coastal Marsh Project research topics:

- Mechanism for marsh loss
- Satellite imagery
- Mixture modeling
- Marsh Surface Condition Index



Historic Marsh Loss

During the twentieth century, coastal marshes have declined dramatically in extent along many areas of the Atlantic and Gulf coasts of the United States. Available historical wetland

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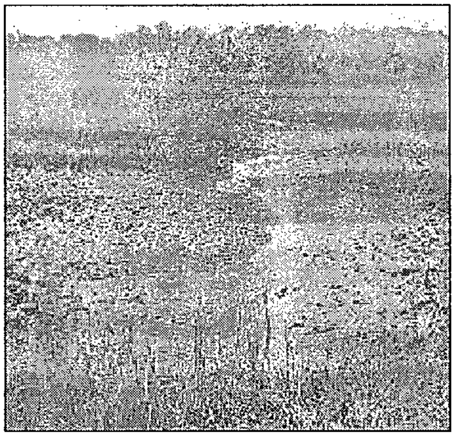
surveys suggest that almost half of the marshes extant in 1900 have disappeared. The reasons for dramatic declines in marsh coverage are often complex. It is clear that human activities are implicated in many losses of coastal marsh. Dredging, filling, and draining of salt marshes probably destroyed most local areas before the 1970s, when their importance in ecological systems became understood and ordinances were set in place. However, in a global sense, sea-level rise is generally acknowledged to be the major driving force underlying most coastal marsh losses. Since the mid-1850s, the rate of world sea-level rise has accelerated, outstripping, in many cases, the ability of the coastal marshes to grow upwards; that is, to accrete sediment vertically. Even though stringent laws protect coastal marshes from depredation, they are still shrinking in area.



A Mechanism for Marsh Loss

Coastal salt marshes all exist in a balance between the buildup of sediment for their roots and the level of the sea that washes over them with tides. Historical records show that marshes form where the balance can be kept: as plants die and fall to the bottom, they fertilize the substrate that is formed by the sediment coming in on the tide. As decades pass, they colonize the new substrate and move outward towards open water, forming their own footing as they expand. If the substrate declines or the sea rises too rapidly, the marsh cannot keep pace.

Along the middle and southeastern coasts of the United States, where subsidence further accelerates the rate of relative sea-level rise, the question of marsh survival may be particularly critical: available data indicate that natural changes in the sedimentary dynamics of these marshes are now promoting sediment export, further enhancing the marsh's vulnerability to sea-level rise. Ultimately, the combination of low rates of vertical accretion and high rates of coastal submergence result in anoxia (poor soil aeration) of the living substrate, decline in plant vigor, and eventual death, producing small areas of open water (interior ponds). Over time, the initially slow, but increasingly rapid, coalescence of interior ponds leads to accelerating losses from wave erosion of unstable pond edges during storms, reducing the marsh to a few isolated remnants within several decades.

A Need for More Information

A uniform data base on the areal extent and status of coastal marshes has been lacking. Detailed information on marsh conditions for much of these coasts is either non-existent or so specific to the site that even adjacent areas cannot be described with certainty.

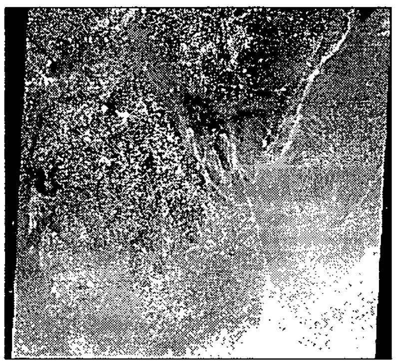
The large area of surface to be analyzed, as well as the need for faster updating in order to initiate strategies for conservation, makes the traditional methods of general surveying or monitoring with aerial photographs unworkable. Conventional methods of assessing marsh vulnerability to sea-level rise and of determining rates of loss have typically relied on a combination of site-specific investigations of vertical accretion rates and analysis of historical maps and aerial photographs. Neither of these approaches is ideal for coast-wide evaluations of marsh health because they are time-consuming, relatively costly in terms of the area covered, and not readily updated. Converting these data to digital form (when available) to enhance planning and management capabilities within the framework of geographic information systems (GIS) and other spatial analysis tools adds another step, further decreasing the timeliness of the data.

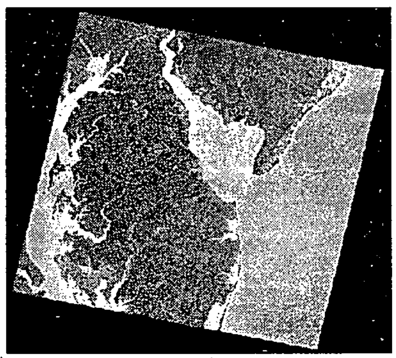
Using New Technology to Answer Old Questions

Using Landsat TM imagery to assess marsh vulnerability over large areas seems to offer a good alternative to costly hand-digitizing and surveys on foot. The spatial resolution of an image is almost fine enough to allow for good visual analysis. However, it is not as straight forward as it might seem. A satellite image is not an aerial photograph, and the pixels are always likely to be "mixed" in a wetlands situation. That is, a given pixel probably contains areas of water, soil, and vegetation, and yet in the image it would show only one of those covers. An essential auxiliary, therefore, to any image analysis of large scale land cover is a mixture model that typifies the pixels and classifies them in a range; in the Coastal Marsh Project (CMP), a range of how degraded the marsh area appears. The CMP definition of "degraded" is based on Dr. Kearney's work on Chesapeake Bay marshes, in which he found that the amount of water in a given area of salt marsh correlated with the imminence of disappearance of the marsh substrate.

Determining What is Being Sensed

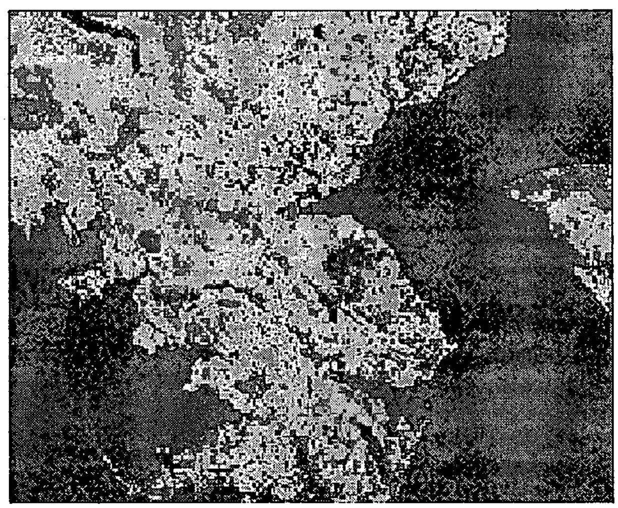
One problem with remote sensing is that the viewer does not "see" clearly the surface of the earth; not only do clouds interfere with the reflection of the energy to the sensor, but the atmosphere itself absorbs, reflects, or transmits the energy in ways that give a false reading to the sensor. In order to clarify what the sensor is reading, a correction of the signal has to be made. This atmospheric correction is a computer model that allows the actual signal to be strengthened and clarified so that the final image seen on the computer corresponds more to what is actually on the ground.





Delaware Bay and the Delmarva Peninsula. On the left is an image before the atmospheric correction algorithm is used. On the right is the corrected image.

Mixture Modeling

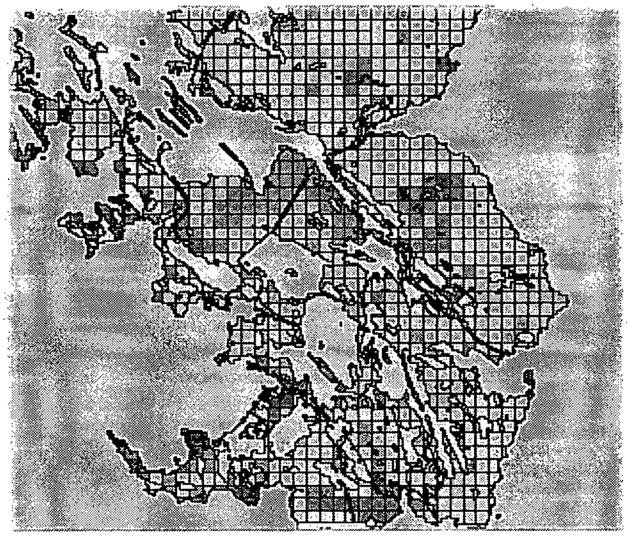


Another problem is the "unmixing" of pixels described above. This is done by finding "endmembers" (pixels in the scene that are most purely the type of spectral signal of interest: soil, vegetation or water) and using them to classify the others and determine what is viewed. After considerable study, the CMP decided to use a mixture model which uses endmembers derived from the image itself, but endmembers not selected directly from the image. The spectral data is transformed into a set of normalized indices (Normalized

Difference Vegetation Index,
Normalized Difference Water Index, Normalized Difference Soil Index, collectively called "NDXI"), in order to classify all the varieties of wet soils (mudflats, exposed salt pannes, etc.) similarly all along the eastern coast.

An example of the results of the CMP mixture model algorithm. This is a topographic quadrangle on the Eastern Shore of Chesapeake Bay. The blue is open water, and the landscape is classified into intact(green) wetlands, and increasingly endangered (yellow and red) wetlands. In this step, all land is classified. It is necessary to mask out the areas that are not being considered.

Bringing It into Focus



Once the TM image has been refined, it is georeferenced and brought into the GIS (ARC/INFO software, by ESRI), where it is combined with digitized data from the (USDA) National Wetlands Inventory. The areas of the image that are not wetlands are masked and the CMP modeling algorithm is run on the combined image. This produces a computer map which contains the desired information: the percentage of water per pixel. This percentage of water is an indicator of how vulnerable the marsh is to degradation, according to the CMP model of marsh health: since salt marshes degrade from within when their substrate declines, in general a wetter wetland is one that is nearing its threshold of collapse. For purposes of analysis, the CMP established categories of percentage of water (up to 10% water is "healthy marsh"; up to 20% is "slightly deteriorated marsh"; up to 30% is "moderately deteriorated marsh"; and above 50% indicates complete deterioration) and assigned them a map color. The final computer map shows a grid of four-hectare cells, with the color of the cell indicating the degree of vulnerability (the marsh "health") of the area, ranging from green for healthy marsh to red for marsh most at risk.

This is the same area shown above, on the Eastern Shore of Chesapeake Bay. The pixels have been aggregated into larger grid cells of 200 meters on a side for ease of mapping. This coarse a resolution means that the map could be used only as an indicator; finer analysis would follow this indication that the marsh was in peril of disintegration.

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