

Land Cover And Land Use Changes And Their Impacts On Groundwater Resources And Carbon Cycling In Southwest Egypt

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The construction of the Aswan High Dam has had major impacts on the landscape, water and carbon reservoirs in SW Egypt. It gave rise to Lake Nasser, an extensive reservoir (capacity: 1.6 x 10¹¹ m³, length: 500 km, average width: 12 km). Recharge from the lake raised the groundwater table by as much as 20m; the lake and the companion agricultural development projects are creating new carbon sinks.

We applied an integrated systems approach (involving remote sensing, geochemical and physical analyses, and hydrologic modeling) to assess, monitor, and model the recent and future impacts of changes in the landscape and land cover in southwest Egypt.

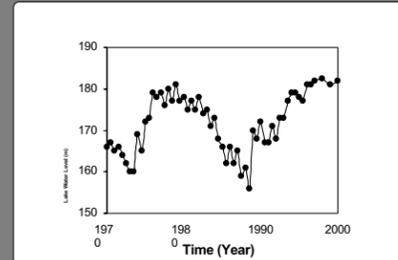
Co-registered temporal satellite images (CORONA, MSS, TM, DTED), and lake stages were used to monitor the temporal variations in the areal extent of Lake Nasser. Temporal variations were accounted for in a 2-dimensional groundwater flow model constructed for the SW corner of Lake Nasser.

The model, constrained by regional-scale groundwater flow and near-lake head data, was calibrated to observed heads from 1970 to 2000. Predictive analyses for the next 50yr period indicate a substantial reduction in recharge with time (~86% reduction in 30yr recharge).

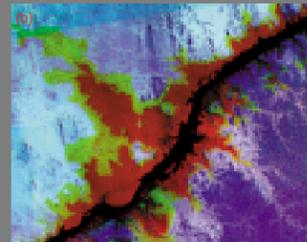
The recharge front advanced northwest at an average rate of 0.24-0.57 km/yr (i.e., <20 km by 2000) consistent with inferences made from O and H isotopic data for groundwater from shallow and deep wells in the vicinity of the Lake that indicate that discharge from the Lake was undetectable in areas that are 20 km or more from the Lake.

Analysis of two suites of soil samples from fields that were reclaimed within the past 100 years indicate that organic carbon and nitrogen are being sequestered at rates ranging from 0.0282 to 0.1705 gm C/kg soil/yr and from 0.003 to 0.0147 gm nitrogen/kg soil/yr.

The geologic and agricultural practice controls on carbon sequestration rates in soils are currently being examined and the hydrology model is being extended to incorporate the entire Lake Nasser and adjoining lakes and lands.



After construction of the Aswan High Dam (1964), surface water level rose from 121 m to 178 m in 1978. Subsequently, the lake level fluctuated (158 m - 182 m), reflecting the intensity of the Nile inflows. In the early 1980s, the lake declined, reaching its lowest level (158 m) in 1987, but the level started to rise again in the early 1990s, reaching 182 m by 1997. This caused the Lake waters to overflow the Tushka spillway and created four lakes.



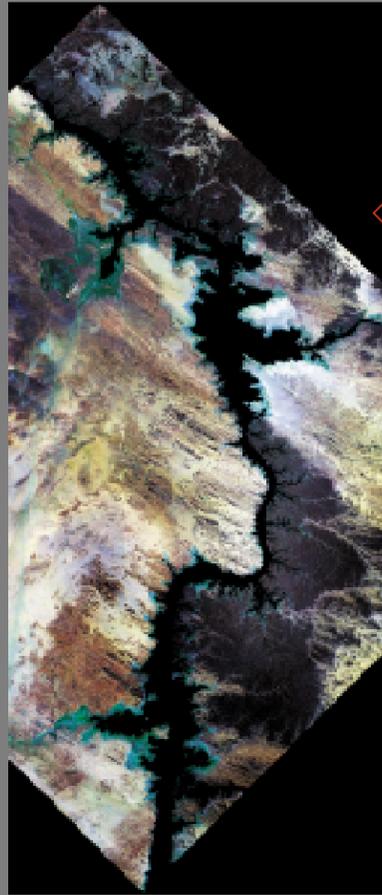
False color composites of satellite images acquired in 1967, mid 1980s, and 2000. Areas in black show the extent of Lake Nasser in 1967, those in red show the change in areal extent of the lake in the 1980s, and those in yellow show the further change of the areal extent in 2000.



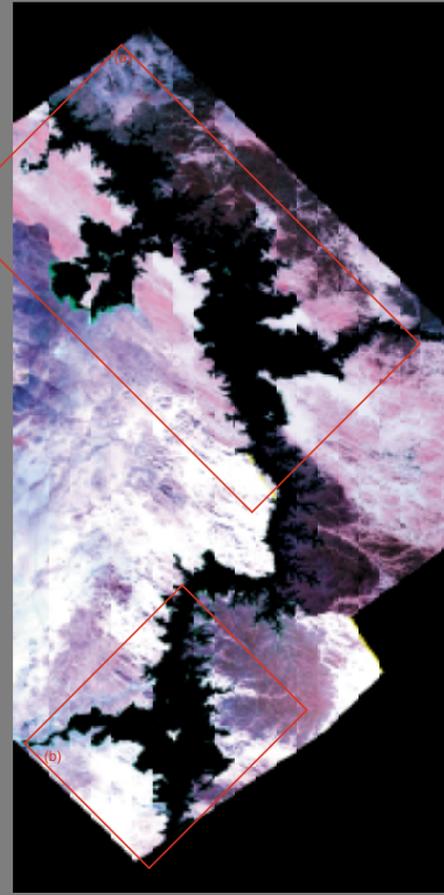
CORONA (KH-4A) mosaic from images acquired on June 30, 1967



Landsat MSS mosaic from images acquired in 1972



Landsat TM mosaic from images acquired in the late 1980s.

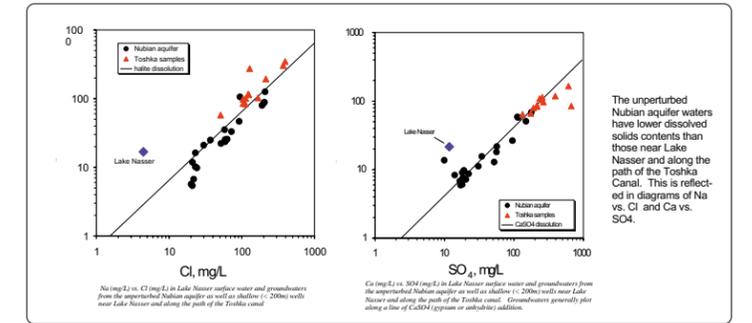


Landsat TM mosaic from images acquired in April 2000

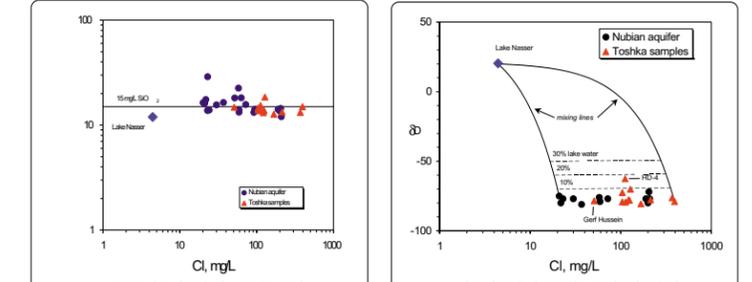
Satellite image mosaics showing the changes in the area covered by Lake Nasser and associated lakes throughout the past three decades that witnessed the construction of the Aswan High Dam



The latest rise in lake levels caused Lake Nasser to overflow through a spillway that was constructed to channel excess water away from the lake, and created 4 lakes to the west of Lake Nasser.



The unperturbed Nubian aquifer waters have lower dissolved solids contents than those near Lake Nasser and along the path of the Toshka Canal. This is reflected in diagrams of Na vs. Cl and Ca vs. SO₄.

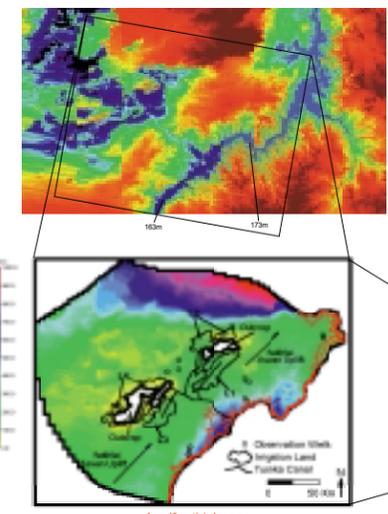


The variation in salinity is also present within the unperturbed Nubian aquifer. Waters from the deepest portions of the aquifer are less saline than those from shallower portions of the aquifer.

Despite this geochemical complexity of the baseline data for groundwaters of the Nubian aquifer, there is clear evidence for mixing of Lake Nasser water with Nubian aquifer water (dD vs. Cl).

Ongoing Geochemical Activities

- Expand our groundwater sample collection and analysis to areas surrounding the entire lake to estimate mixing proportions between lake and Nubian groundwater.
- Conduct additional analyses (e.g., chlorine, radiocarbon) to decipher the origin of added salinity in examined groundwater samples compared to unperturbed Nubian aquifer samples.



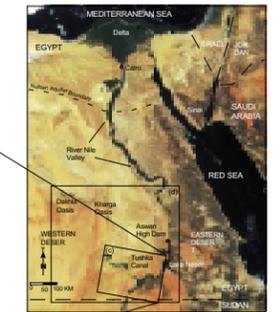
Ongoing Modeling Activities:

- Model is expanded to incorporate the entire length of the lake. Fluctuations in the areal extent of the lake throughout the calibration period are being extracted by:
- Using MSS and TM scenes, the areal extent of the lake is extracted for years 1972, 1984, and 2000. Areal extent corresponding to a specific lake level is inferred by interpolation between these three distributions.
 - Extraction of digital elevation from stereo images preceding the construction of the dam (CORONA)

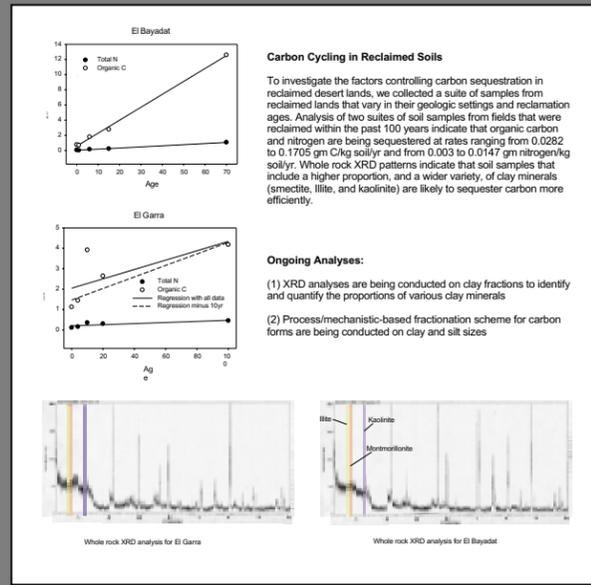
Initial Ground Water Flow Model

A two-dimensional groundwater flow model was constructed. The model, constrained by regional-scale groundwater flow and near-lake head data, was calibrated to temporal-observation heads from 1970 to 2000 that reflect variations in lake levels and areal extent. The areal extent of the Lake throughout calibration period (1970-2000) was extracted from DTED data and observed lake levels. The model was restricted to the NW portions of the Lake, the model is being expanded and refined.

Kim and Sultan (2002), Journal Hydrology, v. 262, p. 68-83



Moderate resolution imaging spectroradiometer (MODIS) satellite image acquired on February 19, 2000, showing the areal extent of the initial model (c), and of the model currently under construction (d).



Carbon Cycling in Reclaimed Soils

To investigate the factors controlling carbon sequestration in reclaimed desert lands, we collected a suite of samples from reclaimed lands that vary in their geologic settings and reclamation ages. Analysis of two suites of soil samples from fields that were reclaimed within the past 100 years indicate that organic carbon and nitrogen are being sequestered at rates ranging from 0.0282 to 0.1705 gm C/kg soil/yr and from 0.003 to 0.0147 gm nitrogen/kg soil/yr. Whole rock XRD patterns indicate that soil samples that include a higher proportion, and a wider variety, of clay minerals (smectite, illite, and kaolinite) are likely to sequester carbon more efficiently.

Ongoing Analyses:

- XRD analyses are being conducted on clay fractions to identify and quantify the proportions of various clay minerals
- Process/mechanistic-based fractionation scheme for carbon forms are being conducted on clay and silt sizes