Impact of climate change and climate variability on the hydrology of the Sudd wetland

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Content

- The Sudd wetland
- Hydroclimatology of the Sudd
- Sudd water balance
- Trend analysis
- Conclusions
Location of the Sudd Wetland

Map showing the location of the Sudd Wetland within the Nile River Basin.
Importance of the Sudd wetland
Hydroclimatolgy of the Sudd

- hydrological influence from upstream (Lake Victoria)
- defines d/s outflow
- little impact on regional climate,
- direct impact on local climate
Impact on Nile Water cycle

Source: Mohamed et al., 2005
Impact on Temperature and Relative Humidity

$\Delta T$ dry season

$\Delta RH$ dry season

Source: Mohamed et al., 2005
Water balance of the Sudd

\[ V_{i+1} = V_i + Q_{in} - Q_{out} + kV_i(P - E) \]

Source: Sutcliffe and Parks, 1987

\( Q_{in} \) = measured at Mangala

\( Q_{out} \) = measured at exit (Malakal – H.D.)

\( P \) = average of three stations

\( E{T_a} \) = \( E{T_0} \) time series scaled based on 3 years data

How does the trends of the water balance components affect the Sudd area?
Water balance results

![Graph showing water balance results with four time series: Qin, Qout, P, and ETa. The x-axis represents years from 1900 to 2000, and the y-axis represents water flow in Mm³/yr and mm/yr.]
Water balance results

![Graph showing water balance results from 1900 to 2000 with data points in 1000 km² scale. The graph displays fluctuations over time with a peak around 1960.]

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- **x-axis**: Years from 1900 to 2000
- **y-axis**: Water balance in 1000 km²
- **Legend**: A
Mean monthly water balance

- Qin
- Qout
- P
- ETa

Month

Mm³/month

mm/month

0 2 4 6 8 10 12 14

0 500 1000 1500 2000 2500 3000 3500

0 20 40 60 80 100 120 140 160 180
Mean monthly water balance

![Graph showing the mean monthly water balance]

- The graph displays the mean monthly water balance in 1000 km².
- The x-axis represents the months, and the y-axis represents the water balance in 1000 km².
- The data shows a fluctuation in the water balance throughout the months, peaking around the 10th month and troughing around the 2nd month.

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**Note:** The graph appears to illustrate the variability in water balance across different months, which is crucial for understanding water resources management.
Trend analysis: Mann-Kendall test

\[ S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sgn}(x_j - x_i), \quad \text{Where} \quad \text{sgn}(\theta) = \begin{cases} +1 & \theta > 0 \\ 0 & \text{If} \quad \theta = 0 \\ -1 & \theta < 0 \end{cases} \]

\[ Z = \begin{cases} \frac{S - 1}{\sqrt{V(S)}} & S > 0 \\ 0 & \text{If} \quad S = 0 \\ \frac{S + 1}{\sqrt{V(S)}} & S < 0 \end{cases} \]

Serial correlation of time series was removed first by TFPW method

\[ \text{Var}(S) = \frac{1}{18} \left[ n(n-1)(2n+5) - \sum_{t=1}^{m} t_i (t_i - 1)(2t_i + 5) \right] \]
MK test Results  (time series  1900 to 2000)

Statistical significance at 5% level is: \((Z < -1.96, Z > 1.96)\)

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
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<th>Oct</th>
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<tr>
<td>(Q_{\text{out}})</td>
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<td>6.3</td>
<td>7.5</td>
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<td>7.9</td>
<td>7.2</td>
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<td>(P)</td>
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</table>
Annual Trends

Area in 1000 km$^2$

1000 km$^2$

1880 1900 1920 1940 1960 1980 2000 2020
Annual Trends

Inflow ($Q_{in}$)

Mm3/yr

1880 1900 1920 1940 1960 1980 2000 2020
Annual Trends

Outflow \((Q_{out})\)

Mm³/yr

1880 1900 1920 1940 1960 1980 2000 2020
Annual Trends

Precipitation (P)

mm/yr

1880 1900 1920 1940 1960 1980 2000 2020
Annual Trends

T max

°C

1880 1900 1920 1940 1960 1980 2000 2020
Annual Trends

T min

°C

1880 1900 1920 1940 1960 1980 2000 2020
Annual Trends: Sunshine hours (n)
Conclusions

- Local climate of the Sudd is changing:
  - $\Delta T_{\text{max}} = +0.6^\circ\text{C}$ in 100 yr
  - $\Delta T_{\text{min}} = +1.5^\circ\text{C}$ in 100 yr
  - $\Delta RH = -10\%$ in 50 yr
  - Sunshine hours $\Delta n = -1$ hr in 50 yr (~10%)

- Neither rainfall, nor $ET_a$ are statistically changing over the Sudd.

- However, the Sudd area is (significantly) increasing: $\Delta A = +19.6 \text{ Gm}^2$ in 100 year (80% increase); attributed to increasing inflows (Lake Vic.)

- Based on RCM experiment (Mohamed et al., 2005):
  - The Sudd has negligible impact on regional water cycle; but very high impact on local climate ($T$, $RH$).

- Therefore, the Sudd hydrology is largely influenced by upstream climate than local climate.

- Information about Sudd hydrology is key for wetland management
Thank you