

Spatial and Seasonal Variations of the Mesopotamian Marshes' Hydro-pattern Under Natural and Regulated Flow Conditions

Ali Al-Quarishi (usur2010@ufl.edu) and David Kaplan (dkaplan@ufl.edu), Engineering School of Sustainable Infrastructure and Environment, Department of Environmental Engineering Sciences, University of Florida

1. BACKGROUND

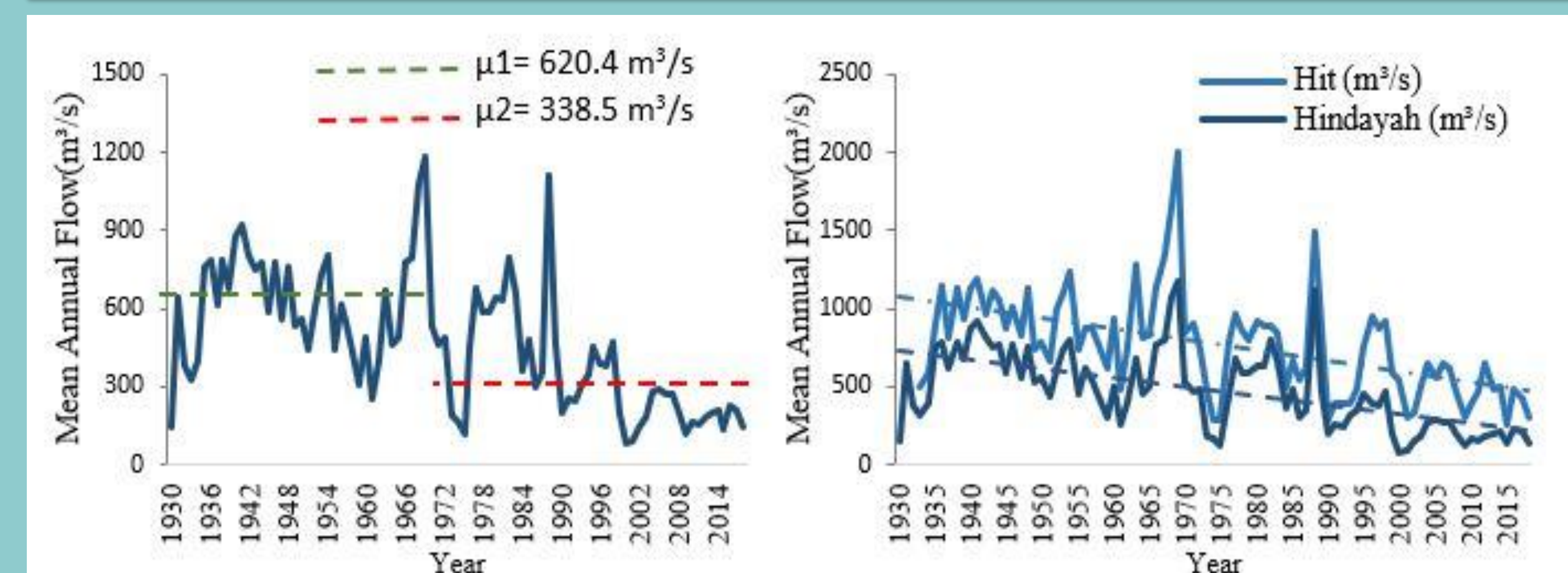
- The Mesopotamian Marshlands once covered ~20,000 km² of permanent and seasonal wet habitats and have been home to several ancient civilizations.
- The marshes are **Hammar, Central, and Huweizah**, which were drained by Saddam Hussein's regime after the first Gulf War in 1991, displacing 200,000 Marsh Arabs.
- The Marshes restoration began in 2003 but is constrained by **limited water supplies and build up of salt in soil over time**.



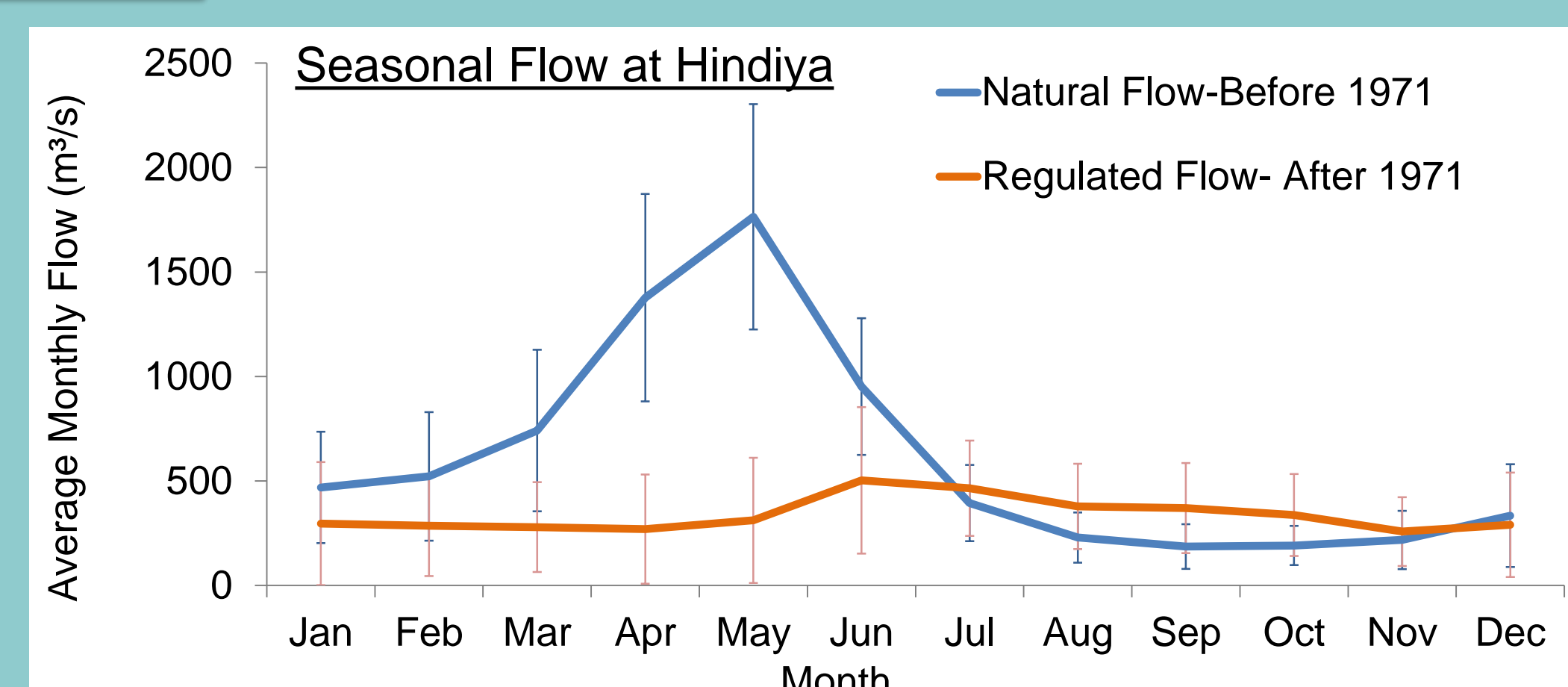
2. OBJECTIVES AND METHODS

- Quantify changes in Euphrates River flow regime
 - Mann-Kendall tests, breakpoint analysis
- Identify role of dams on observed flow changes
 - Investigate seasonal changes of flow
- Quantify how altered flow regimes have affected WMM hydro-pattern (Area, Timing, Duration, Water Depth, Frequency)
 - Remote sensing-based supervised classification; vegetation index (NDVI)

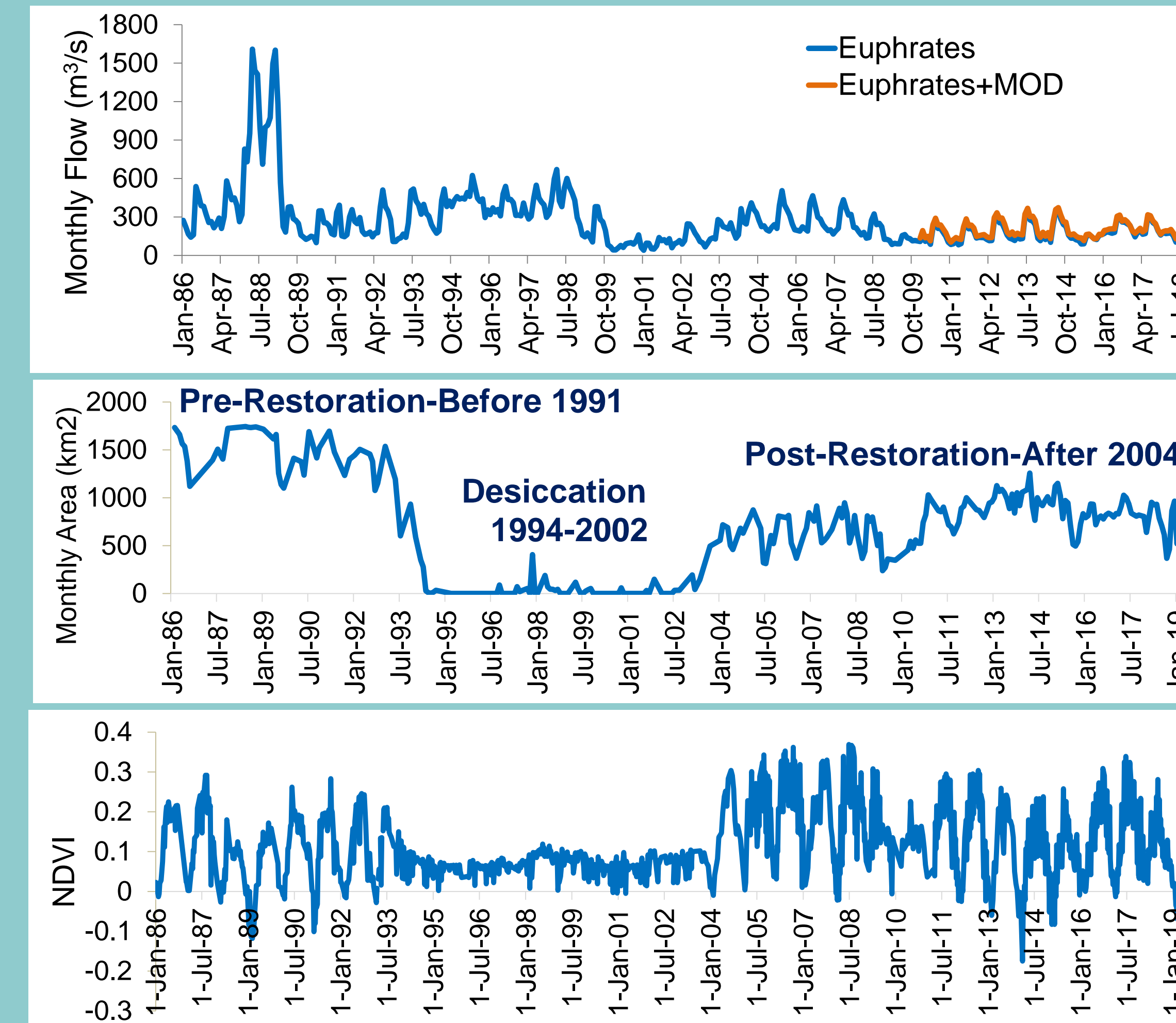
3. MAJOR FINDINGS



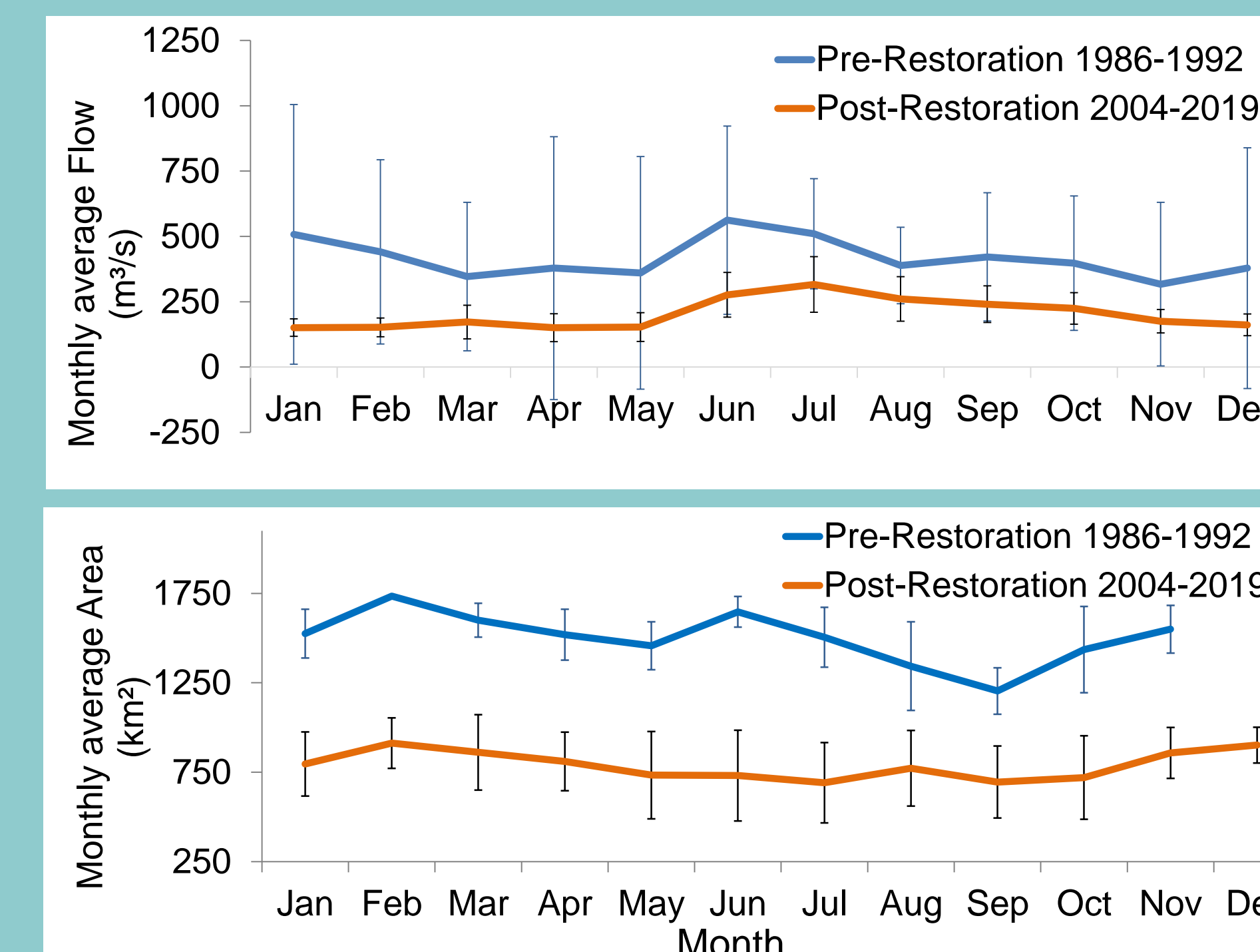
- Euphrates River flow: **significant change-point in 1971** ($p < 0.0001$) and overall **declining trend** ($p < 0.001$).



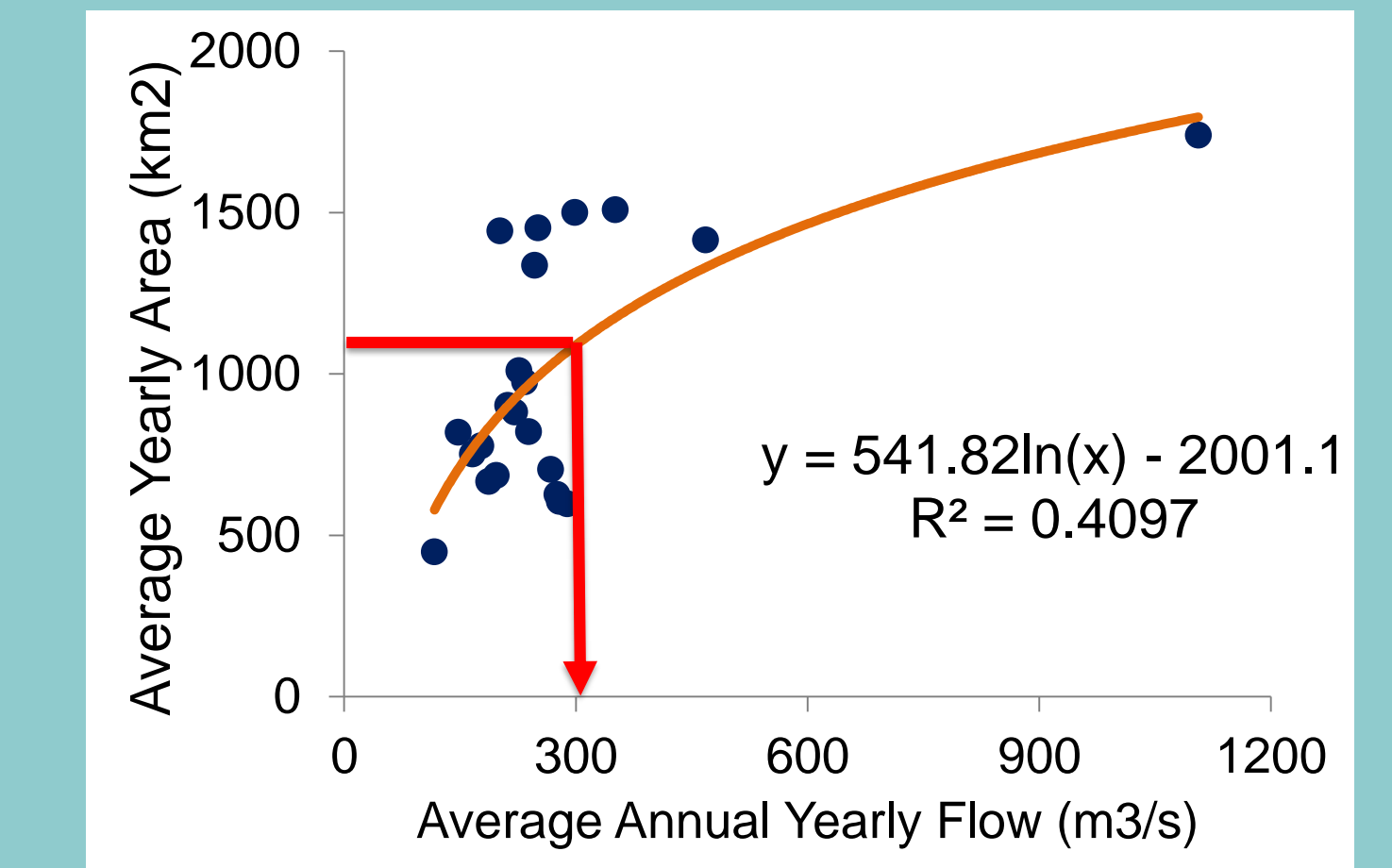
- Flow magnitude & seasonality severely reduced in "regulated" period after 1971.



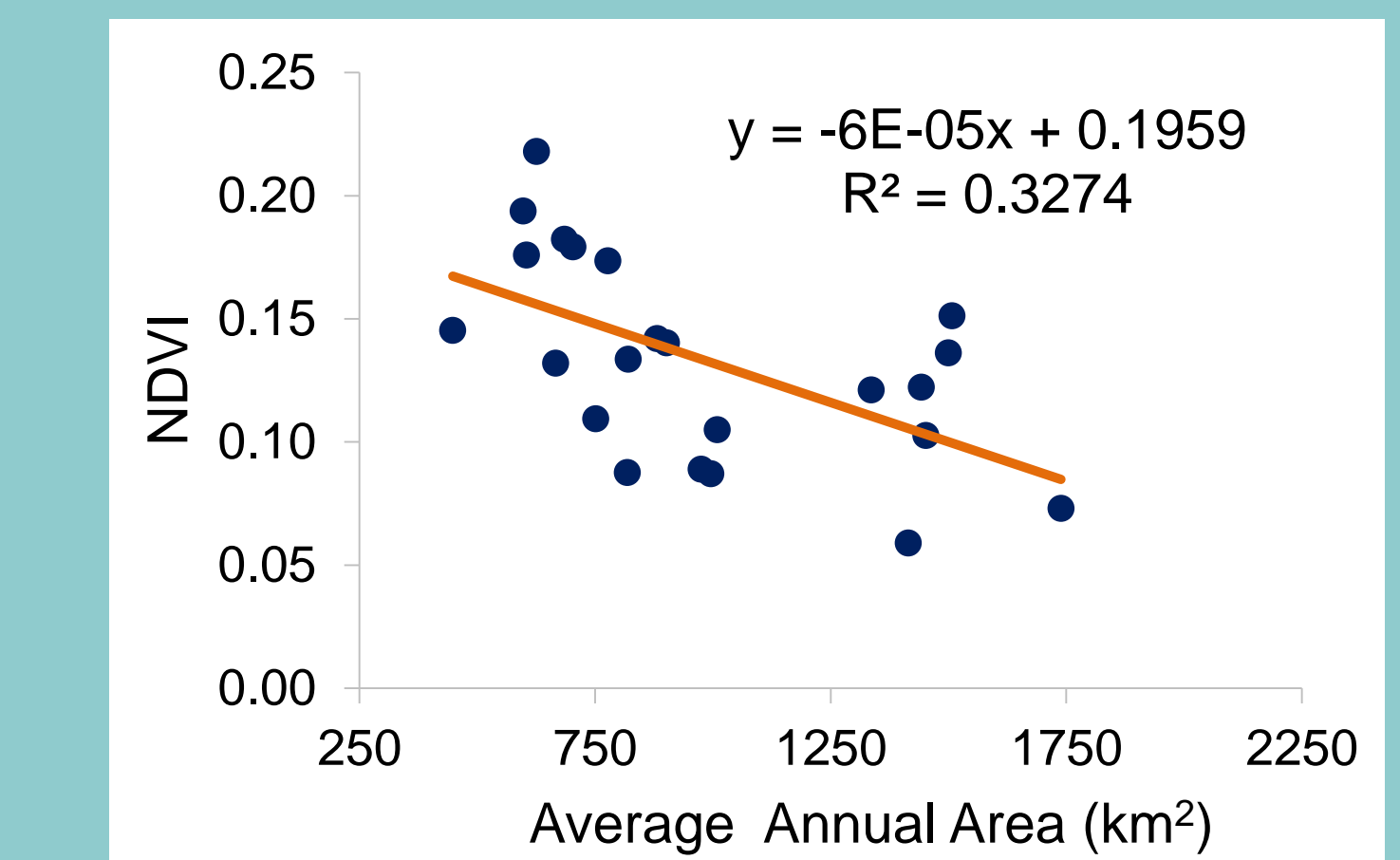
- Higher flows** in the pre-restoration period consistently inundated larger areas.



- Higher flows - Lower wetland area variation**
- Summary of the hydro-pattern elements of the WMM



- Higher flows - Higher inundated area**



- Higher open water areas - Lower NDVI**

Hydro-pattern Element	Limits	Pre-Restoration	Post-Restoration
Area (km ²)	Avg. Min/month	1271(-/+214)/Sep	541(-/+188)/Sep
	Avg. Max/month	1687(-/+76)/Jan	978 (-/+139)/Feb
Timing (day)	Min	227(-/+50)	208(-/+80)
	Max	141(-/+97)	142(-/+117)
Duration (day)	Min	81(-/+45)	135(-/+87)
	Max	73(-/+35)	163(-/+114)
Water depth (m)	Avg.	2- 2.5	1-1.25
	Max	3-3.5	2-2.5
Frequency (Reversal/yr)	Rising & Falling	2.5	5.2
	Change rate (km ² /day)	Rise rate	2.26
	Fall rate	3.18	3.28

4. CONCLUSIONS & IMPLICATIONS

- Euphrates River flow has declined by 35 to 50% since 1930, driven largely by anthropogenic changes in the watershed that make Iraq extremely vulnerable to water-use decision by upstream countries.
- The flow regime has become more regulated after 1974, and the WMM require at least **300 m³/s** Euphrates flow.
- The hydro-pattern elements of the WMM have significant changes between the pre-restoration and post-restoration.

5. REFERENCES AND ACKNOWLEDGMENTS

Al-Ansari N., S. Knutsson, A.A. Ali, 2012. Restoring the Garden of Eden, Iraq. *Journal of Earth Sciences and Geotechnical Engineering* 2(1):53-88. https://ichef.bbci.co.uk/news/1024/media/images/67872000/jpg/_67872057_iraqmarshbluejetty.jpg
<http://america.aljazeera.com/articles/2014/7/13/restoring-iraqs-lostmarshes.html>
http://news.bbc.co.uk/earth/hi/earth_news/newsid_9364000/9364044.stm

The authors thank Dr. Dr. Ali Douabul, Director General of the Basrah Marine Science Center for guidance in advancing this work and the Iraqi Ministry of Water Resources, Center for Restoration of the Iraqi Marshes and Wetlands, and the United Nations for providing valuable data.