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Assessment of Flash Droughts in the Kashkadarya Region, Uzbekistan

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The Kashkadarya River Basin is situated in the southern region of Uzbekistan. It plays a crucial role in overall water supply, offering essential resources for irrigation and agriculture in the Kashkadarya Valley. The river originates primarily from scarce precipitation of the Pamir-Alay Mountain system. The river runoff of the Kashkadarya River Basin is formed at the western extremities of the Zarafshan and Gissar mountain ranges.

The intensive agricultural practices in the region demand substantial water volumes during the summer, which face limitations due to the arid climate. Unlike other river basins nearby, the Kashkadarya River lacks substantial glaciers to augment water supply during the high vegetation season. Additionally, it's noteworthy that the available free land in the Kashkadarya Valley surpasses the area that river waters can irrigate. To enhance water supply an, extra water is transferred from the basins of the Zarafshan and Amu Darya rivers (fig. 1).

The region faces an escalating challenge in managing water resources due to flash droughts. This phenomenon, characterized by rapid and severe water deficit in fast and short temperature rise (heat wave), has become a pressing concern, especially considering that approximately 90% of the region's water is allocated to agriculture. The existing water distribution system relies on early-season hydrological forecasts, urgently requiring innovative strategies to address water scarcity issues. This research postulates that a real-time monitoring system for flash droughts can play a pivotal role in identifying areas experiencing or nearing plant stress. The proposed strategy involves timely irrigation in stressed regions and the postponement of irrigation in "healthier" areas, thereby optimizing water resource management.

The introductory segment provides an overview of the region's vulnerability to climate change, emphasizing the critical nature of water scarcity. This study seeks to assess the intensity of flash droughts in the Kashkadarya region, unraveling patterns and potential implications for agriculture. The methodology includes the computation of the Flash Drought Intensity Index, covering the period from March to September between 1990 and 2020.

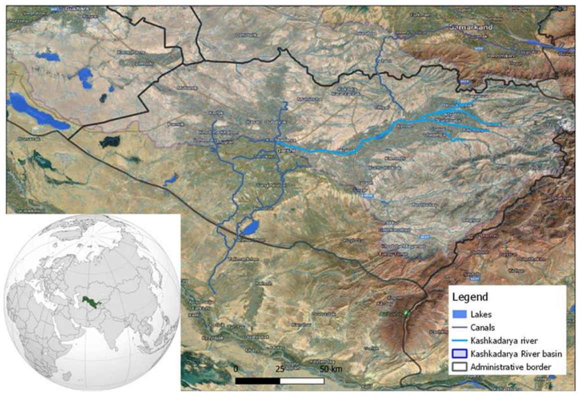

Fig. 1. Kashkadarya River basin. Source: wikimedia

Method

The Flash drought intensity index (FDII) (Otkin et al. 2021) accounts for both the unusually rapid rate of drought intensification and its resultant severity. FDII includes two components: one that measures the rate of intensification (FD_INT) and a second that captures the drought severity (DRO_SEV).

For that study, a minimum intensification rate equivalent to a 15th percentile decrease (ΔPER_BASE) in soil moisture during a 4-pentad period (ΔT_BASE) was required: $FD\_INT = \left(\frac{\Delta \text{PER\_BASE}}{\Delta \text{T\_BASE}}\right)^{-1} \times \left(\frac{\Delta \text{PER\_OBS}}{\Delta \text{T\_OBS}}\right)_{max}$

Similarly, the baseline percentile threshold used to represent the onset of drought conditions (DRO_BASE) was set at the 20th percentile of the distribution:

$DRO\_SEV = \frac{1}{np}\sum_{n=1}^{np}(DRO\_BASE - DRO\_OBS(n))$,where

np is the number of pentads,

DRO_OBS(n) is the observed percentile for pentad n.

In cases where intensification or severity does not meet the aforementioned minimum requirements, these parameters should be set to zero. Finally, the FDII is then computed as the product of the FD_INT and DRO_SEV components/.

The Agricultural Stress Index (ASI) is a rapid indicator for early detection of cropland and grassland facing a high probability of water stress, commonly called drought. This index integrates the Vegetation Health Index (VHI) in two critical dimensions for evaluating agricultural drought events: temporal and spatial. The initial step involves temporal averaging of the VHI, assessing the intensity and duration of dry periods at the pixel level during the crop cycle. The subsequent step determines the spatial extent of drought events by calculating the percentage of pixels in arable areas with a VHI value below 35 percent, a critical threshold identified in previous research (Kogan 1995). Administrative regions are then classified based on the percentage of the affected area, facilitating quick interpretation of the results.

Results

To comprehensively understand the factors influencing flash drought occurrences, an analysis involving comparisons with air temperature, evapotranspiration, and radiative temperature. The correlation of the indexes with key indicators, such as the Normalized Difference Vegetation Index (NDVI) and Agriculture Stress Index (ASI), was applied to assess the impact of flash droughts on plant conditions. Preliminary findings suggest a discernible correlation between flash drought severity and radiative temperature, hinting at a potential climatic influence on their occurrence.

Further analyses, incorporating NDVI and ASI, unveiled distinct patterns of vegetation stress corresponding to flash drought events (fig 2). These outcomes substantiate the proposed irrigation strategy, which hinges on flash drought monitoring. By identifying areas where plants are under stress or on the brink of stress conditions, timely irrigation interventions can be strategically implemented to mitigate adverse impacts on crop yields.

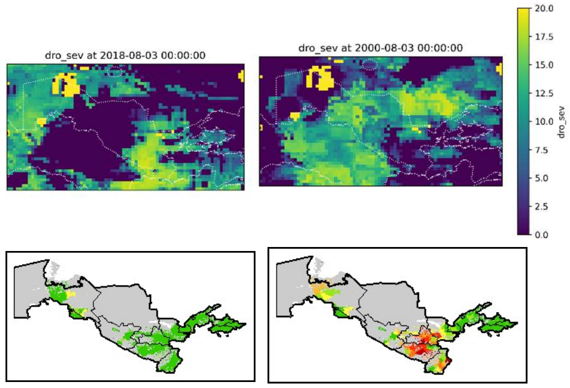

Fig. 2. Comparing drought severity with vegetation index.

a) Drought severity in Uzbekistan b) ASI for croplands

Conclusion

This research significantly contributes to the evolving landscape of water resource management in the Kashkadarya region. The integration of flash drought monitoring into decision-making processes seeks to elevate water use efficiency in agriculture, fostering sustainable practices amidst the challenges posed by climate change. Future endeavors will focus on refining the real-time monitoring system and undertaking on-the-ground validation to ensure the practical applicability of the proposed irrigation strategy. This study advances our understanding of flash drought implications for agricultural regions and provides a robust foundation for the formulation of climate-resilient water management strategies.

References

Kogan, F. N. 1995. “Application of Vegetation Index and Brightness Temperature for Drought Detection.” Advances in Space Research: The Official Journal of the Committee on Space Research 15 (11): 91–100.

Otkin, Jason A., Yafang Zhong, Eric D. Hunt, Jordan I. Christian, Jeffrey B. Basara, Hanh Nguyen, Matthew C. Wheeler, et al. 2021. “Development of a Flash Drought Intensity Index.” Atmosphere 12 (6): 741.