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Hotspots for water conservation due to climate change and water use in the Red River Basin U.S.

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March 2018

Summary of findings from previous study (Mcpherson, et al. 2015):

Precipitation: Slightly less in the western side and more in the east.

Temperature: Increasing 6 ℃ under RCP 8.5

Hydrology: Slightly higher in the eastern side and less in western side.

Regulated flows: Lower flow in the western side

Reservoirs: Overall, higher water levels

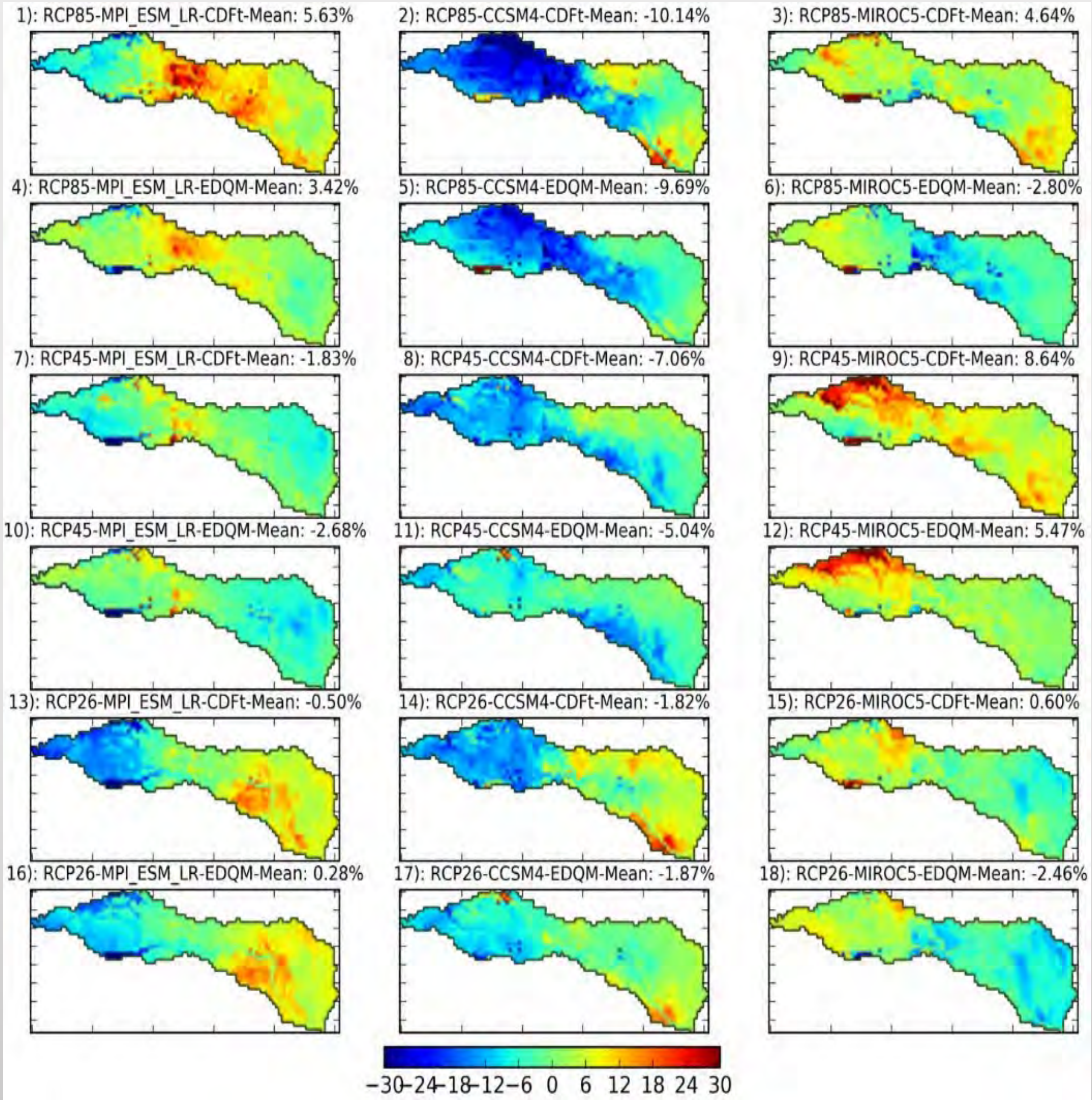

Fig. 1. Streamflow Change Map Projection Data (2010-2039) over the basin based on 1976-2005 mean corresponding historical data under three GCMs and two Down Scaling methods (Mcpherson, et al. 2015)

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Motivation and Objectives

Motivation:

Extended, severe drought (2011- 2015), hypothetically attributed to climate change

Increased water consumption rates within the RRB

Objectives:

Use the VIC model to project future runoff scenarios for 3 GCMs and 3 RCPs (Xianwu Xue and Yang Hong)

Identifying hotspots of where future water availability does not meet growing water demand (Hamed Zamani Sabzi, Hernan Moreno, and Thomas M. Neeson)

Study area

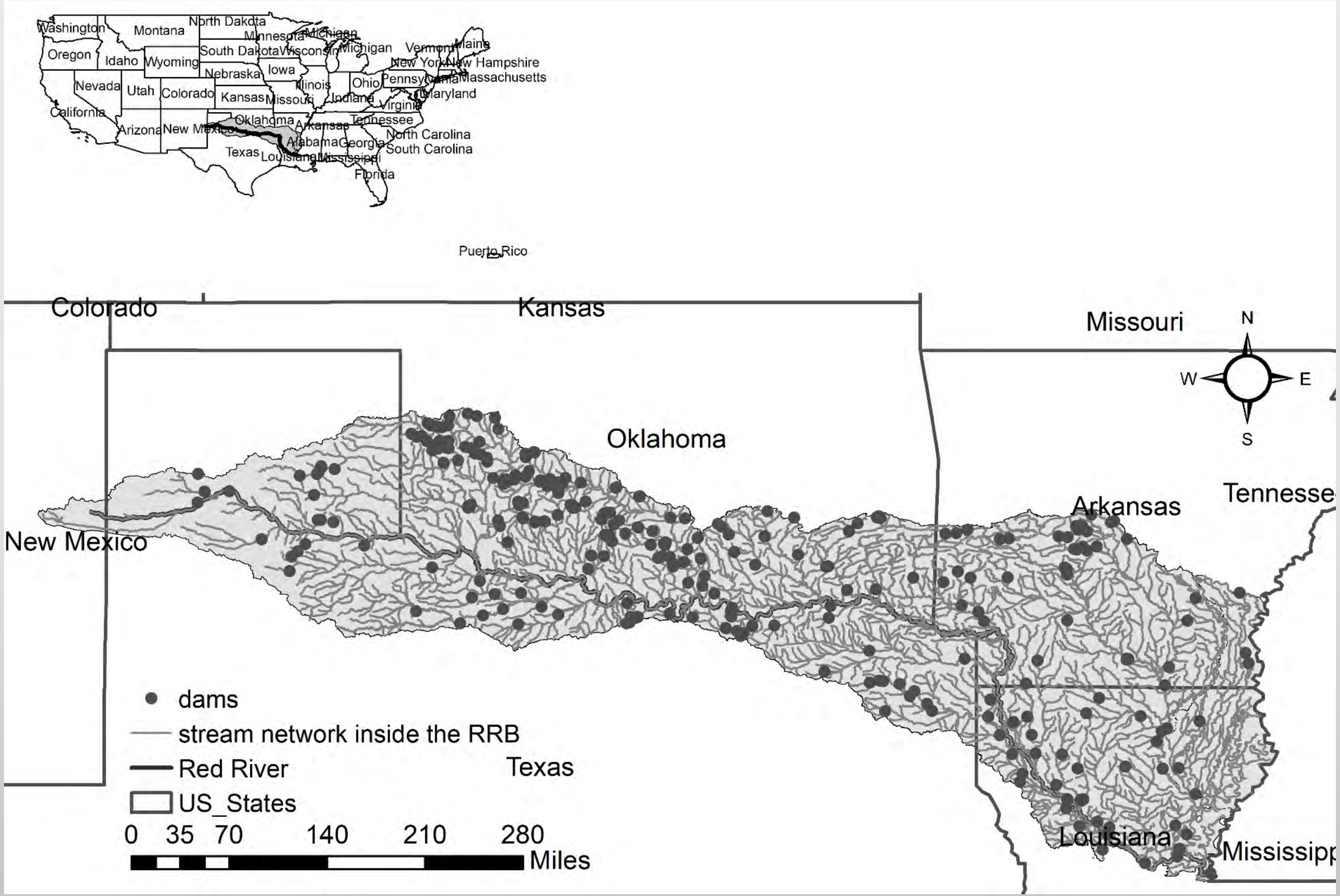

Fig. 2. Study area, Red River Basin

General procedure of transferring projected climate variable to the hydrologic outputs

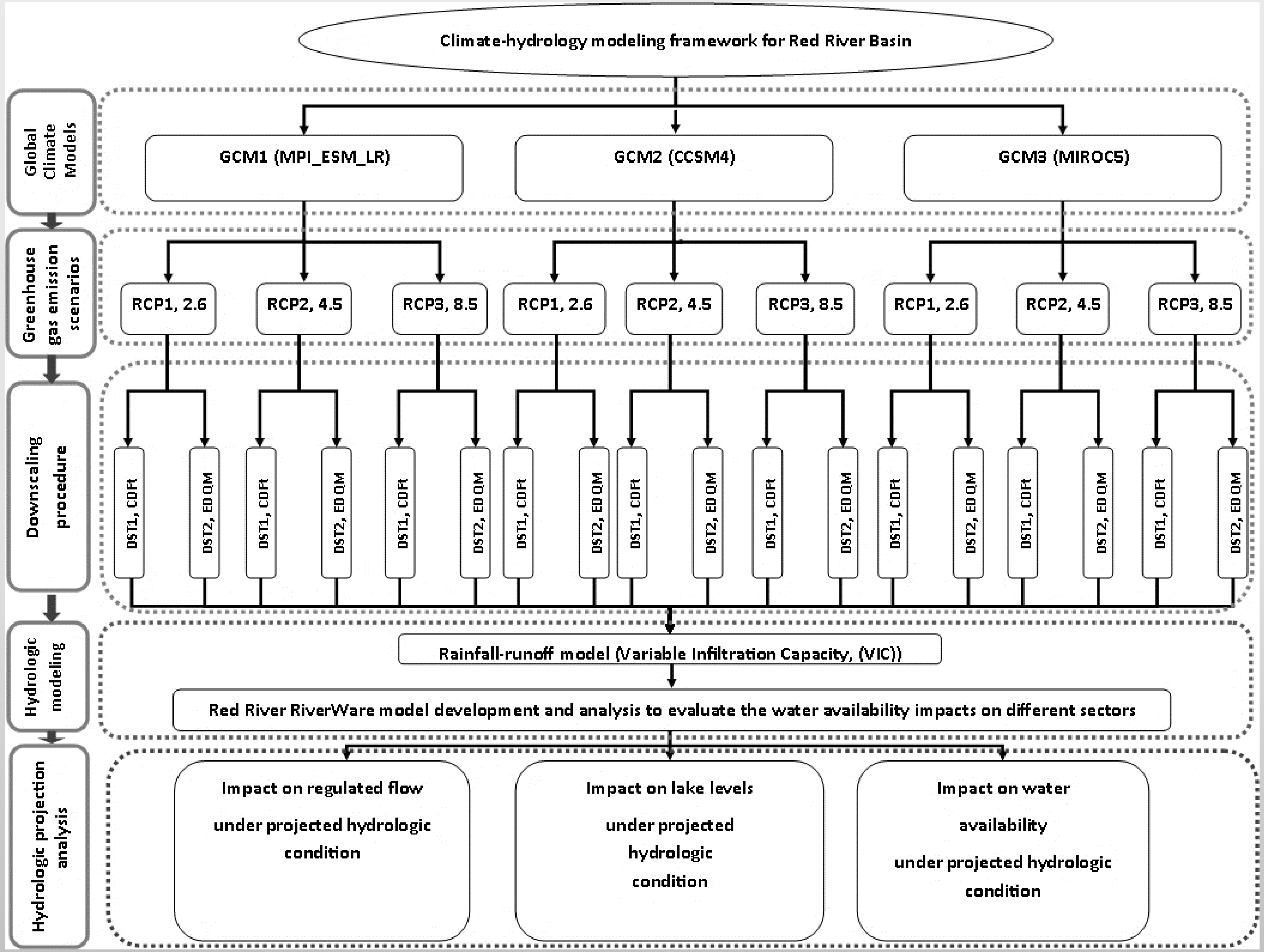

Fig. 3. Schematic procedure of the projecting hydrologic parameters in Red River Basin

Projecting water usage (PWU) across the basin by the years 2050 and 2075

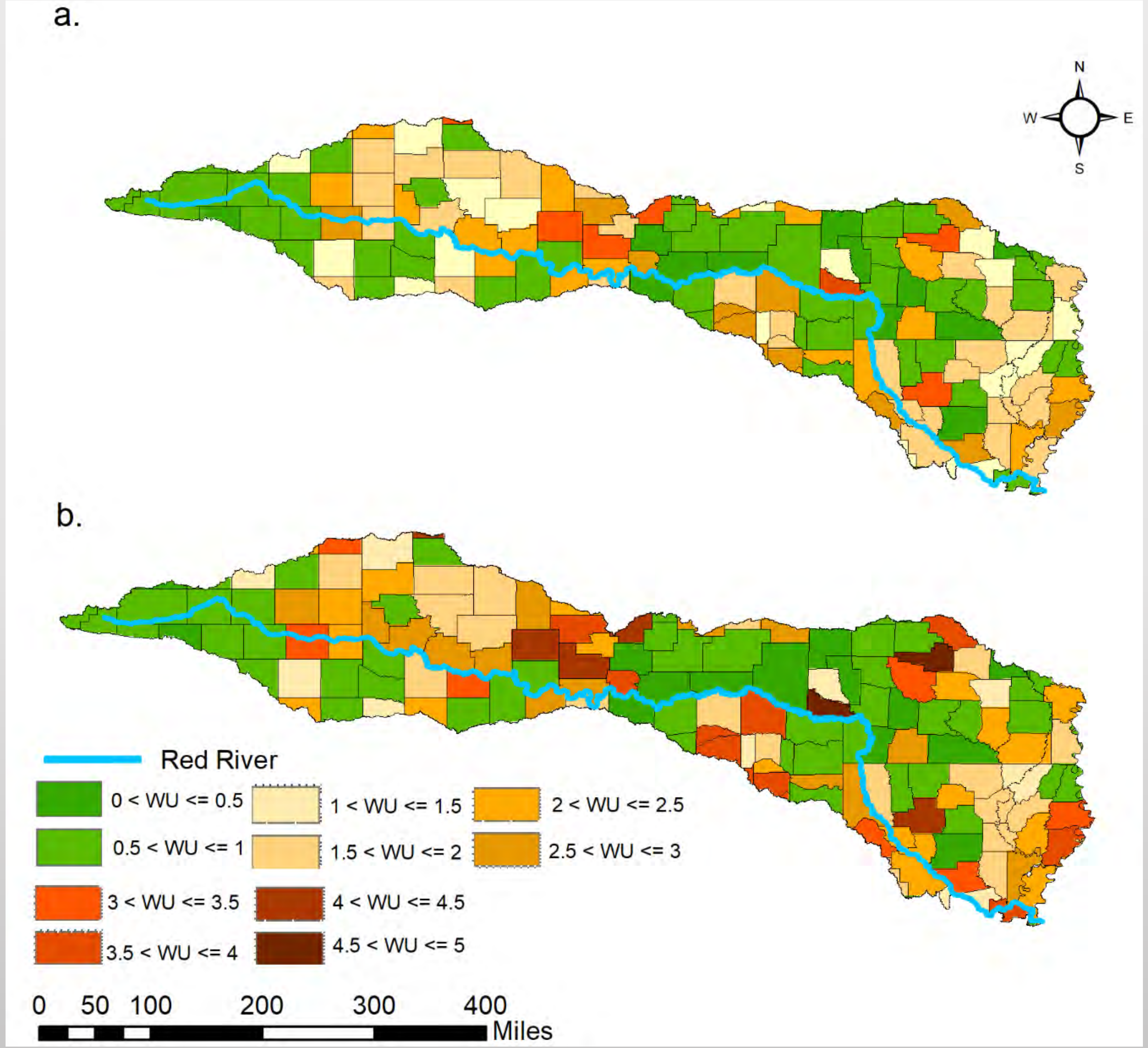

Fig. 4. Projected water usage (PWU) for counties in the Red River Basin in the year 2050 (a.) and 2075 (b.). Usage trends give the proportional change relative to the year 2010; for example, a value of 1.28 means that water usage will increase by 28%.

Projected unit-area based runoff change across the basin (comparing the year 2050 with 2010)

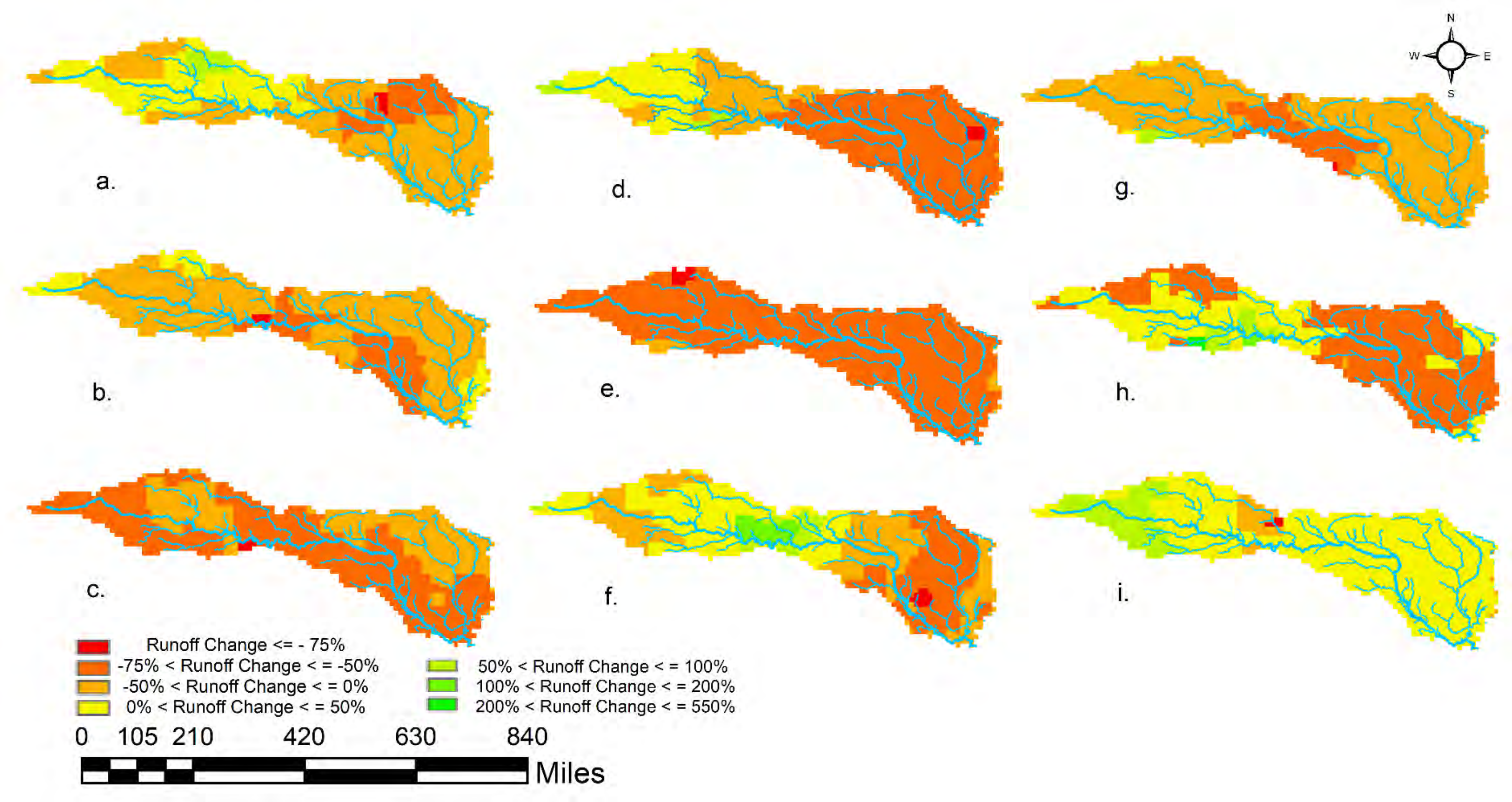

Fig. 5. Projected runoff changes by 2050 compared to the 2010 under three GCM models (MPI_ESM_LR, CCSM4 and MIROC5) using CDFt Downscaling methods, and considering three RCP levels

Projected unit-area based runoff change across the basin (comparing the year 2075 with 2010)

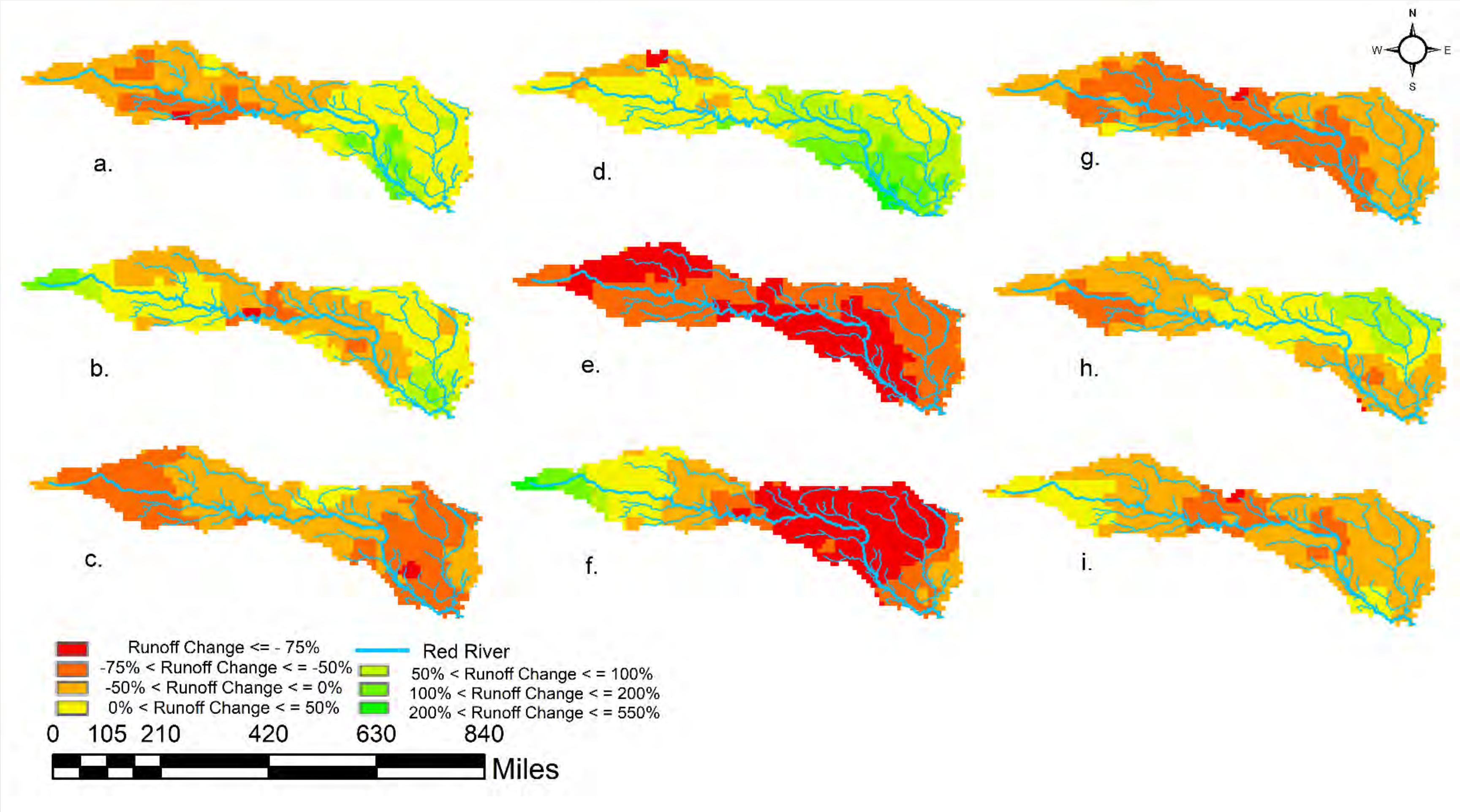

Fig. 6. Projected runoff changes by 2070 compared to the 2010 under three GCM models (MPI_ESM_LR, CCSM4 and MIROC5) using CDFt Downscaling methods, and considering three RCP levels

Developing the rate of projected water availability to water demand (comparing the year 2050 with 2010)

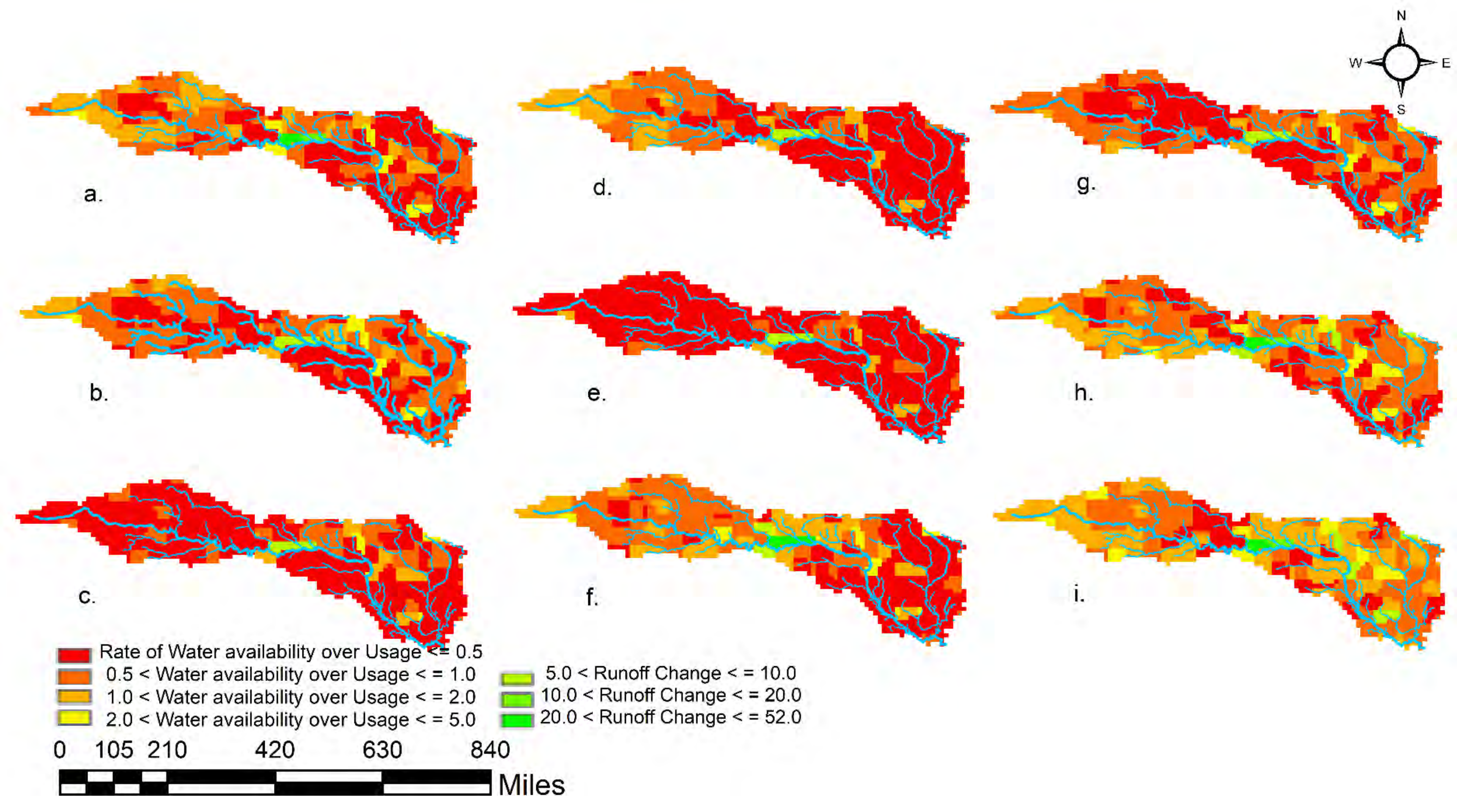

Fig. 7. Spatial map of rate of projected water availability versus projected water demand across the RRB for the year 2050 compared to 2010 considering three GCM models (MPI_ESM_LR, CCSM4 and MIROC5) using CDFt Downscaling methods, and considering three RCP levels

Developing the rate of projected water availability to water demand (comparing the year 2075 with 2010)

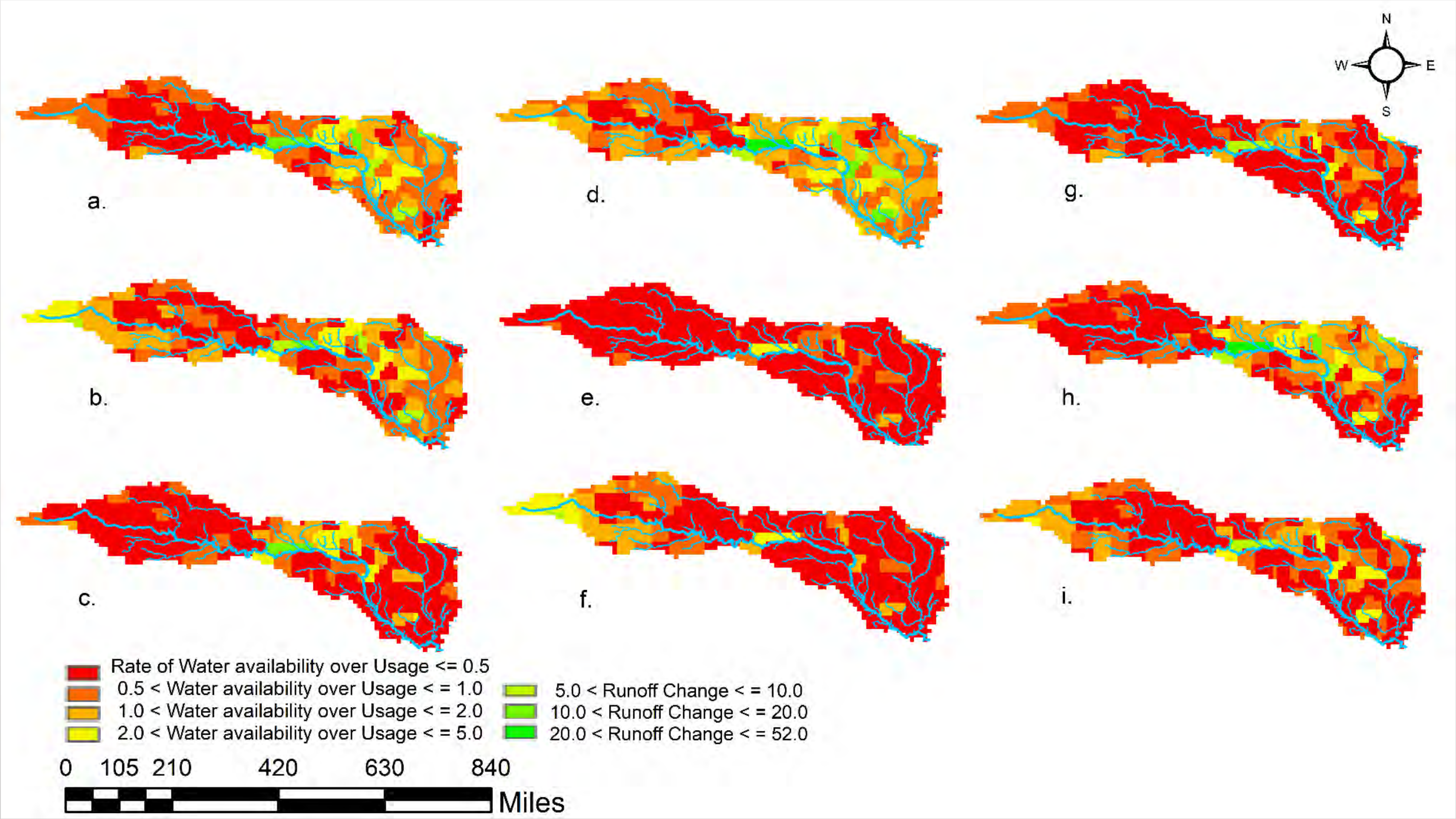

Fig. 8. Spatial map of rate of projected water availability versus projected water demand across the RRB for the year 2075 compared to 2010 considering three GCM models (MPI_ESM_LR, CCSM4 and MIROC5) using CDFt Downscaling methods, and considering three RCP levels

Streamflow trend analysis along the Red River

Fig. 9. 15 Streamflow trend analysis along the Red River under potential climate change scenarios; a. RCP26-CCSM4; b. RCP45-CCSM4; c. RCP85-CCSM4; d. RCP26-MIROC5; e. RCP45-MIROC5; f. RCP85-MIROC5; g. RCP26-MPI_ESM_LR; h. RCP26-MPI_ESM_LR; i. RCP45-MPI_ESM_LR; RCP85-MPI_ESM_LR

Developing the flow duration curves (FDCs) to evaluate the relationship between magnitude and frequency of runoff.

Calculation process:

a.) Sorting daily discharge n values for a specific period

b.) Ranking the discharge values

c.) Then, the exceedance probability (P) is calculated as follows:

$$P=100*\left(\frac{M}{(n+1)}\right)$$

P: probability that a given runoff will be equaled or exceeded (% of time)

M: rank of runoff magnitudes

n: number of recorded values

Drought analysis on RRB based on flow duration curves under climate change impacts

Analyzing flow duration curves to evaluate the projected relationships between the magnitude and frequency of runoff values.

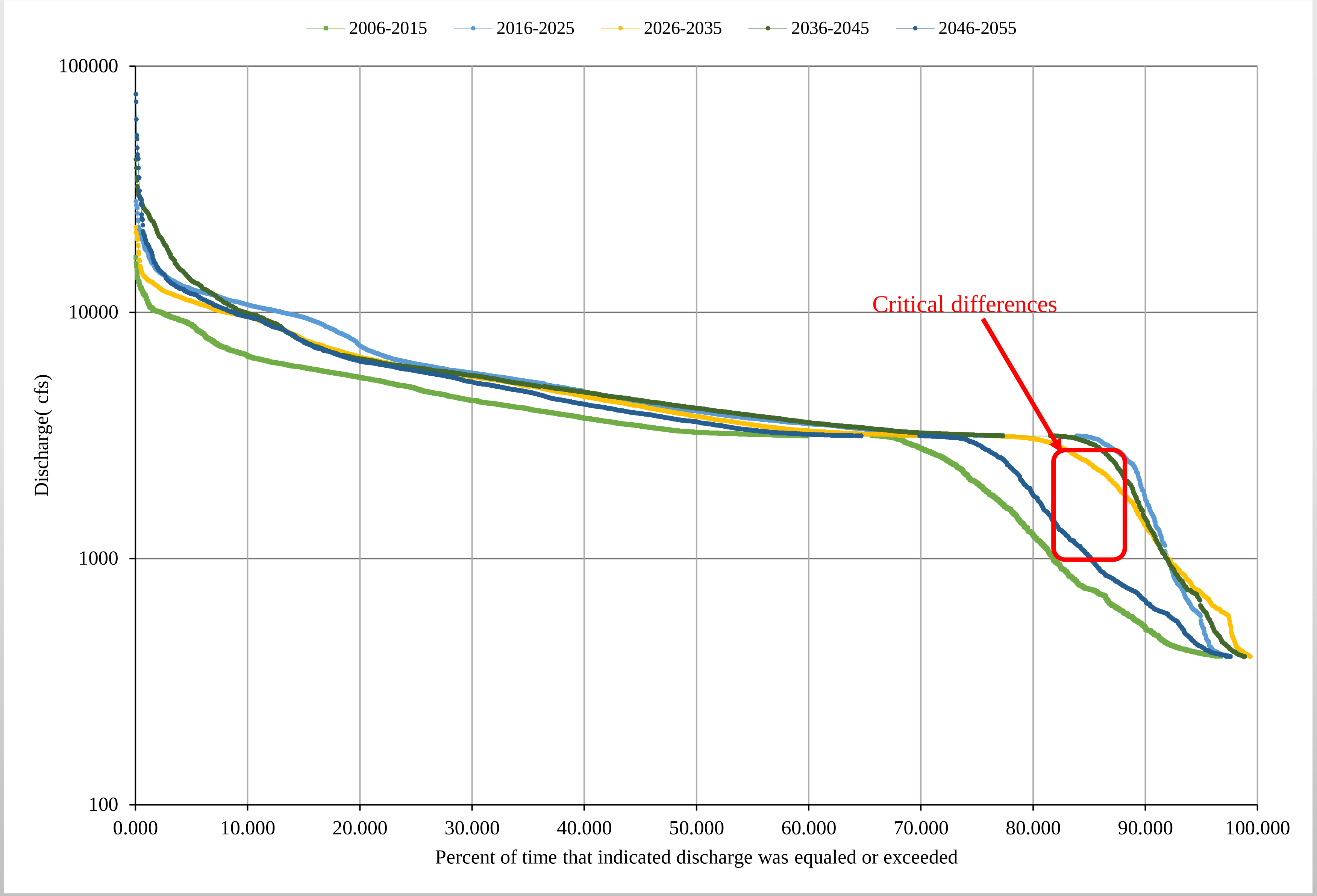

Fig. 10. Flow duration curve sample analysis, selected location: Arkadelphia, AR

Analyzing Streamflow Variation to Evaluate the Potential Future Drought across the RRB based on flow duration curves under climate change impacts

In most of western side, projected magnitudes of the potential droughts for different future periods for higher probabilities of exceedances would be significantly higher compare to the eastern side. (Comparison of the projected runoff values for future decades (2016-2025, 2026-2035, 2036-2045, and 2046-2055) with the period of 2006-2015)

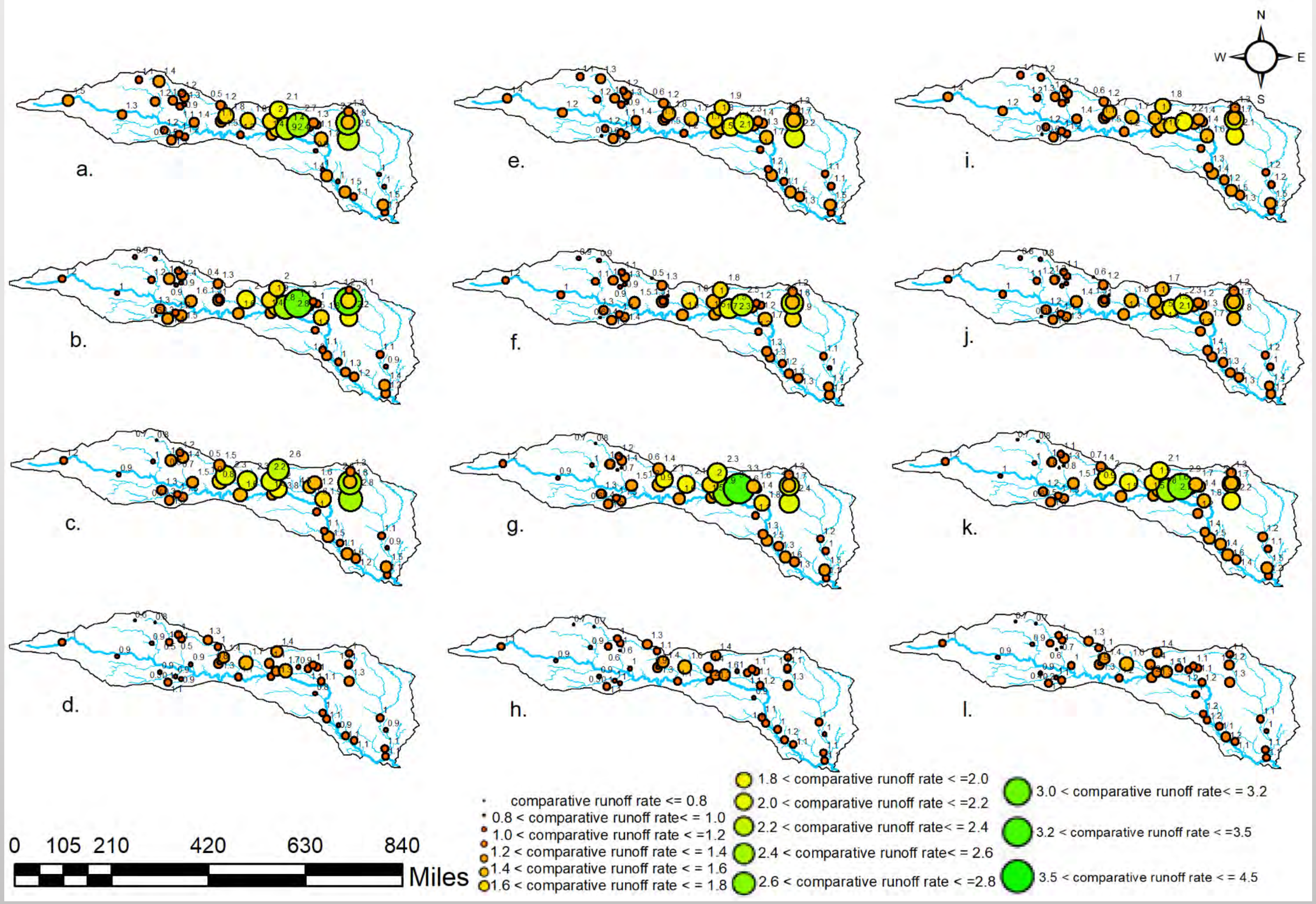

Fig. 11. Rate of expected magnitudes for specific higher probability of exceedances through different projected future periods considering the CCSM4, RCP26, and CDFt;

Ongoing and Future Work

Project 1: Hamed Zamanisabzi (Postdoc): Trade-off Analysis between two major water users (Societal and Environmental sectors)

Project 2: Rachel Fovargue (Postdoc): Optimal allocation of water conservation strategies under potential climate change scenarios

Project 3: Ken Gill (MS Student): Species distribution modeling of Great Plains fishes under climate change

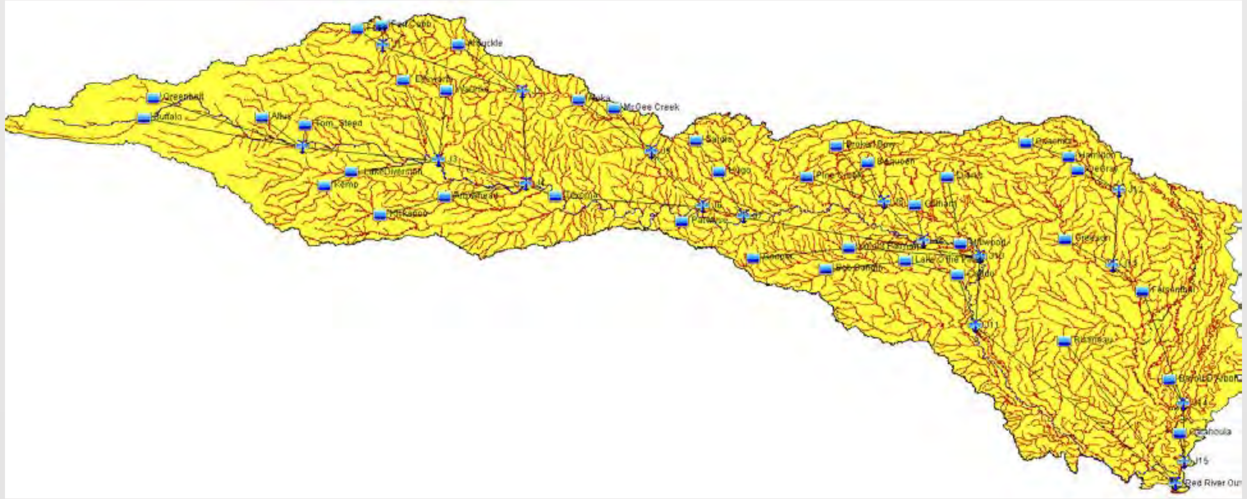

Fig. 12. Network of dams in Red River Basin

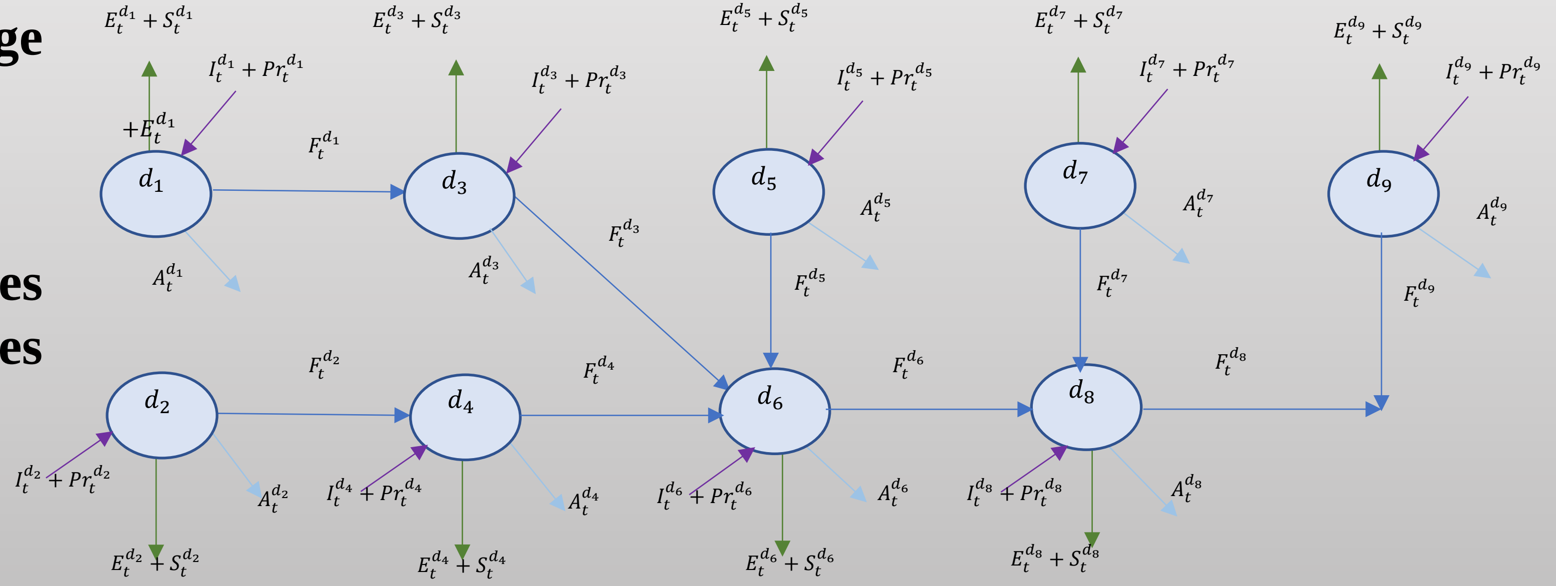

Fig. 13. A sample network of dams.

Trade-off Analysis between two major water users

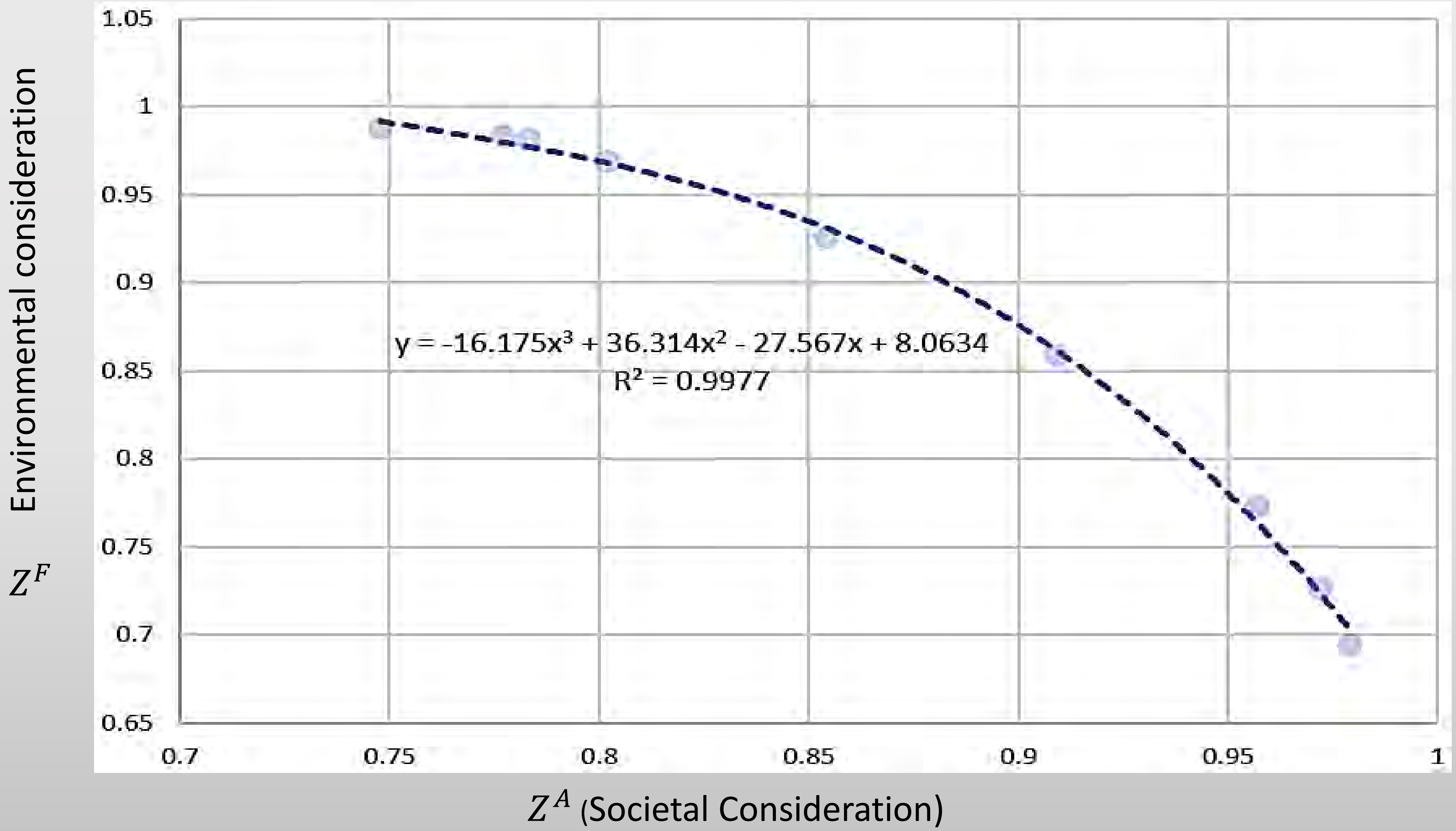

Figure 14. Trade-off between the ecological and engineering considerations (related to **project 1 and 2**).

Project 4: Lin Guo (Ph.D. Student): Managing Conflicting Water Resource Goals And Uncertainties In A Multi-Reservoir System

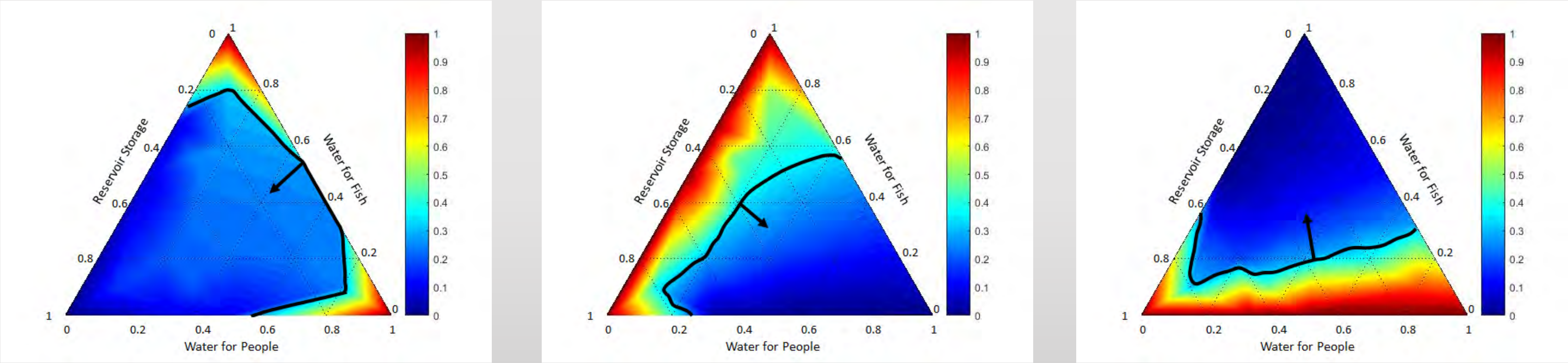

Figure 15. Developing feasible solution spaces considering different water using sectors and limited water sources to satisfy all users (sectors)

Conclusion

- Projected flow duration curves allow quantifying streamflow changes for prescribed exceedance probabilities.
- Coupled the hydrologic projections and water use for different sectors helped us to identify the areas across the RRB that will need water-environmental conservation actions in different periods of the future.
- Those hotspots of where future water availability will not meet growing water demand are locations where regional water policy makers, environmental managers, municipal, and agricultural and industrial sectors must proactively plan to deal with diminishing water availability over the coming decades.

Acknowledgements

Funding was provided by the Great Plains Landscape Conservation Cooperative and the South Central Climate Science Center

SOUTH CENTRAL
CLIMATE SCIENCE CENTER

Great Plains
Landscape Conservation Cooperative

References:

Mcpherson, R.A., 2015: Title of the report: “Impacts of climate change on low flows in the Red River Basin” (Several Researchers at the University of Oklahoma and the Choctaw and Chickasaw Nations have been involved in developing the projections of future hydrology for the Red River Basin under possible future climate conditions).

THANK YOU

QUESTIONS?

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