Yield Gap: Rainfed Maize in Western Kansas

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Background

A key strategy for increasing production is to close the gap between farmer fields and maximum yield attainable with best practices in a given environment. Thus, quantifying yield gap and identifying yield limiting factors may assist improving crop productivity.

Objectives

✓Identify the changes in simulated water-limited yield potentials and actual farm yields of maize.

✓ Evaluate the main factors causing maize yield gaps (genotype x environment x management practices, G x E x M).

Methodology

Datasets

Climate data: daily minimum and maximum temperatures, precipitation, solar radiation and wind speed from 3 weather stations from 1990 to 2014 from the United States Historical Climatology Network (USHCN).

Crop data: from the Kansas State University Agricultural Experiment Station, including maize phenology, cultivar type, yield and management practices; used to calibrate and evaluate the APSIM-Maize model.

Soil data: from United States Geological Survey (USGS).

Actual county yield: National Agricultural Statistic Service from 1990 to 2014.

The APSIM-Maize Model

☐ In this study, APSIM-Maize model was run with the climate data to quantify the water-limited yield potential in Western Kansas under rainfed condition. For simulated water-limited yield potentials, a high-yielding maize hybrid was selected for each county based on the average yield and the planting years (Fig. 1).

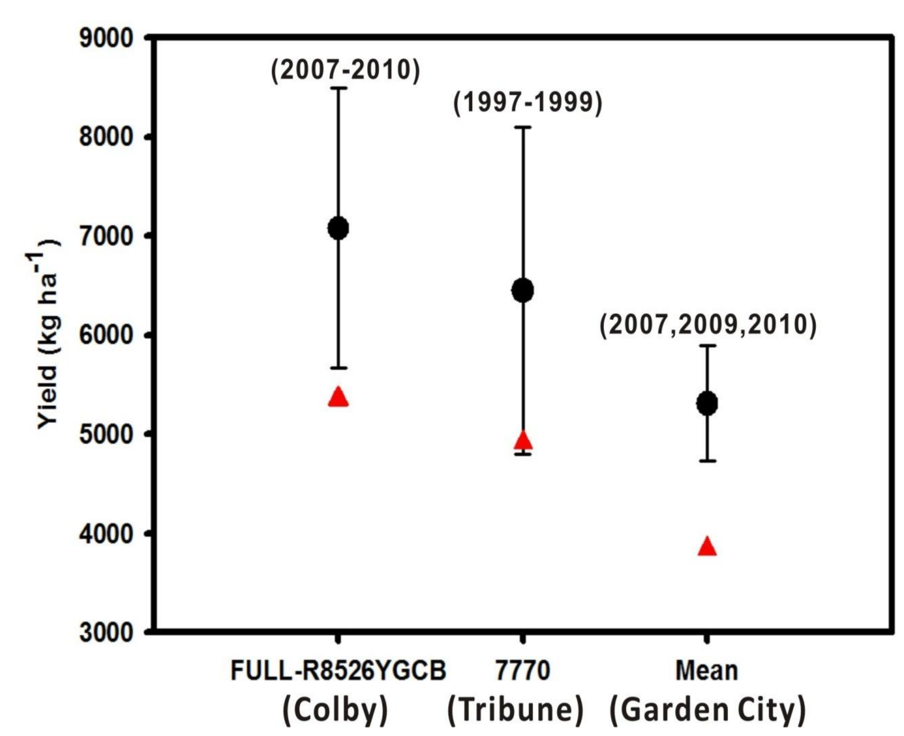

Fig.1 Detailed information about high-yielding maize hybrids. The black dot denotes the average yield for the selected hybrid during the planting year (in brackets). The red triangle denotes the average yield of all the maize hybrids planted in the selected location during 1997-2013 under rainfed condition.

☐ Under water non-limiting conditions (the conditions assumed in this study), the biomass growth rate was given by the following equation (see details in www.apsim.info).

dlt_dm_rue=RUE*radiation_interception

☐ High-stable coefficient (*HSC*) of the hybrid was used to evaluate hybrid suitability. Greater *HSC* indicated better suitability (Zhao et al., 2016).

$$HSC_i = \frac{(X_i - S_i)}{\overline{X}}$$

Where HSC_i is the high-stable coefficient for a specific hybrid, X_i is the arithmetic mean of yield potential for a specific location, S_i is the standard deviation of yield potential and $\overline{X}$ is the arithmetic mean of yield potential in all the locations for the specific hybrid in this study.

Study sites and The conceptual framework

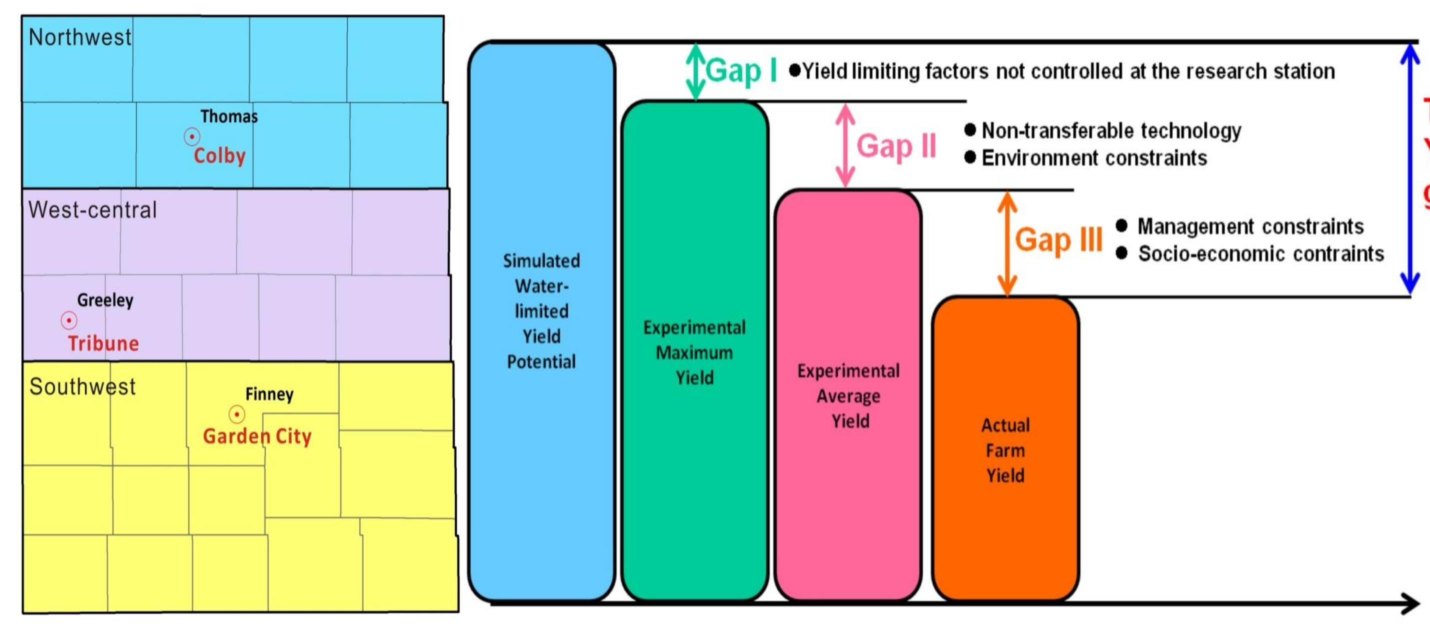

Fig. 2 The study sites and the conceptual framework about the rankings of yield. The red circles indicated the agricultural experiment stations used for APSIM-Maize calibration and evaluation.

Results

The simulated water-limited yield potential and the actual farm yield

✓ APSIM-Maize can simulate crop development and yield (Fig. 3).

✓ For the three maize hybrids, the *HSC* of hybrid 7770 was the highest (0.92), more stable and suitable of all three genotypes. Hence, hybrid 7770 was selected to simulate the water-limited yield potential in the three counties for yield gap analysis (Fig. 4 and Fig. 5).

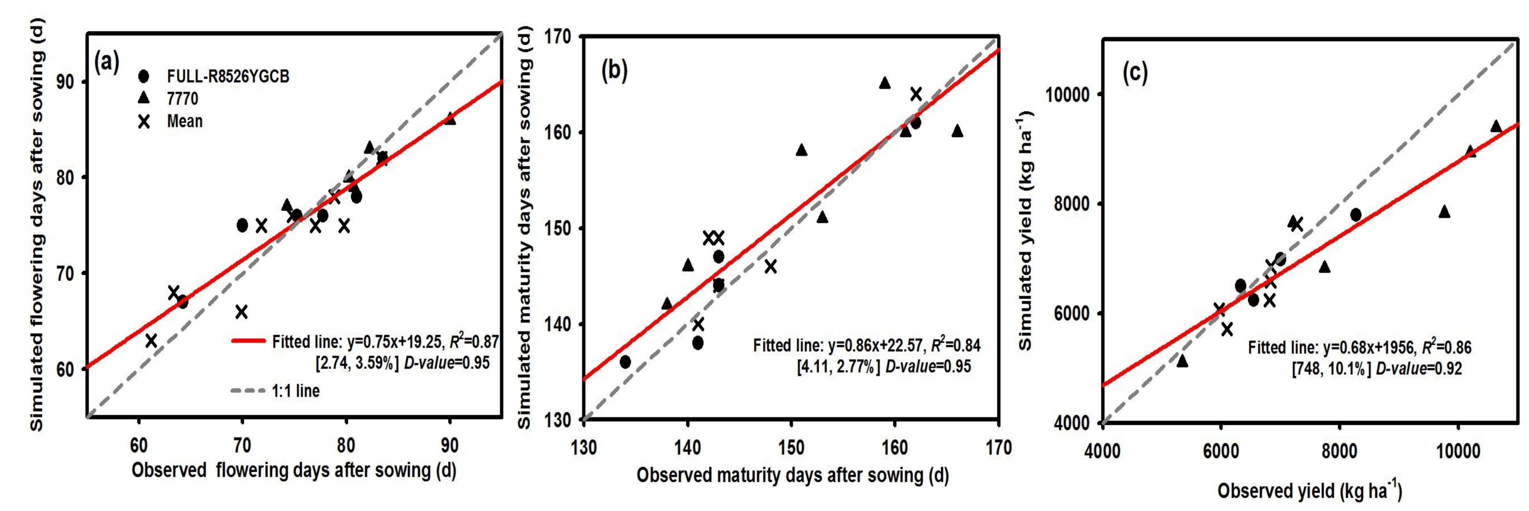

Fig. 3 Validation of the APSIM-Maize model simulations on flowering days after sowing, maturity days after sowing and yield at the three counties. Numbers in the square brackets ([a, b]) refer to the values of RMSE and NRMSE, respectively.

Analysis of the yield gaps

☐ Yield Gap I: YG_I cannot be narrowed by the current technology due to the non-controllable yield limiting/reducing factors (Fig. 6).

☐ Yield Gap II: This gap was caused by the non-transferable technology and environment conditions, which was very difficult to be narrowed.

☐ Yield Gap III: This gap was relatively higher than YG_I and YG_{II} (except in Finney) and mainly caused by management and socio-economic factors, which was the most potential part to be narrowed.

☐ The total yield gap percentages were estimated to decrease by 0.5%, 1.6% and 11.5% per decade insignificantly from 1990 to 2014 across three counties (Fig. 7).

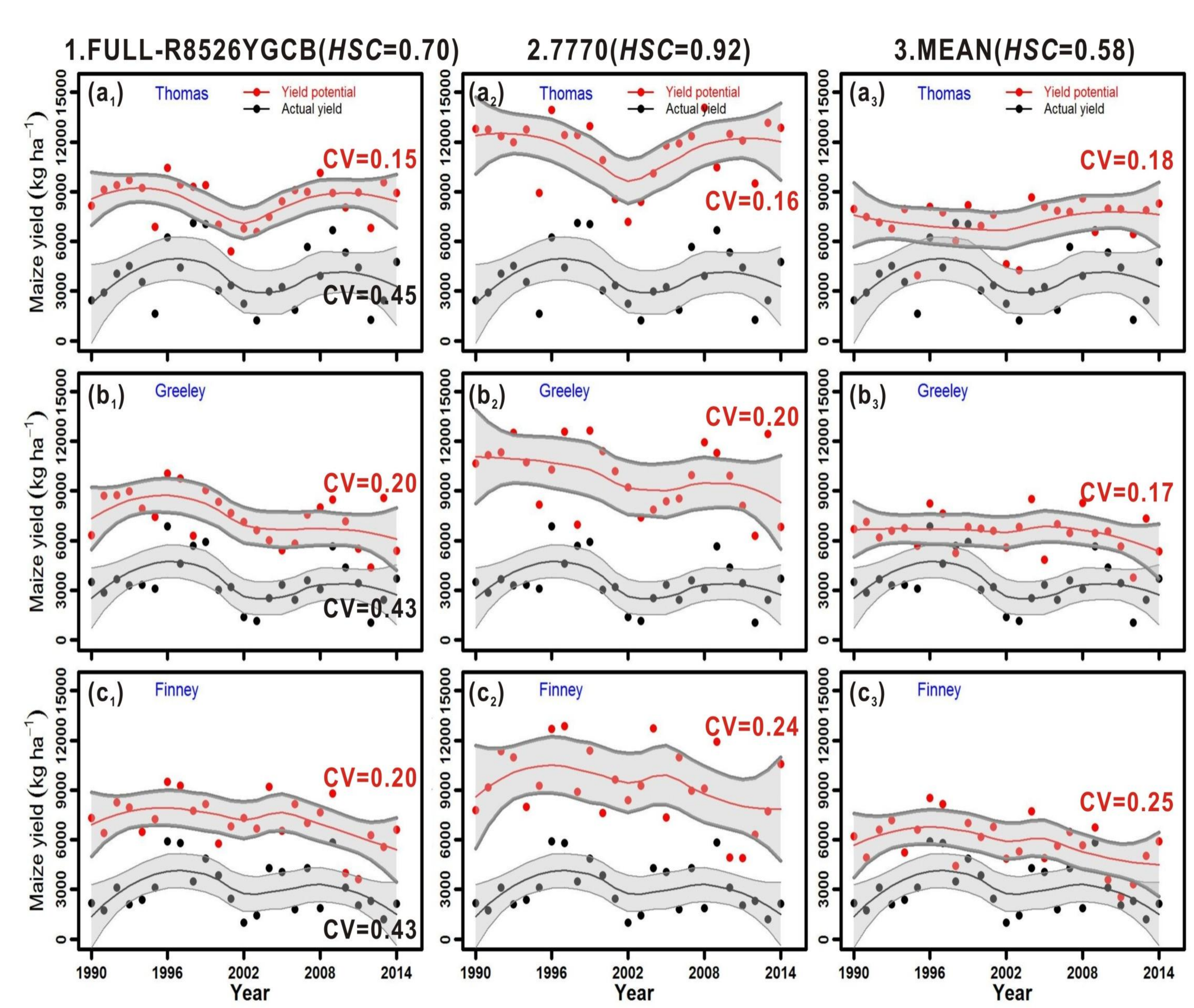

Fig. 4 Actual farm yields and simulated water-limited yield potential of maize for three different hybrids from 1990 to 2014. The numbers in red means the *CV* of the simulated water-limited yield potential and the numbers in black means the *CV* of the actual farm yield.

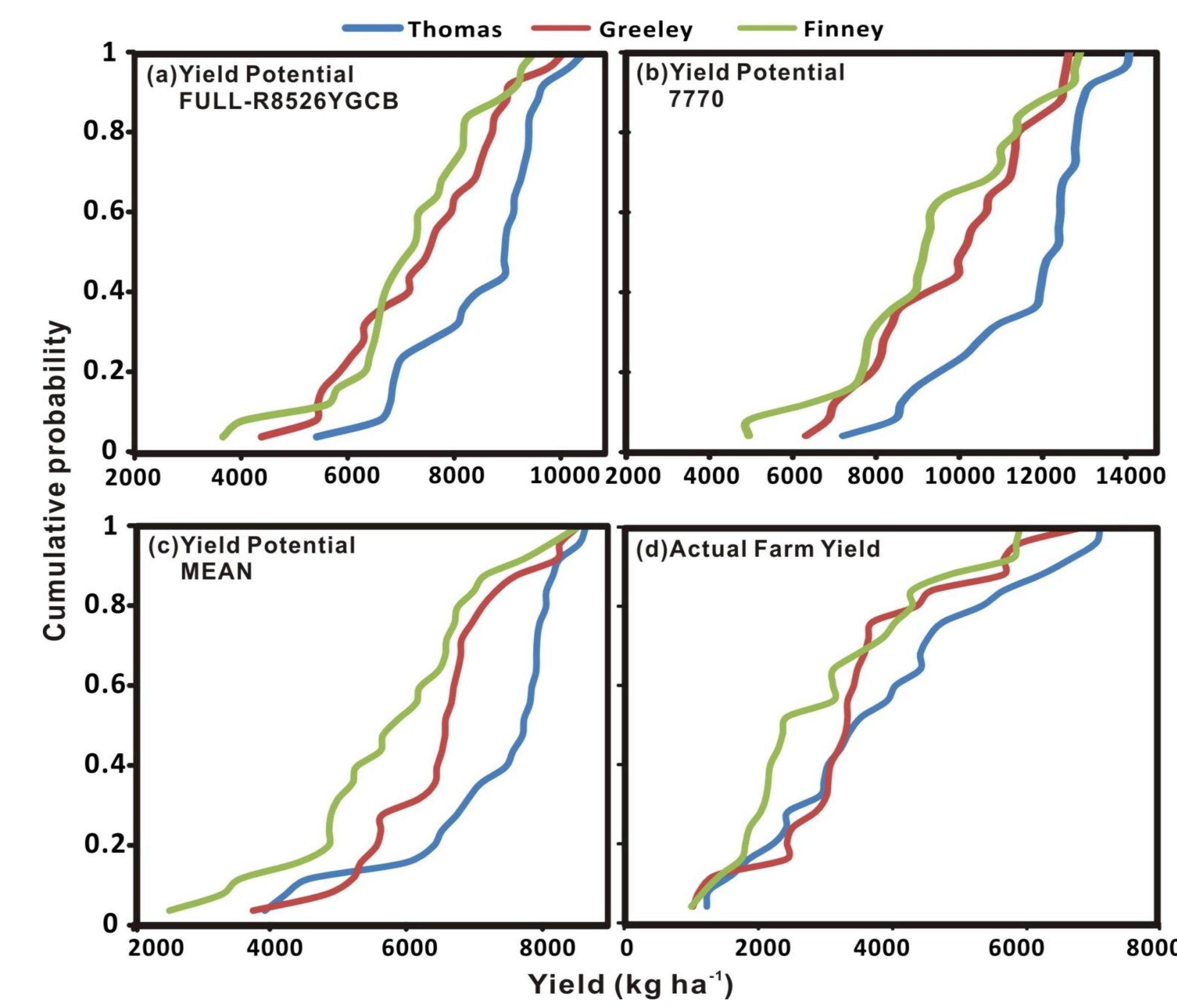

Fig. 5 The cumulative probability of yield potential for the three hybrids (a-c) and actual farm yield (d)

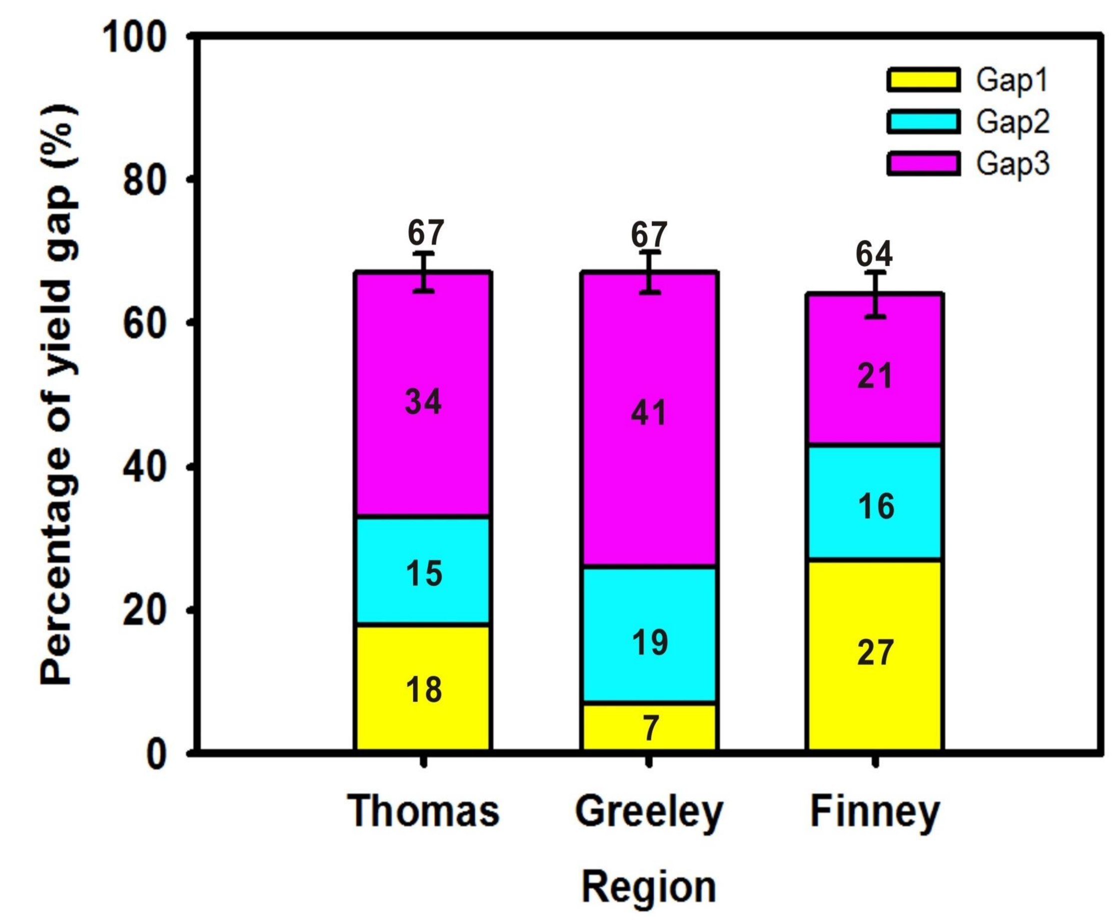

Fig. 6 Estimated yield gaps of maize from 1990-2014

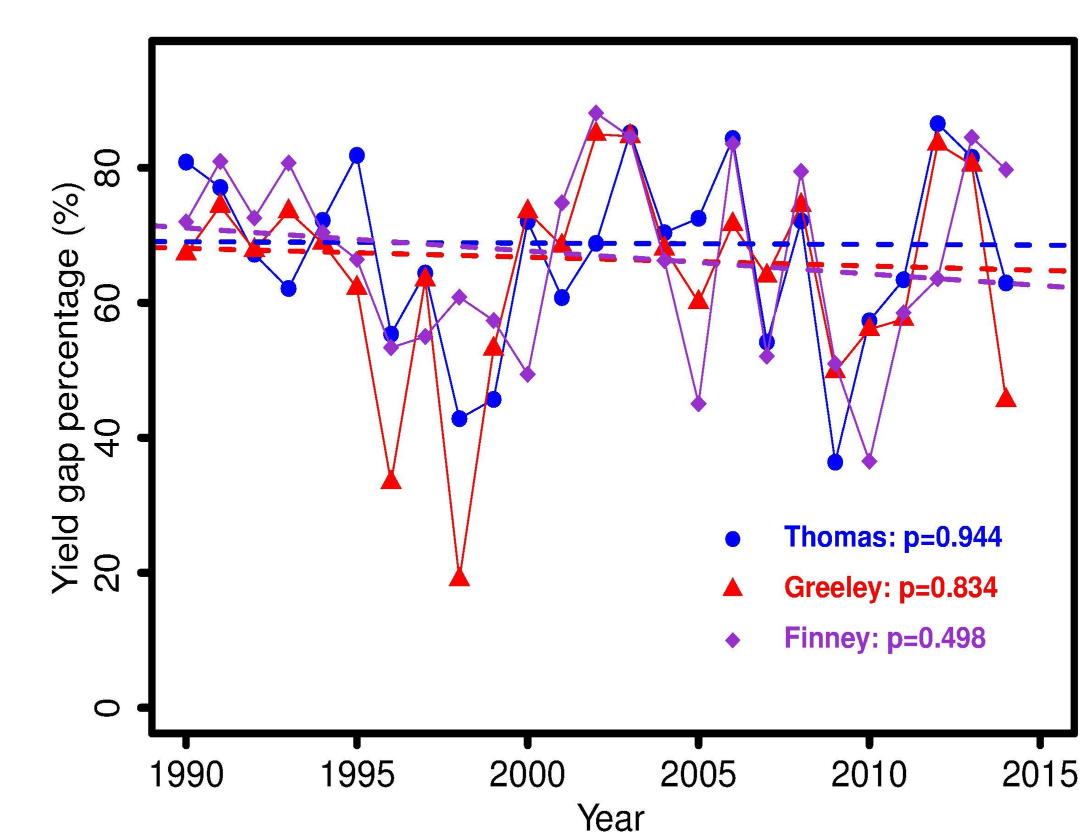

Fig. 7 Temporal trends in yield gap percentage over 1990-2014 across three counties. Dashed lines denote insignificant linear relationships with p>0.05 using the Theil-Sen Method (Gilbert, 1987)

Conclusion

✓ Current maize yields in the three counties were only about 35% of the simulated water-limited yield potential in Western Kansas under rainfed condition.

✓ The total yield gap showed a decreasing trend in the three counties insignificantly over 1990-2014.

✓ Under rainfed condition, YG_{III} seemed to be dominant compared with YG_I and YG_{II} across the three counties except Finney, which was the most potential part to be narrowed and suggested that government and farmers should focus on reducing YG_{III} by improving the agronomic management practices.

References

Gilbert R.O., 1987. 6.5 Sen's Nonparametric Estimator of Slope. Statistical Methods for Environmental Pollution Monitoring. John Wiley and Sons, pp. 217–219.

Zhao J *et al.*, 2016. Variations in the potential climatic suitability distribution patterns and grain yields for spring maize in Northeast China under climate change. Climatic Change, DOI 10.1007/s10584-016-1652-y.