# Application of CERES-Sorghum: Sensitivity Analysis

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## 1.0 INTRODUCTION

Kansas ranks first in grain sorghum production in the US. Crop modeling has provided useful insights about the functioning of crops, agricultural systems and, in particular about the interactions between crops and their environments. Sensitivity analysis (SA) is an important preliminary analysis to answer some basic fundamental questions. To the best of our knowledge SA for CERES-sorghum has not been published yet.

## 2.0 OBJECTIVES

- To identify and rank the input parameters based on their sensitivity in response to simulated output.
- To identify how well does the model represent the underlying physics of crop growth and yield. This can assist us to identify the model limitations.

## 3.0 METHODOLOGY

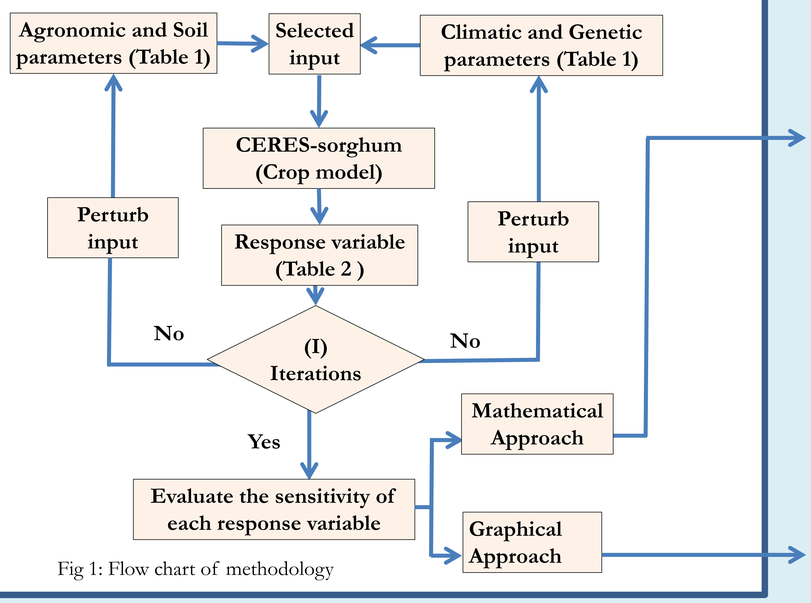


Fig 1: Flow chart of methodology

### 3.1 Sensitivity Analysis Approach

- One-at-a-time (OAT) :Each input perturbed while keeping rest of input constant.
- **Mathematical approach :**
  Sensitivity index (SI) calculated using formula:
  Where $I_1$, $I_2$, and $I_{avg}$ are the minimum, maximum, and average values of a selected input , $O_1$, $O_2$, and $O_{avg}$ are the corresponding modeled output.

$$SI = \frac{O_2 - O_1}{O_{avg}} / (I_2 - I_1)/I_{avg})$$

- **Graphical approach :**
  1) Response variable vs. input parameters. 2) % change in yield vs. input parameters .

### 3.2 Input and Output Parameter

- Crop management, soil and weather data were based on year 2009 for Manhattan in Kansas.

Table 1: Climatic, genetic, agronomic and soil input parameters used in the SA

| Abv. | Input parameter definition | Units | Range | Increment |
|---|---|---|---|---|
| **T** | Temperature | $^oC$ | ±4 | 1 |
| **SR** | Solar radiation | $MJ/m^2/day$ | ±20% | 5% |
| **$CO_2$** | Carbon dioxide | ppm | 187-887 | 100 |
| **Rain** | Rainfall | mm | 80-60 | 10% |
| **DLL** | Drainage lower limit | $mm^3mm^{-3}$ | 0.11-0.29 | 0.01 |
| **DUL** | Drainage upper limit | $mm^3mm^{-3}$ | 0.35-0.46 | 0.01 |
| **PH** | Soil water PH | ------ | 4.0-9.0 | 0.5 |
| **SWT** | Saturated water content | $mm^3mm^{-3}$ | 0.41-0.56 | 0.01 |
| **SOC** | Soil organic carbon | % | 0.5-4.0 | 0.5 |
| **Pdate** | Planting date | day of year | 81-146 | 1 |
| **Pdepth** | Planting depth | cm | 1.5-5.5 | 0.5 |
| **Popn** | Plant population | $No/m^{-2}$ | 12-20 | 0.5 |
| **Rw Sp** | Row spacing | cm | 50-100 | 5 |
| **P1** | Juvenile phase coefficient | GDD | 100-800 | 20 |
| **P20** | Critical photoperiod | hrs | 10-17.5 | .25 |
| **G1** | Leaf size coefficient | ------ | 1-25 | 1 |
| **G2** | Panicle size partitioning coefficient | ------ | 4-7 | .25 |
| **P5** | Grain filling duration coefficient | GDD | 400-800 | 25 |

Table 2: List of response variables used for study

| Abbreviation | Response variables (output) | Units |
|---|---|---|
| **YL** | Yield | Kg/ha |
| **BM** | Biomass | Kg/ha |
| **AD** | Anthesis days | DAS |
| **MD** | Maturity days | DAS |
| **LAI** | Leaf area index | -- |
| **LN** | Leaf number at maturity | Number |

## 4.0 RESULTS

### 4.1 Sensitivity Index

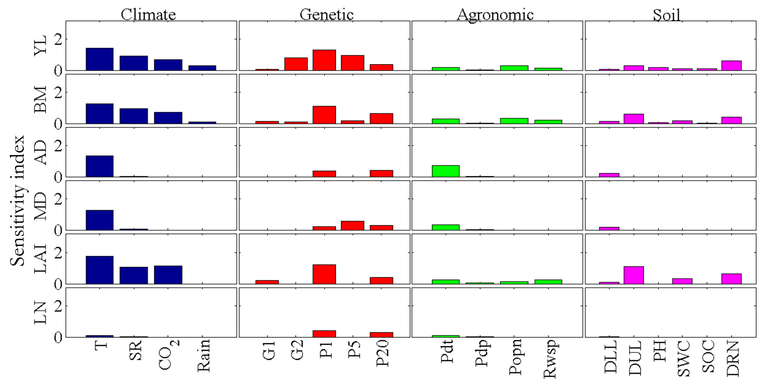


Fig 2: Sensitivity Index for combinations of input parameters & response variables

- Temperature is the most sensitive parameter affecting all response variable except leaf number which is sensitive to P1 and P2O.

### 4.2 Response to Climatic Variables

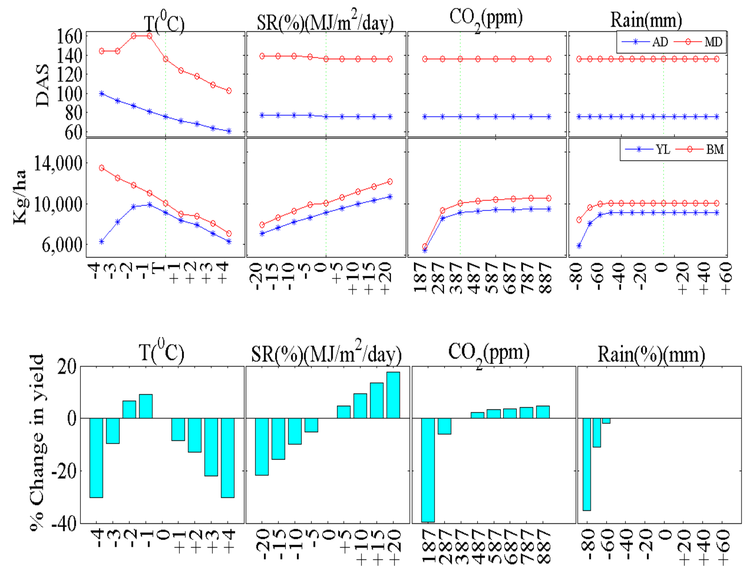


Fig 3: Graphical approaches used to represent sensitivity in climatic variables

- Increasing temperature by 4°C reduces the sorghum grain yield up to 30%, whereas a decreasing temperature (1 -2°C ) increases yield (~7 and ~9%).
- Perturbation of SR by ±20% and rainfall by (-80% to +60%) and $CO_2$ (187 to 887ppm) did not impact on days to anthesis and maturity.

### 4.3 Response to Genetic Parameters

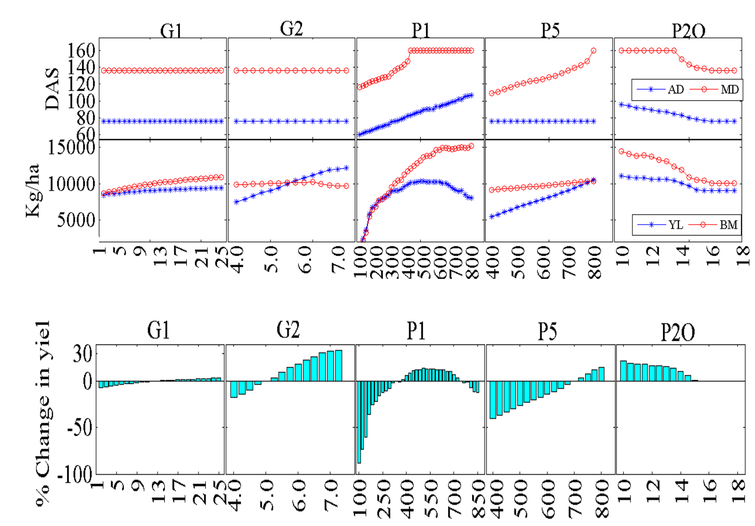


Fig 4: Graphical approaches used to represent sensitivity to genetic parameters

- Increasing P1 increases the AD and yield, but yield starts declining after P1(460).
- MD and yield increases with increase in P5.
- G2 is the most sensitive parameter affecting grain yield.
- P2O and all response variables have a non-linear relation.

## RESULTS CONTD.

### 4.4 Response to Agronomic Parameters

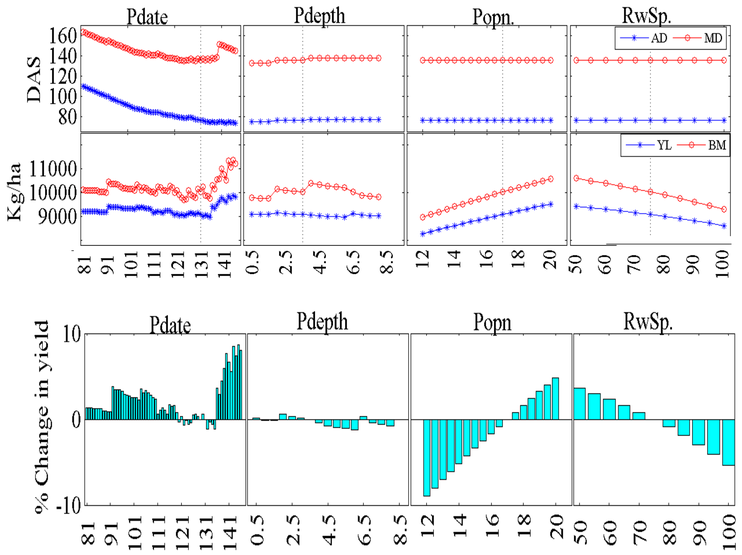


Fig 5: : Graphical approaches used to represent sensitivity in agronomic parameters

- AD and MD are found decreasing with increasing planting date. On Pdate 136, sudden increase in yield (up to 9%) was observed. This needs to be explored in detail.
- Pdate is the most sensitive parameter affecting grain yield.
- Decreasing Rwsp and increasing Popn increase the yield and biomass and vice versa.

### 4.5 Response to Soil Parameters

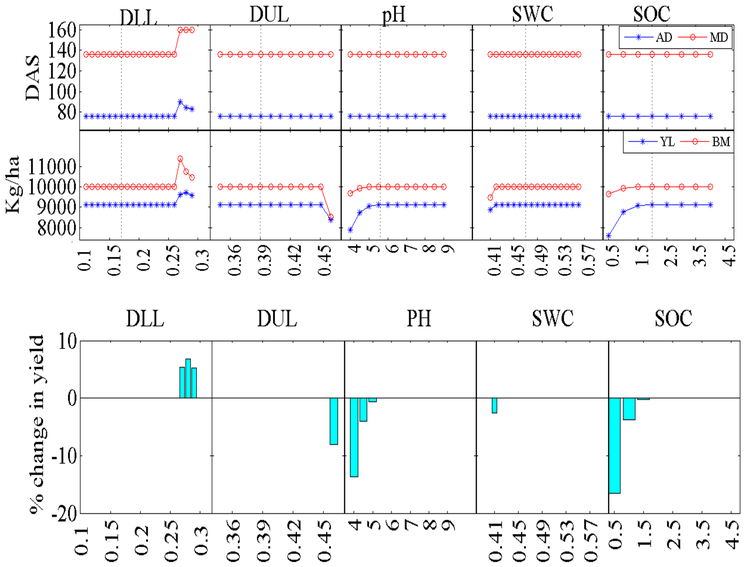


Fig 6: Graphical approaches used to represent sensitivity in soil parameters

- Yield and biomass are only sensitive to DLL in the range 0.26 to 0.29 and DUL greater than 0.45 $mm^3mm^{-3}$.
- SOC is sensitive to yield and biomass with in the range of 2 to 0.5%.

## 5.0 CONCLUSION

- Temperature is the most sensitive parameter for all response variable except leaf number.
- The ranking of sensitive parameter vary with response variables.
- Sorghum yield is often constrained by DUL, DLL, SWC, PH, Rainfall, but our SA doesn't capture them. This needs to be explored in more detail.

### 5.1 Future works

- Uncertainty due to different location and year will be tested.

## 6.0 ACKNOWLEDGEMENT

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