Modeling Climate Change Impacts on Farm Households in Zambia

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Objectives

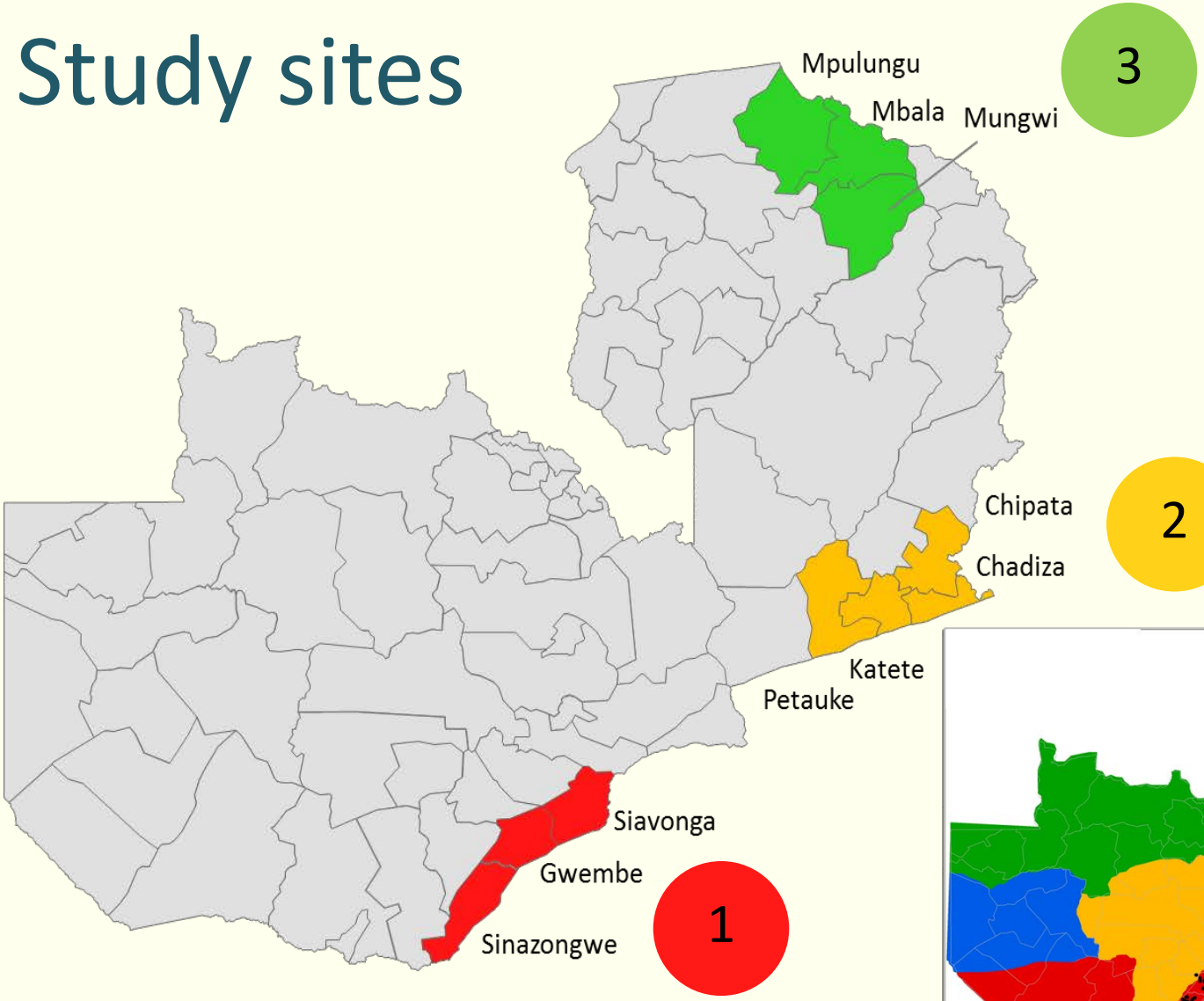
- To estimate how representative farm households in Zambia will respond to effects of climate change on crop yields

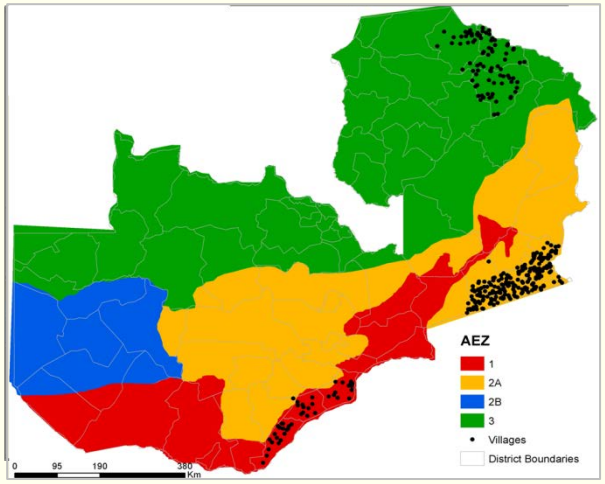
- To identify the extent to which farmers can minimize the negative effects of climate change by changing crops or production technologies

How the model works

- Choose the set of crops and production technologies that best meets the household's objectives (profit, food consumption needs)
- Taking into account:
  - Crop yields
  - Inputs required for each production activity
  - Prices of crop outputs and inputs
  - Availability of land, labor, cash
  - Household calorie consumption needs
  - Desire to maintain soil fertility

Study sites


Mpulungu
Mbala
Mungwi
3
Chipata
Chadiza
2
Katete
Petauke
Siavonga
Gwembe
Sinazongwe
1


AEZ
1
2A
2B
3
Villages
District Boundaries
0
95
190
380
Km

Household types

Smallholder

- ~1.75 hectares
- ~2.75 working-age members
- 350-500 ZMK available

Emergent farmer

- ~7 hectares
- ~3.25 working-age members
- 150,000-200,000 ZMK available

Female-headed household

- ~1.5 hectares
- ~2 working-age members
- 350-500 ZMK available

We assumed households need 2,100 calories from field crops per day per adult equivalent.

Crops and technologies used

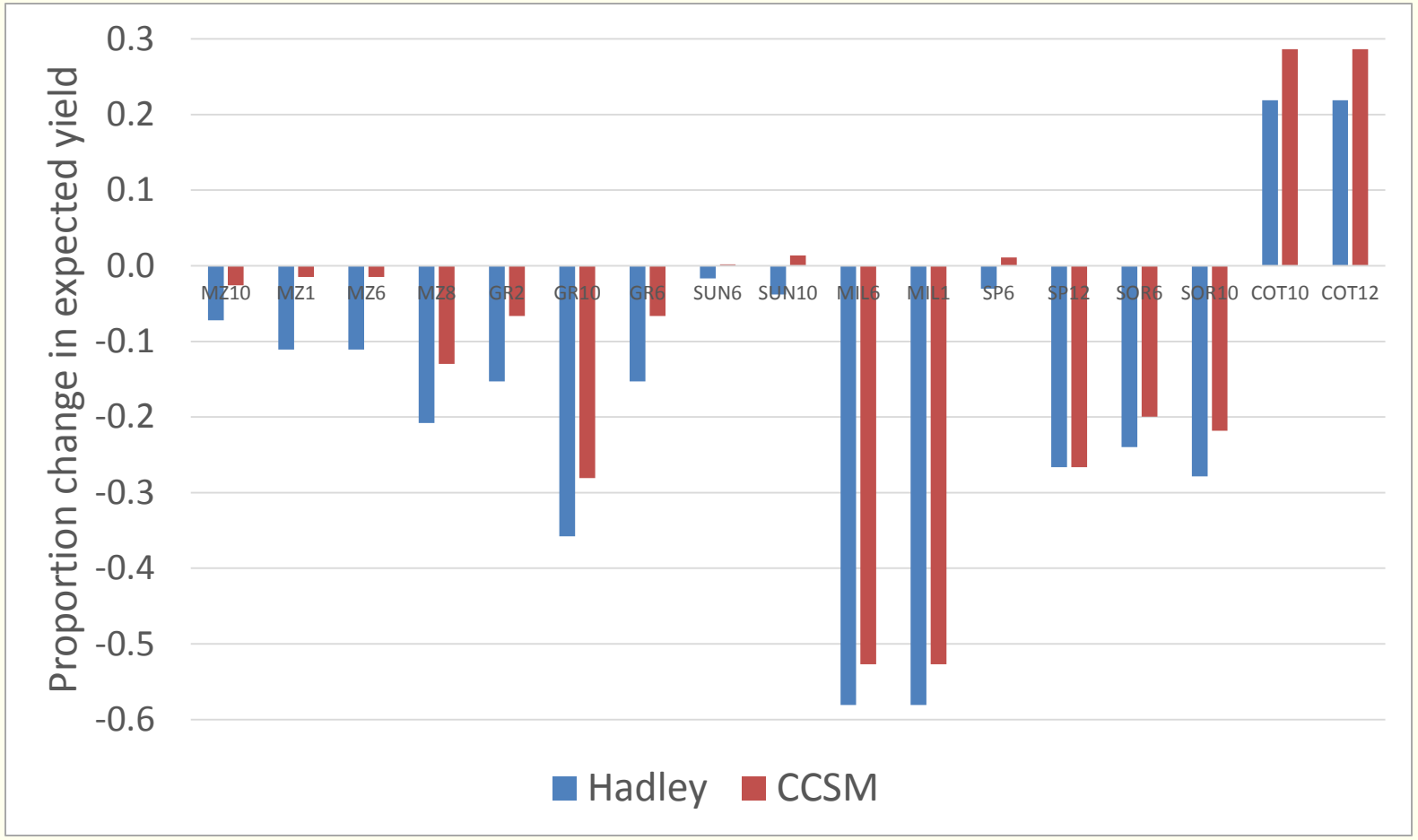
Based on data from Crop Forecast Survey

Crop	Seed Type	Tillage Method	Fertilizer	Management	Code
Maize	Local	Hand	No	High	MZ1
Maize	Hybrid	Hand	Yes	Low	MZ4
Maize	Local	Hand	Yes	High	MZ9
Maize	Local	Ox	No	Low	MZ6
Groundnuts	Local	Hand	No	High	GR1
Groundnuts	Local	Hand	No	Low	GR2
Groundnuts	Improved	Hand	No	Low	GR12
Groundnuts	Local	Ox	No	Low	GR6

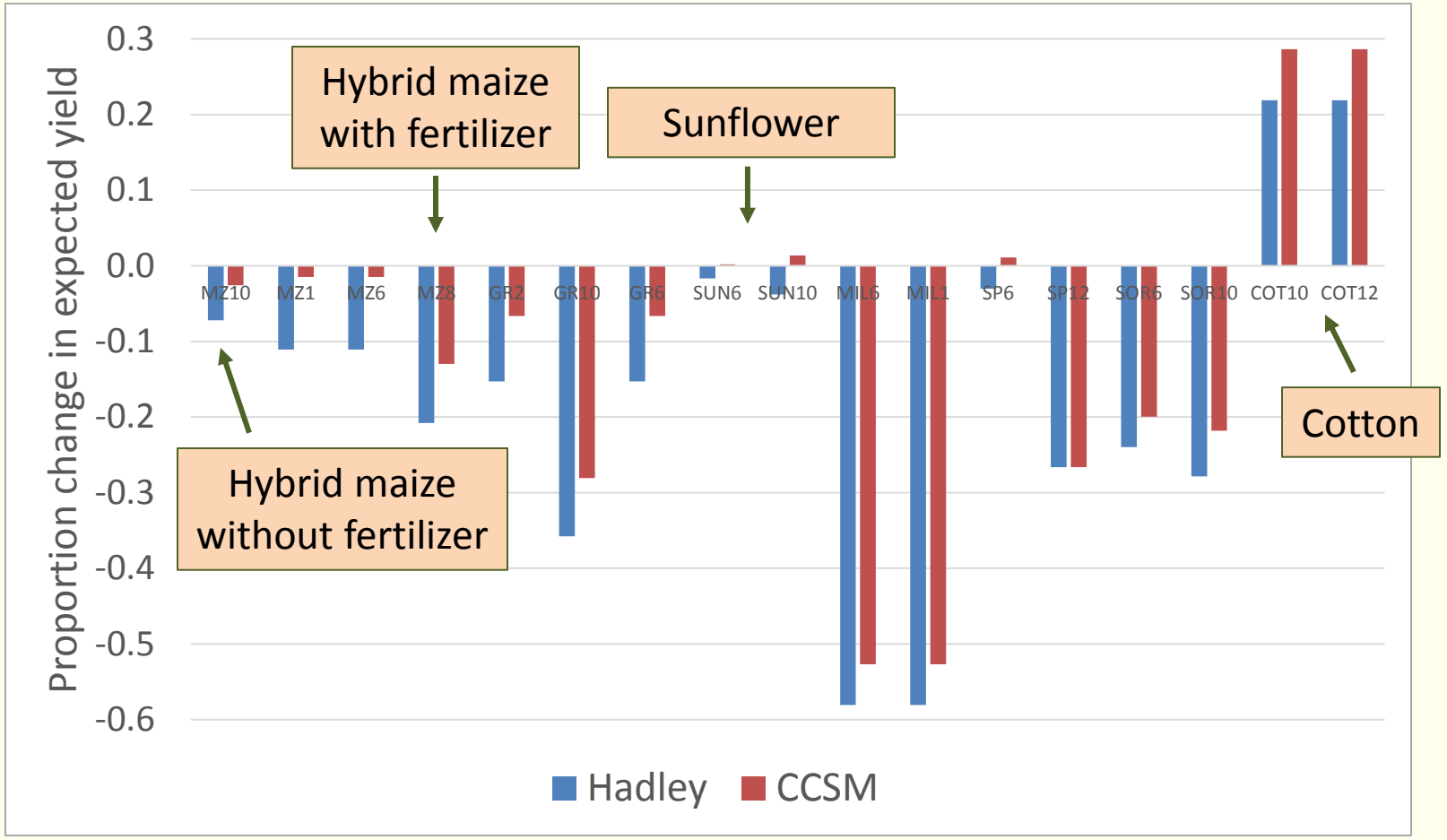
Climate change scenarios

- The Hadley (HadCM3) model (relatively “dry”)
  - Declines in rainfall
  - Somewhat more variable rainfall
  - Increases in temperature
- The CCSM model (relatively “wet”)
  - Increases in rainfall
  - Increases in temperature similar to Hadley model

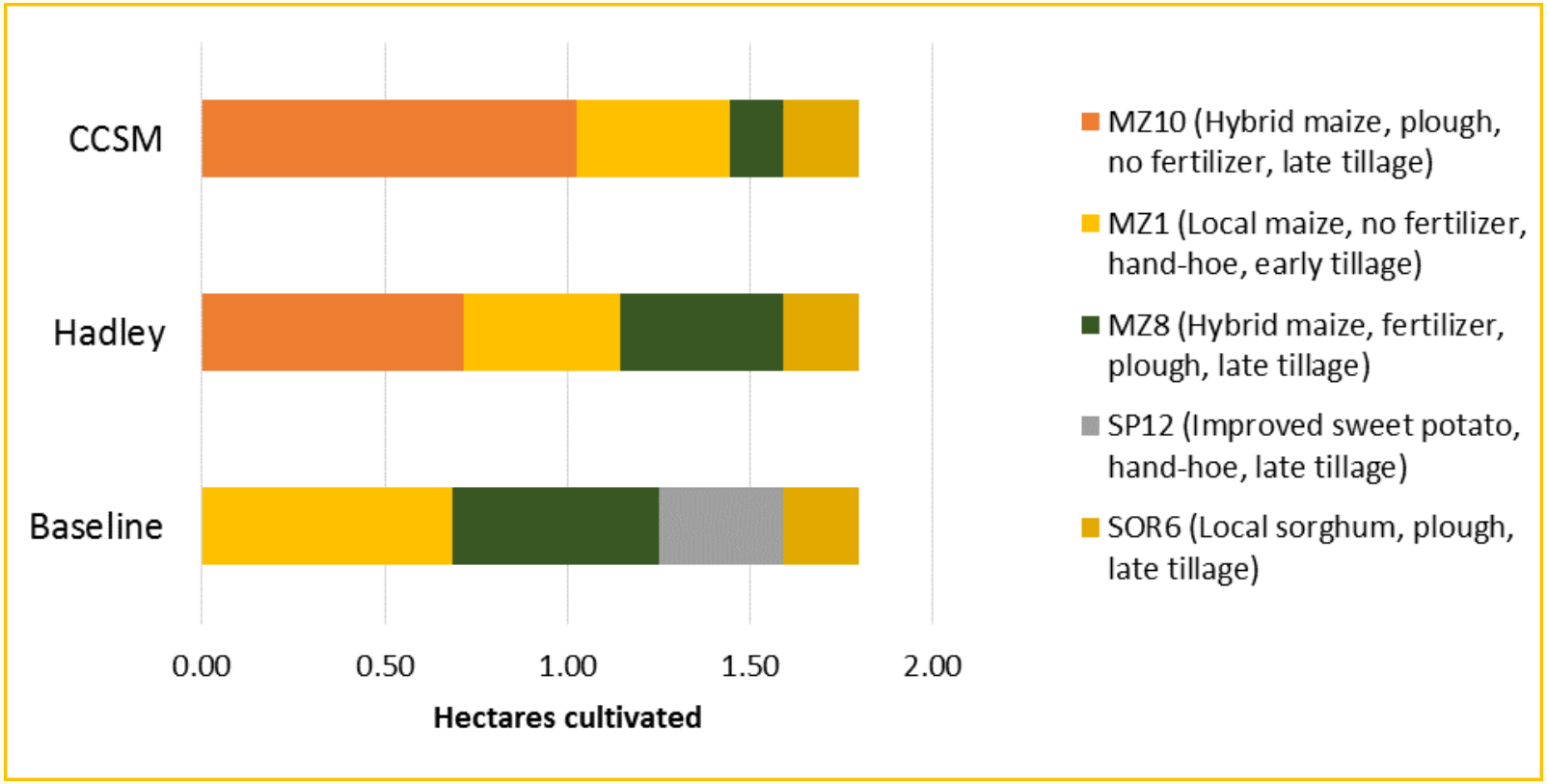
Future yield predictions for Southern Province based on statistical yield analysis



Future yield predictions for Southern Province based on statistical yield analysis



Results
Smallholder in Southern Province

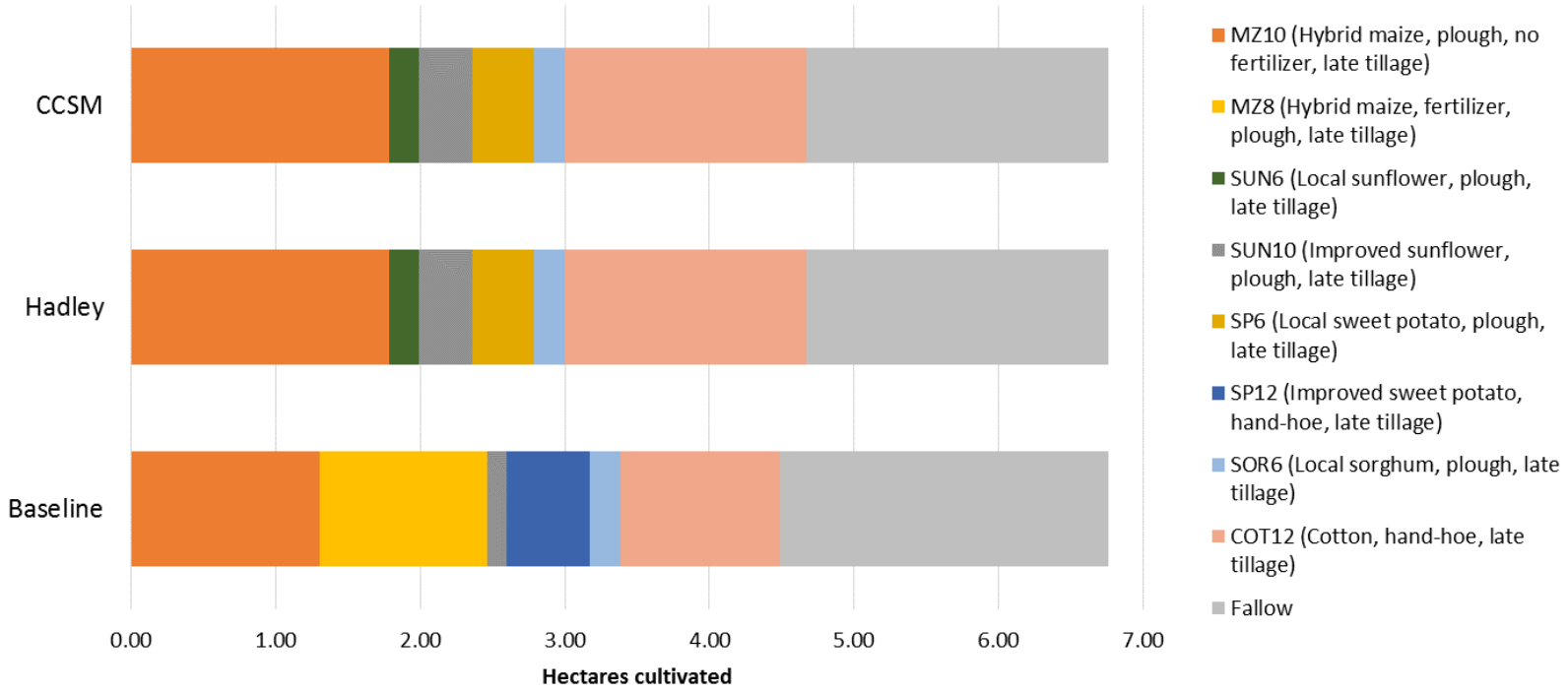


CCSM outcome: 4,155 kcal/AE/day

Hadley outcome: 3,849 kcal/AE/day

Baseline outcome: 4,431 kcal/AE/day

Results
Emergent farmer in Southern Province

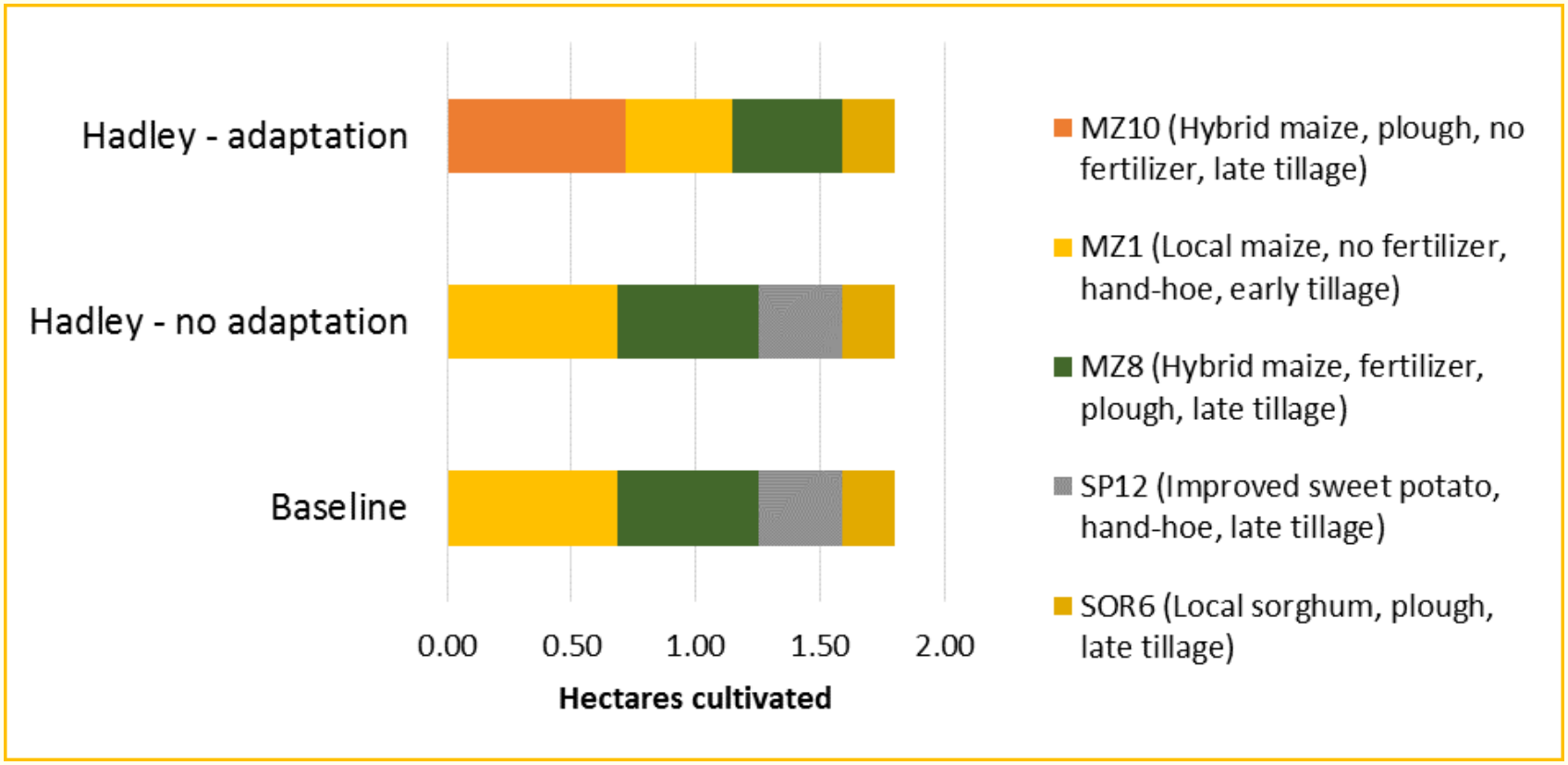


CCSM outcome: 10,965 kcal/AE/day

Hadley outcome: 10,440 kcal/AE/day

Baseline outcome: 11,549 kcal/AE/day

Smallholder results
with and without adaptation

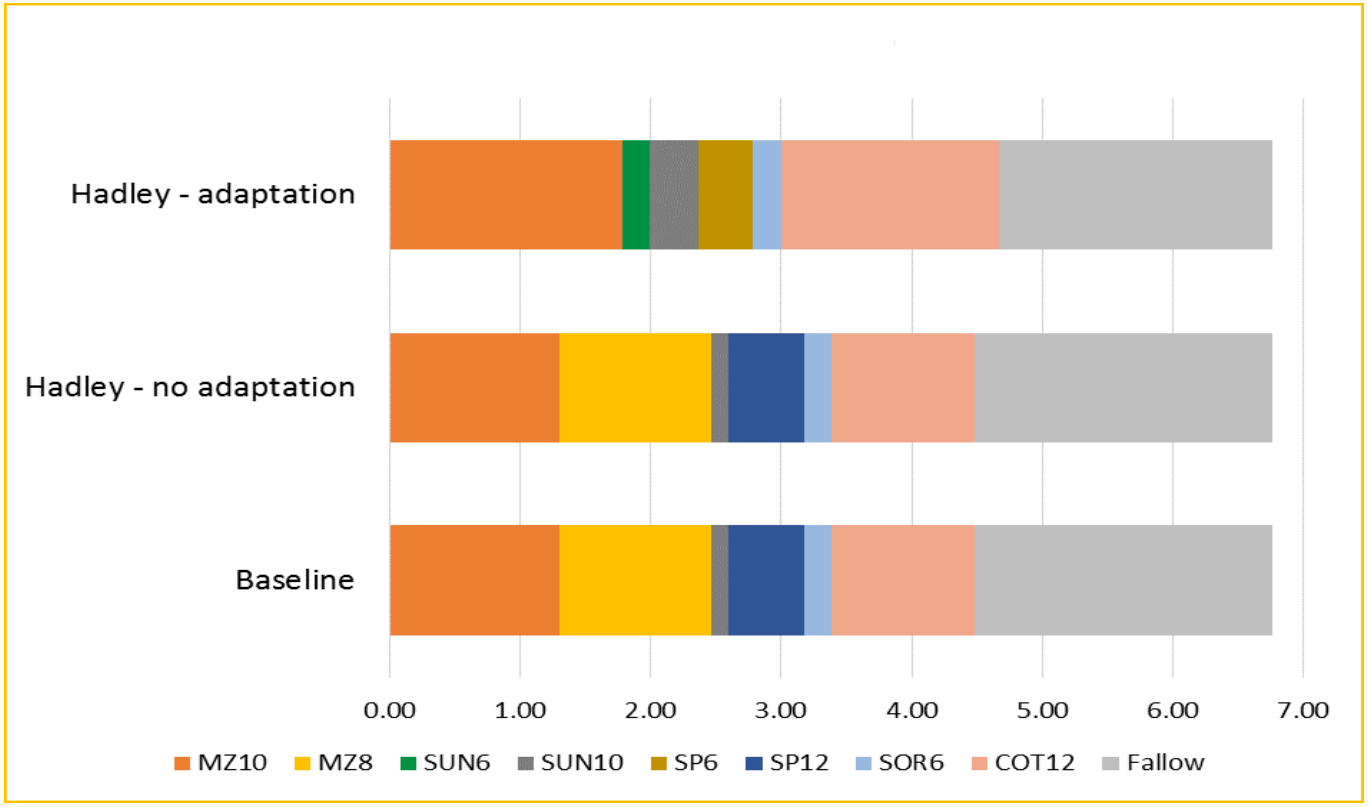


Hadley – with adaptation: 3,849 kcal/AE/day = **-13.15%**

Hadley – no adaptation: 3,656 kcal/AE/day = **-17.49%**

Baseline outcome: 4,431 kcal/AE/day

Emergent farmer results
with and without adaptation



Hadley – with adaptation: 10,440 kcal/AE/day = **-9.60%**

Hadley – no adaptation: 10,135 kcal/AE/day = **-12.25%**

Baseline outcome: 11,549 kcal/AE/day

Main findings and conclusions

- Climate change will generally reduce crop yields.
- In response, model results to date show that farmers will choose different crops (cotton, cassava) and technologies (lower fertilizer).
- This reduces the negative effects of climate change . . . but not by much.
- Of the three household types modeled, smallholder farmers are most vulnerable to obtaining low production outcomes in a bad year.
- Larger-scale adaptation measures are needed (e.g. heat-tolerant seed varieties, agricultural investments & policies to reduce risk for small farmers).

Questions?

Slides for reference

Mathematical structure of model

$$max\ calories = \sum_{j=1}^{n} K_j\, X_j$$

subject to:

- Input requirements for each crop activity
- Resource constraints: $\sum_{j=1}^{m} a_{ij}\, X_j \ \leq \ b_i$

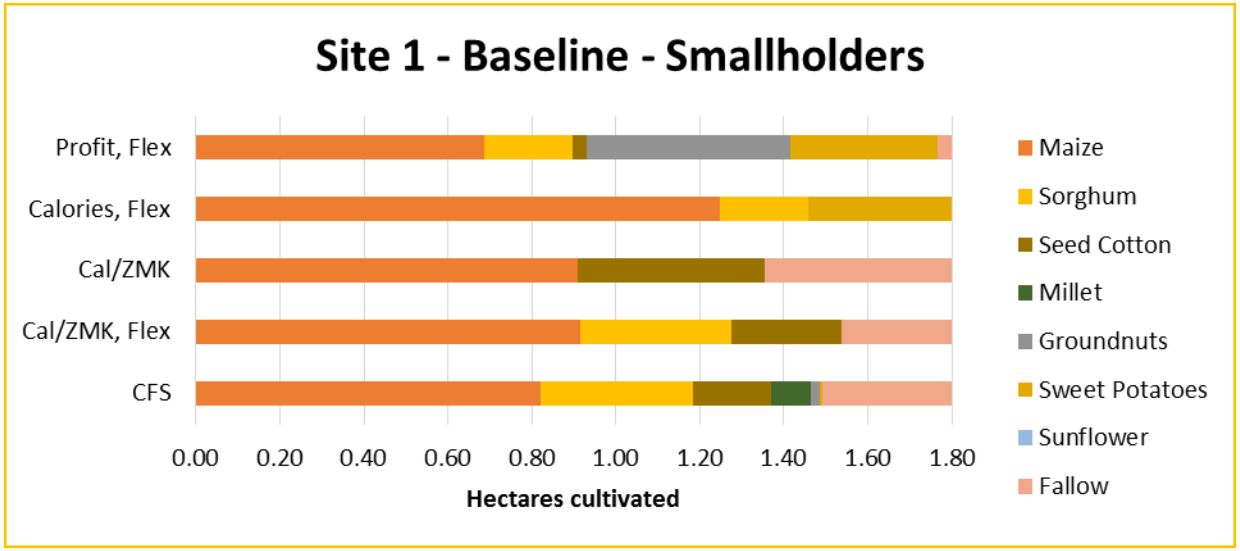
  → For land and biweekly labor
- Budget constraint: $\sum_{j=1}^{n} C_{ij}\, X_j \leq \ \omega$
- Household calorie requirement: $K_j X_j \geq \ \theta$
- Non-negativity constraint: $X_j \ \geq 0$
- Flexibility constraints (sometimes): $K_j X_j \geq \ \varphi$

Model validation

How well do model results reflect observed farmer practices?

42.42% of land diverted from observed crop patterns

9.43% diverted



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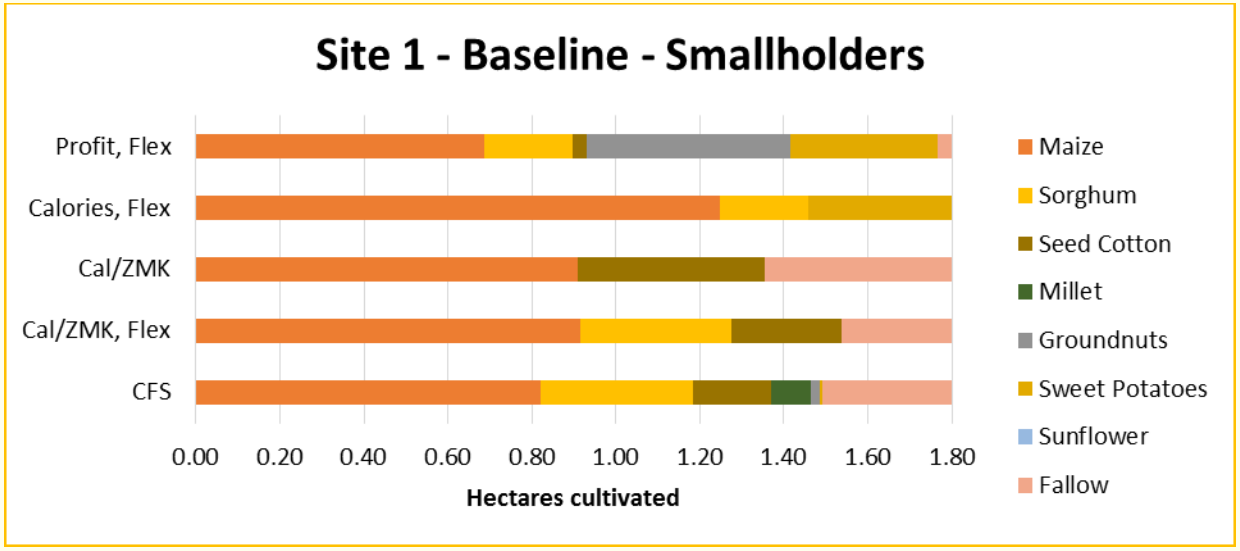
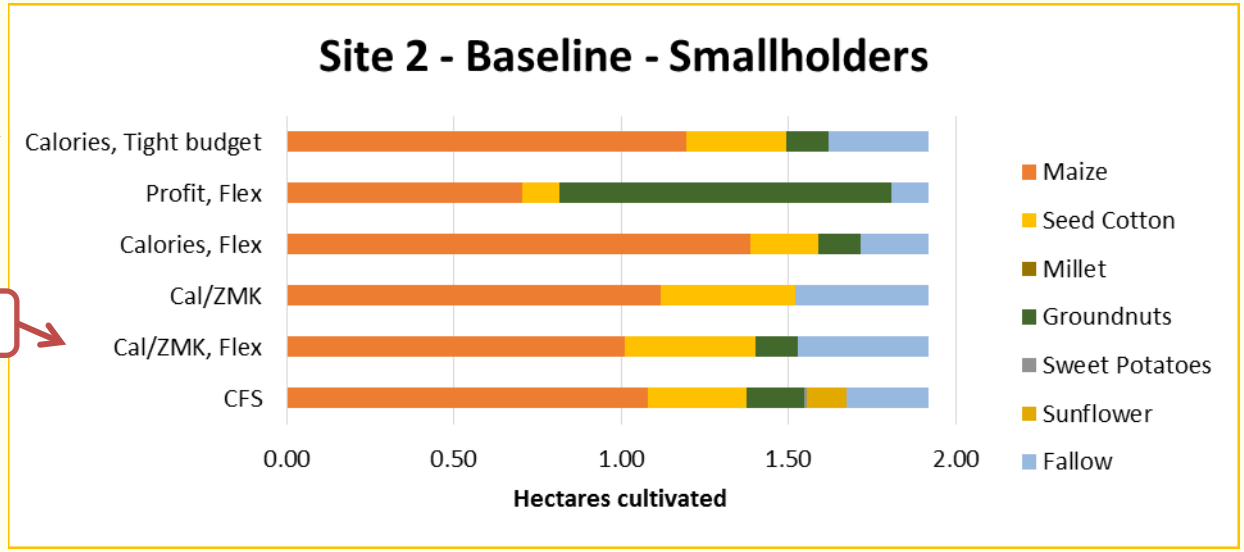


9.01% diverted

9.37% diverted

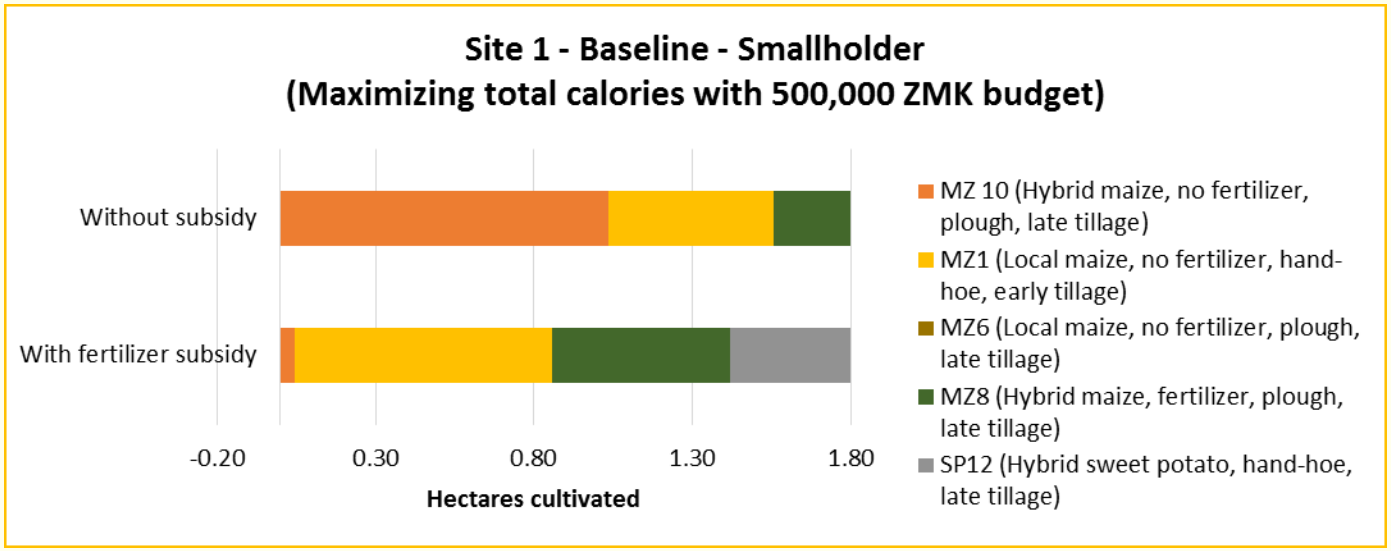


With/ without a fertilizer subsidy

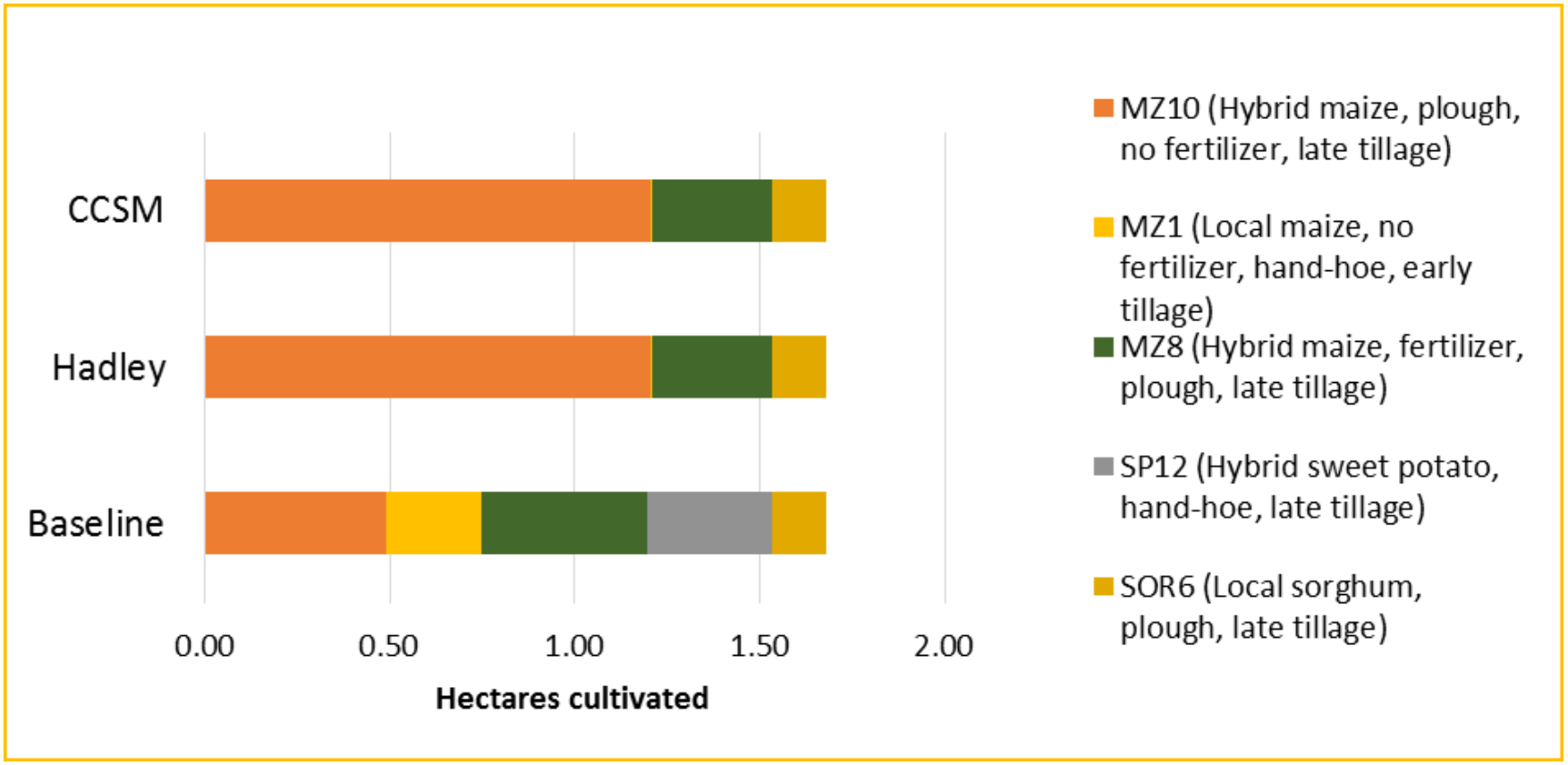
		Median fertilizer cost (per kg), including transport	
		FISP + commercial	Commercial only
Site 1	Basal	1,997	3,452
	Top	2,064	3,549
Site 2	Basal	2,775	3,523
	Top	2,919	3,572
Site 3	Basal	2,193	3,847
	Top	2,193	3,700

4,652 kcal/AE/day

4,770



Results
Female-headed household in Southern Province



CCSM outcome: 5,379 kcal/AE/day

Hadley outcome: 5,072 kcal/AE/day

Baseline outcome: 5,714 kcal/AE/day