Global Yield Gap Atlas

Impact of root zone depth on yield gap estimates and uncertainties in SSA

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Outline

- Why does soil depth matter?
- A sensitivity analysis based on the Global Yield Gap and Water Productivity Atlas framework
- Effect of soil depth on maize yields and total production in SSA
- Importance of good soil data for reliable food security studies

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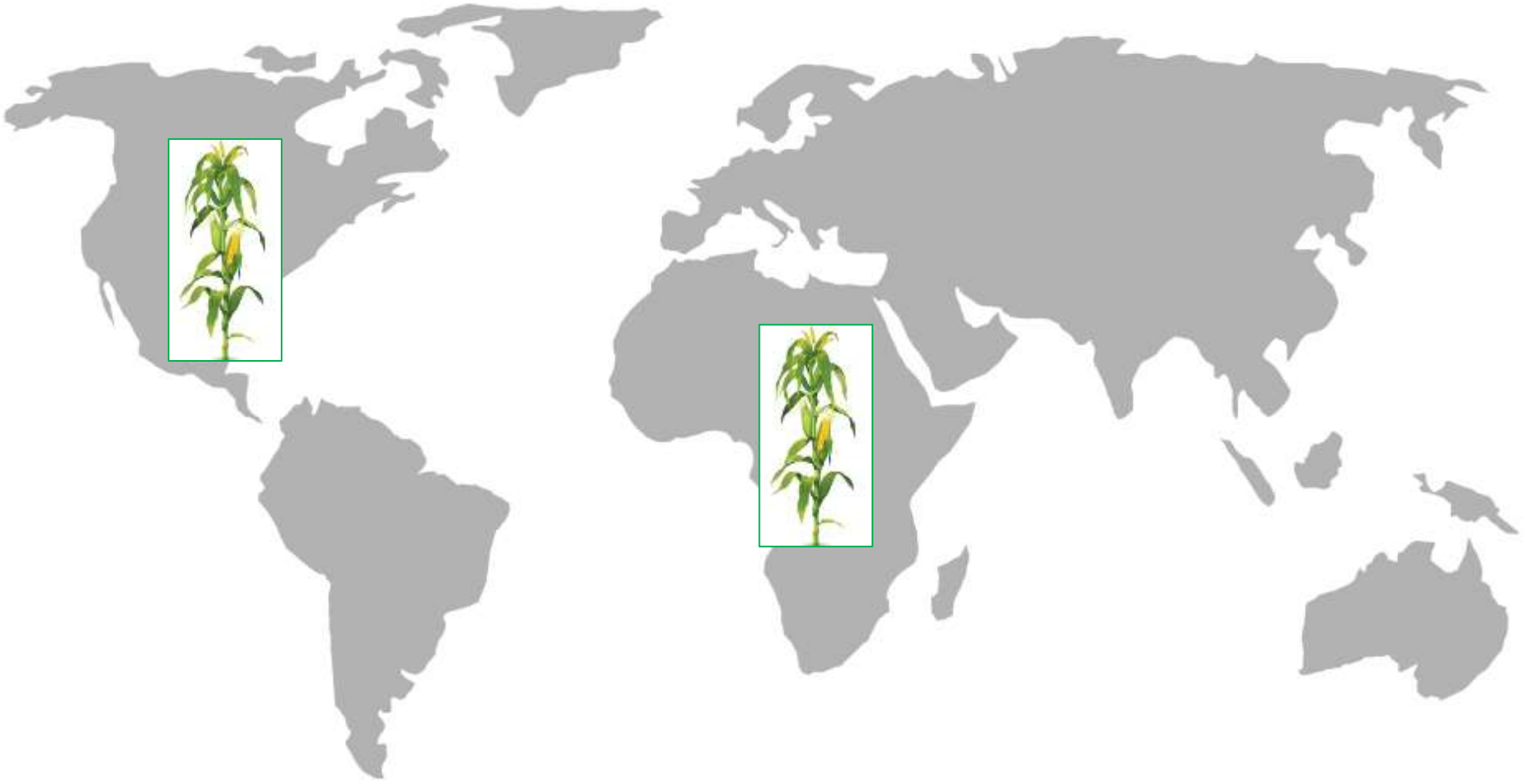
The US Corn Belt and (the Guinea Savannah zone in) Sub-Saharan Africa: two rainfed crop production bread baskets?



World Bank 2009. Awakening Africa's sleeping giant.
Grassini et al. 2014. High-yield maize–soybean cropping systems in the US Corn Belt.
Leenaars et al. 2015. Root Zone Plant-Available Water Holding Capacity of SSA soils. ISRIC Report.

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Why does soil depth matter?

Variable	Unit	US Corn Belt	Nigeria
Ya	t ha^{-1}	9.7	1.6
Yw	t ha^{-1}	13.2	10.6
Yg	t ha^{-1}	3.5	9.0
Rainfall	mm	600 – 1000	700 – 1100
Soil depth	cm	> 150	≈100
PAWHC*	mm	200-300	≈80

*** Plant-available water holding capacity in the root zone**

World Bank 2009. Awakening Africa's sleeping giant.
Van Wart et al., 2013. Estimating crop yield potential at national scale. Field Crops Res 143:34-43.
Leenaars et al. 2015. Root Zone Plant-Available Water Holding Capacity of SSA soils. ISRIC Report.

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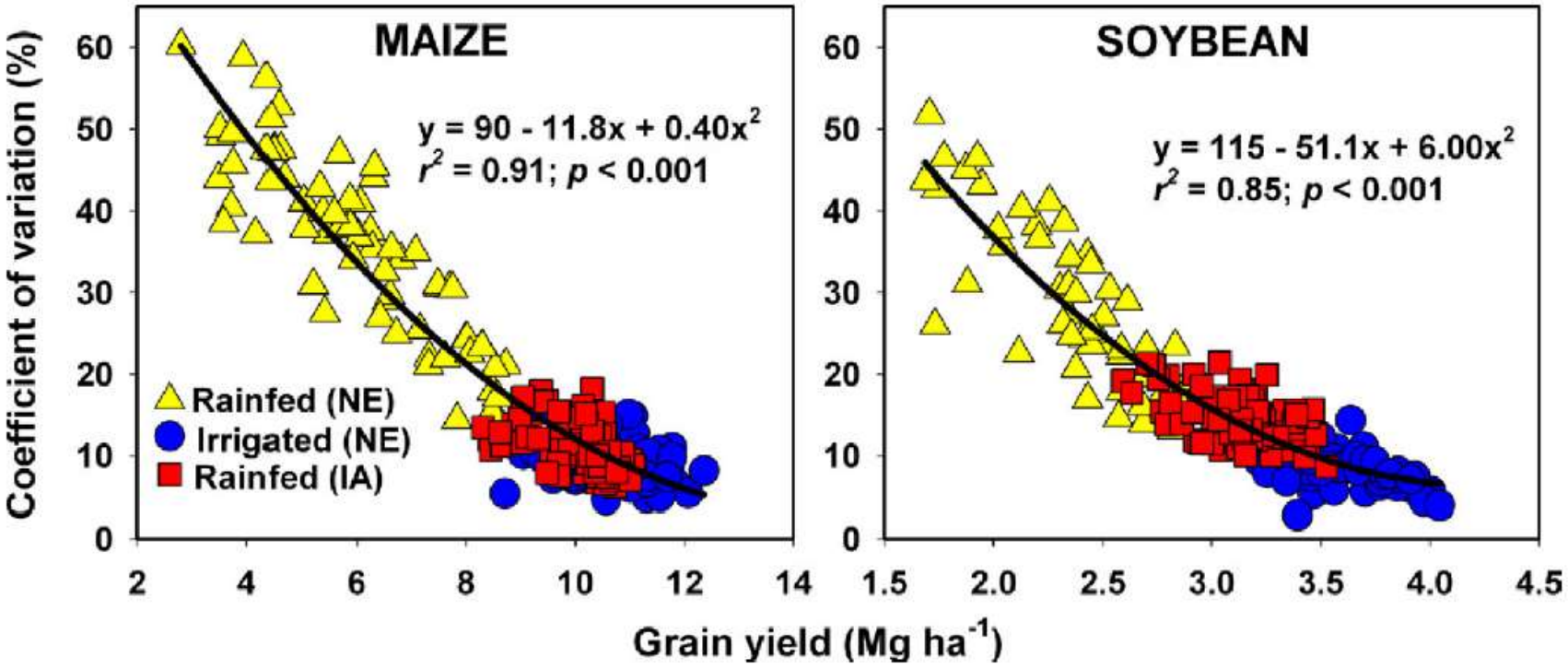
In the US Corn Belt, rainfed yield variability decreases in regions with higher average yield

County data from Iowa (reliable rainfall) and Nebraska (less and variable rainfall, irrigation)



Grassini et al., 2014. In *Crop Physiology,* Oxford Academic Press, pp 15-42.

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What determines plant-available water holding capacity? (RZ-PAWHC)

- Soil depth to which roots are able to grow ('rootable soil depth')
  - Determined by depth to bedrock, laterite, or poor drainage layer (high bulk density), or by chemical soil constraints such as acidity, alkalinity, or salinity.
- Soil properties that influence plant-available water holding capacity
  - Texture, mineralogy, organic matter content
- RZ-PAWHC is the product of rootable soil depth and volumetric PAWHC

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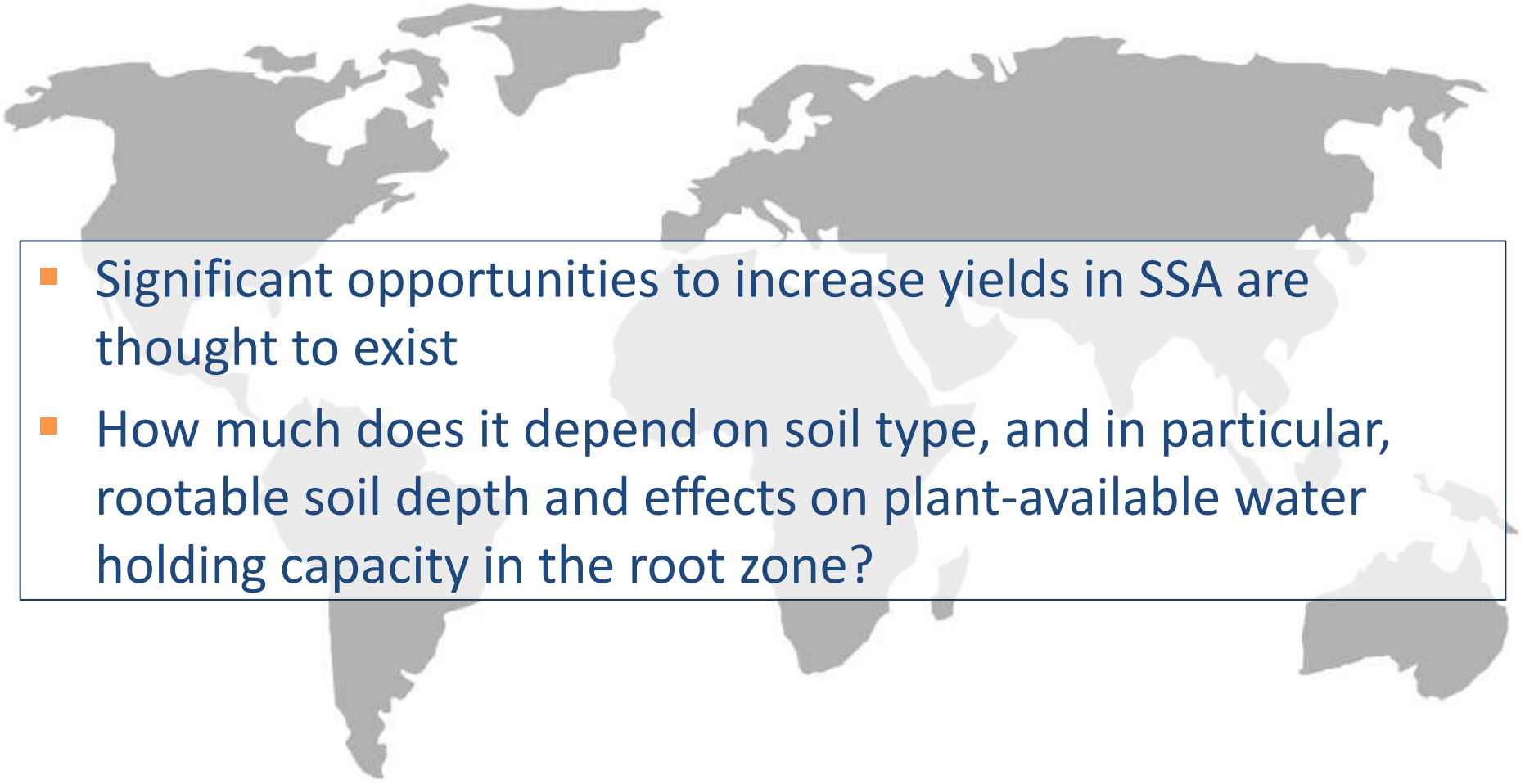
Question



- Significant opportunities to increase yields in SSA are thought to exist
- How much does it depend on soil type, and in particular, rootable soil depth and effects on plant-available water holding capacity in the root zone?

Foley et al., 2011; Mueller et al., 2013

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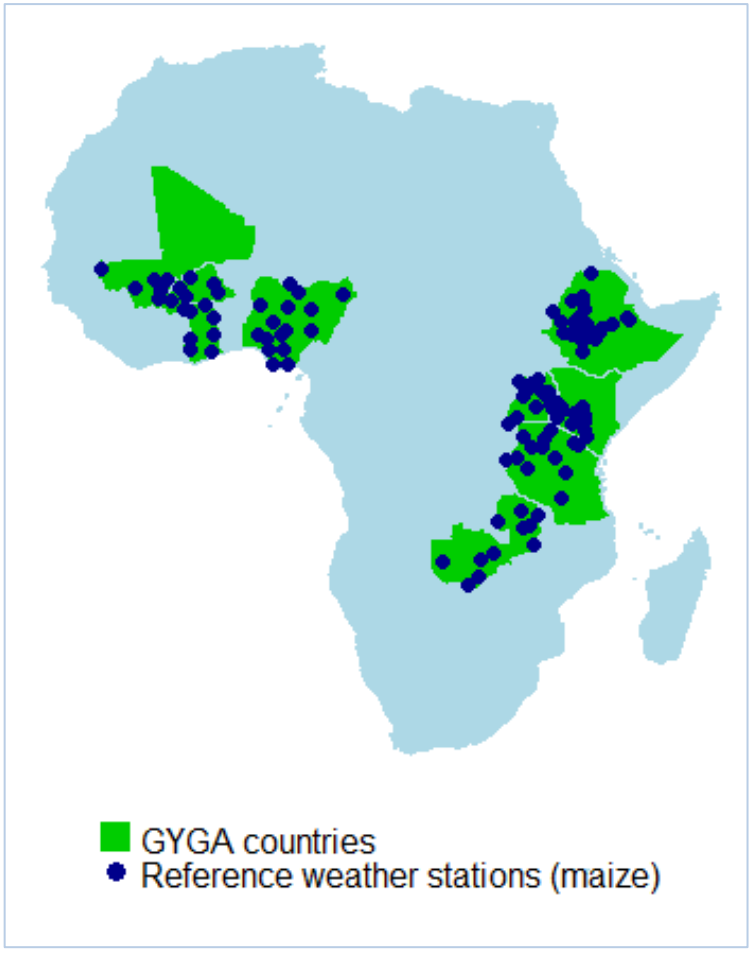
A sensitivity analysis based on the Global Yield Gap and Water Productivity Atlas framework



Simulation

- **Model**: Hybrid Maize
- **Locations**: 110 weather stations
- **Coverage**: 70 % of 13 Mha of maize are within the climate zones where the RWS are located
- **Water-limited (Yw)**: 4 rootable soil depths (50, 75, 100, 150 cm)

Upscaling via GYGA protocols:

- RWS
- Climate zone
- Country
- Region (9 SSA countries)

Yang et al. 2004. Hybrid Maize – a simulation model. **Grassini et al. 2015.** How good is good enough? **Van Bussel et al. 2015.** From field to Atlas.

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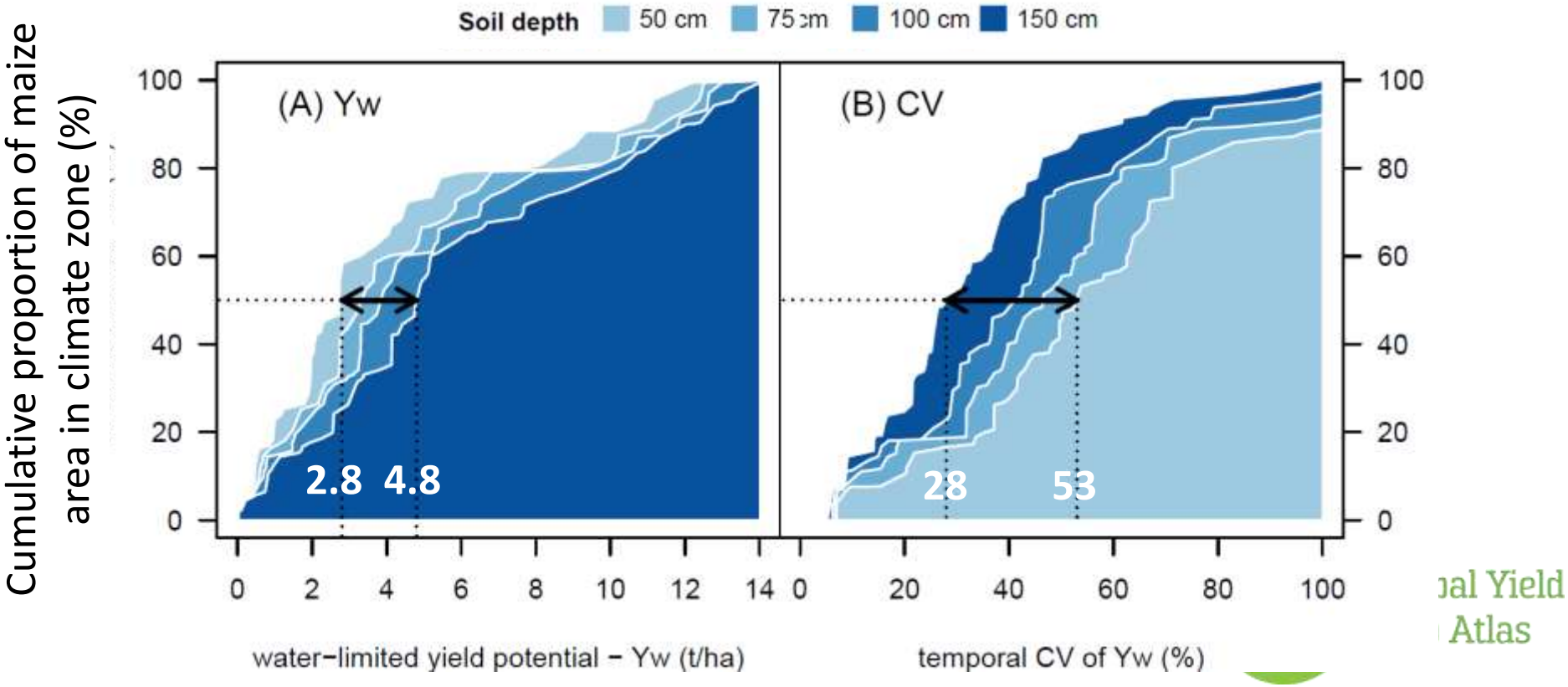
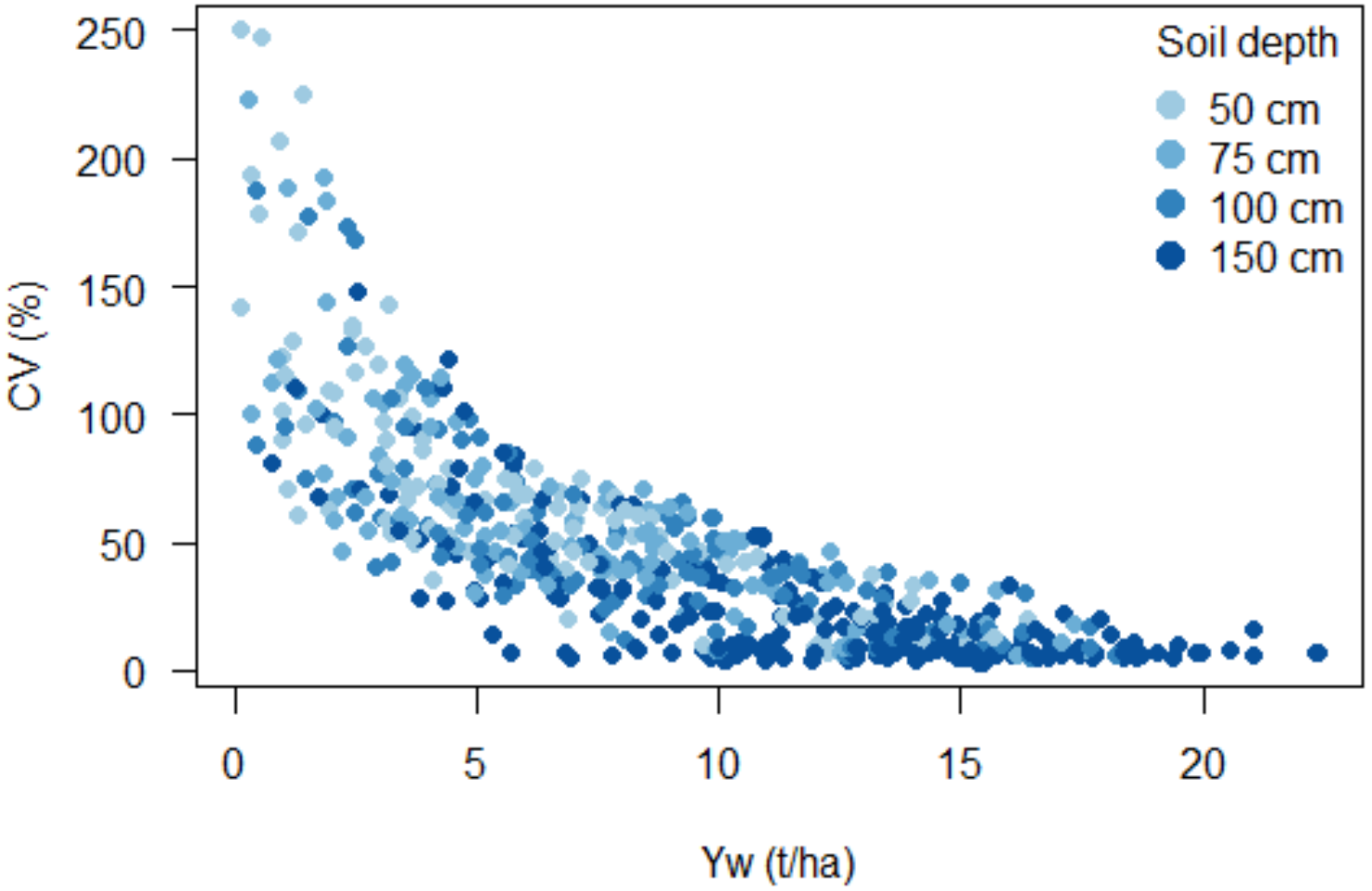
Effect of soil depth on Yw and its CV

	Soil depth (cm)	50	75	100	150
All 9 countries	**Yw (t ha^{-1})**	5.6	6.7	7.3	8.4
	CV (%)	7	5	4	3



In the SSA rainfed maize yield variability decreases in regions with higher average yield



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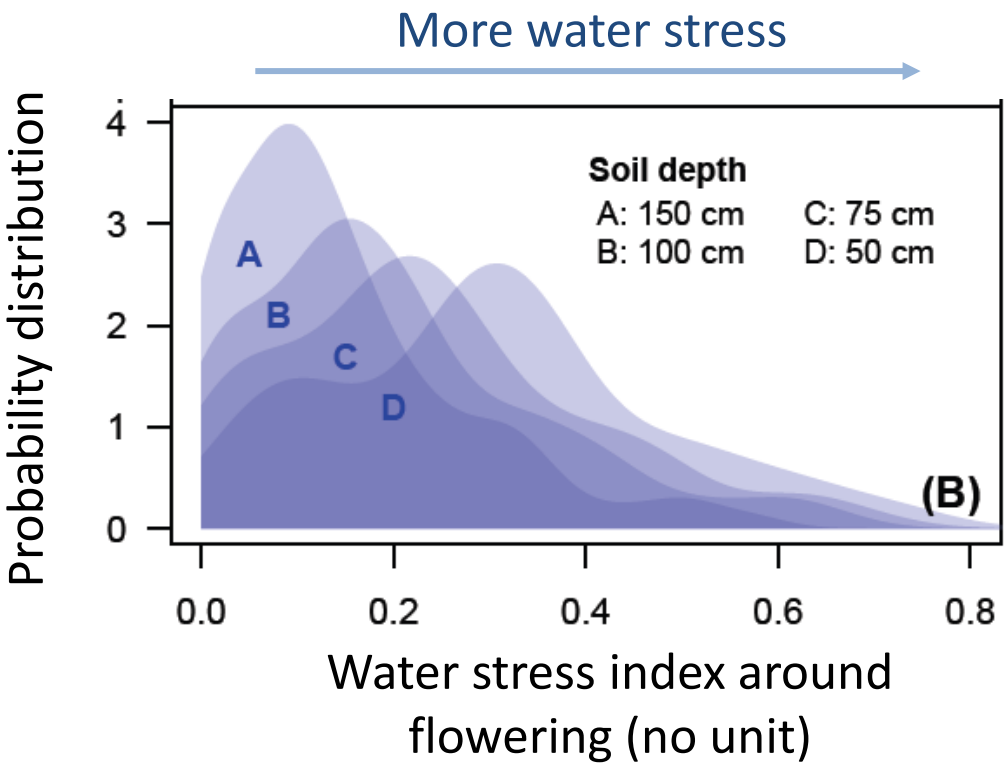
Soil depth affects water stress at key stages for yield formation



- water stress around flowering (silking) increases when soil depth decreases
- Kernel number is determined during flowering

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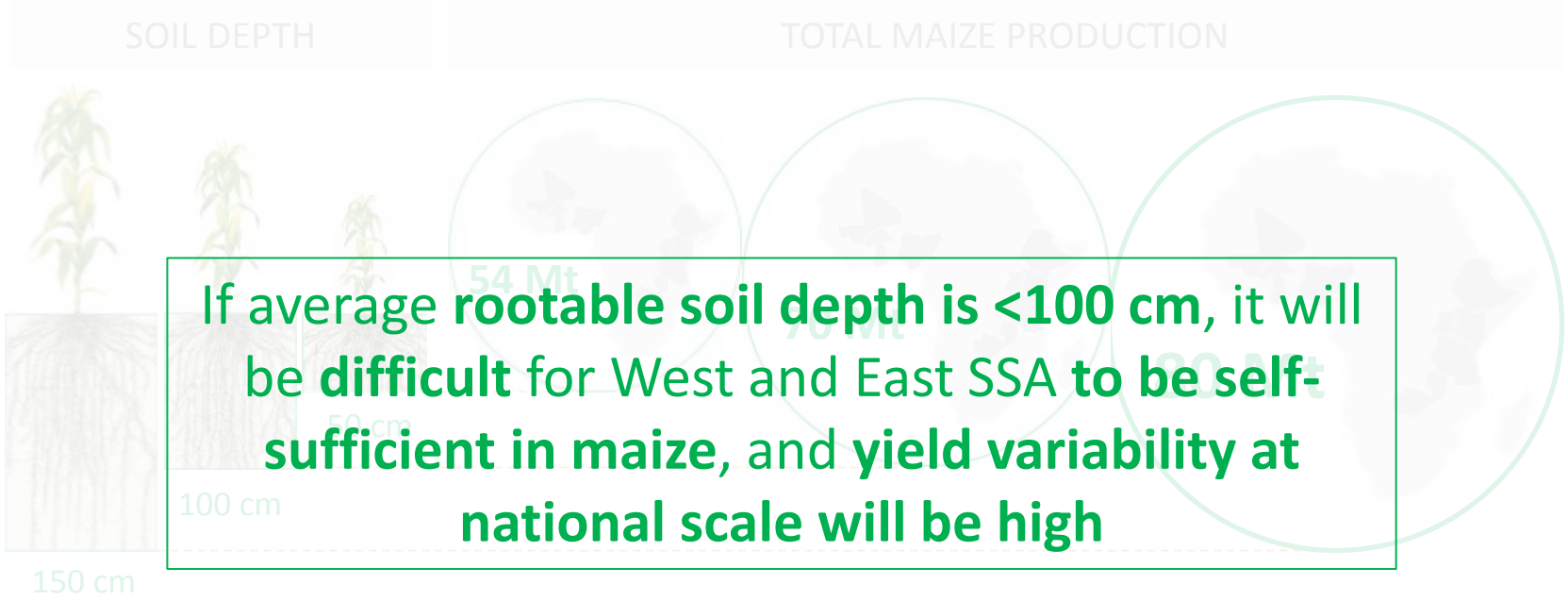
Effect of soil depth on potential water-limited production
(based on average yields equal to 80% of Yw)



If average **rootable soil depth is <100 cm**, it will be **difficult** for West and East SSA **to be self-sufficient in maize**, and **yield variability at national scale will be high**

Projection of total demand of maize by the IMPACT model for the 9 GYGA countries

2010	2030	2050
24 Mt	41 Mt	62 Mt

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Conclusions

Soil depth and maize yields

- A shallower soil decreases the **water-limited yield potential**, which can be **reduced by 35%** (8 to 5.2 t ha^{-1}) if soil depth drops from 150 cm to 50 cm
- A shallower soil **increases** the inter-annual **variability** of rainfed yields
- This is mainly due **to more frequent and more severe water stress episodes** during key stages for yield formation

Implications for food security

- The total (water-limited) **production of maize** may be **decreased by 30%** over the 9 countries if soil depth drops from 150 cm to 50 cm.
- If average rootable soil depth is **<100 cm**, it will be **difficult** for West and Eastern SSA to be **self-sufficient** in maize, and **yield variability** at national scale will be **high**

Good soil data are crucial to evaluate local to global food security scenarios involving rainfed systems

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Thanks for your attention!

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