Sustainable Intensification and Resilient Dryland Cropping Systems: Opportunities in Sub-Saharan Africa

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Presentation: Outline

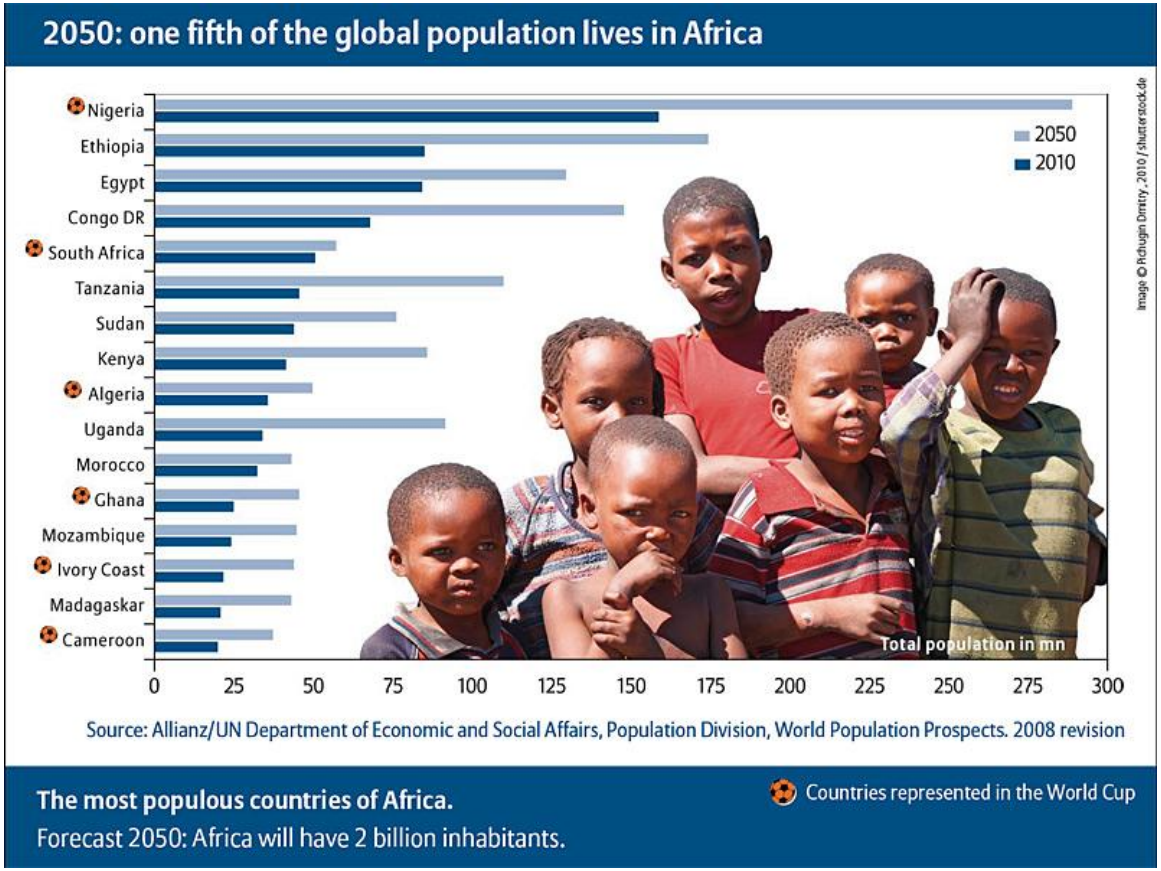
1. Sustainable Intensification and Resilient Cropping Systems

2. Challenges and Opportunities: Potential and Actual Yields

3. Case Study – Results – SANREM, INTSORMIL, Africa RISING, SARI, Literature
   Focus on Ghana: Maize, Sorghum, and Soybean.

4. Conclusions and Discussion

Population Growth: Africa



✓Population in most sub-Saharan African countries will almost double by 2050.

✓To meet increasing world population we have increase productivity of grain crops by about 50%.

Medium Growth Scenario: World = 9.5 billion people by 2050

Africa = 2.2 billion people by 2050.

Africa: Future Climate Change

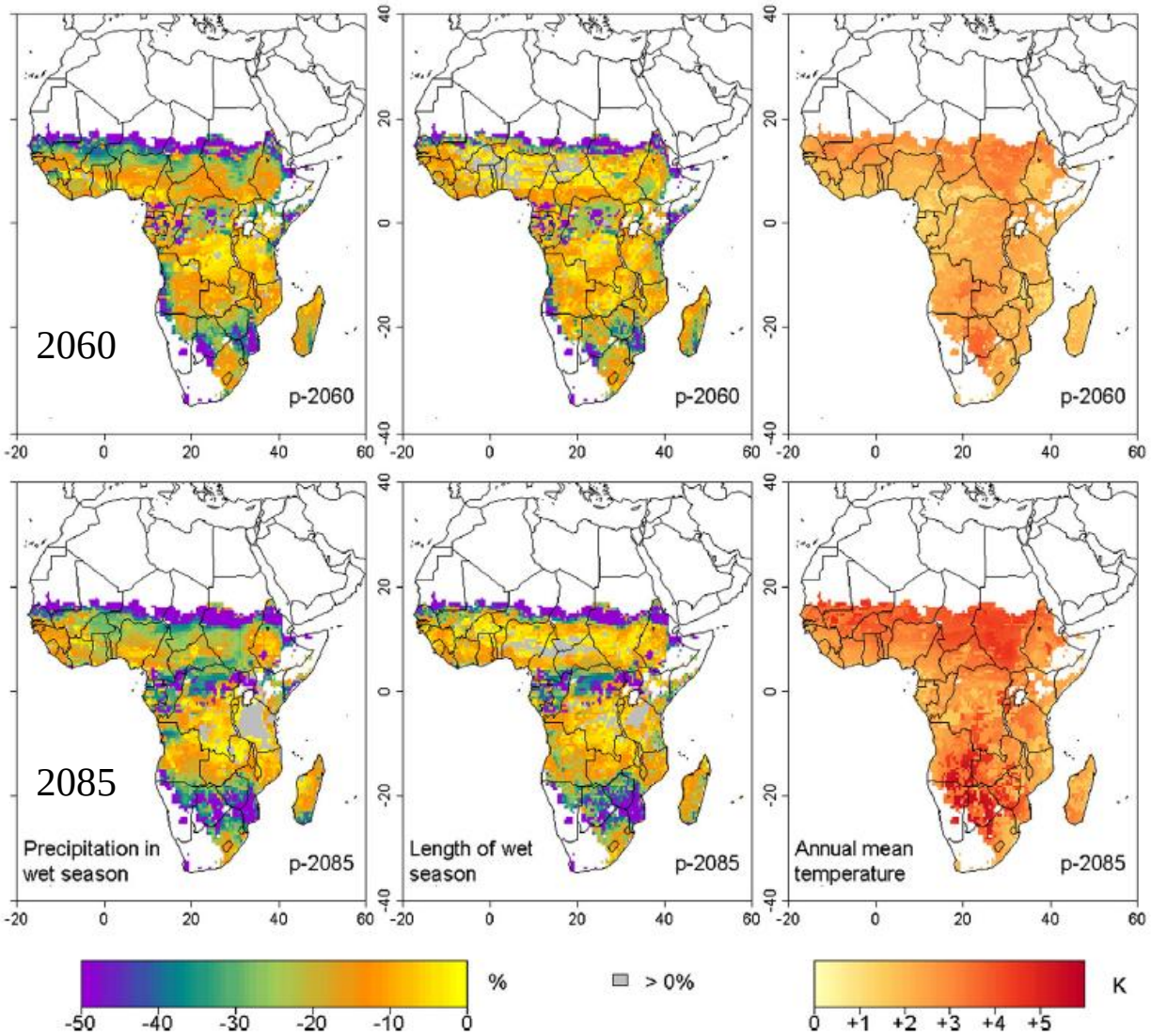


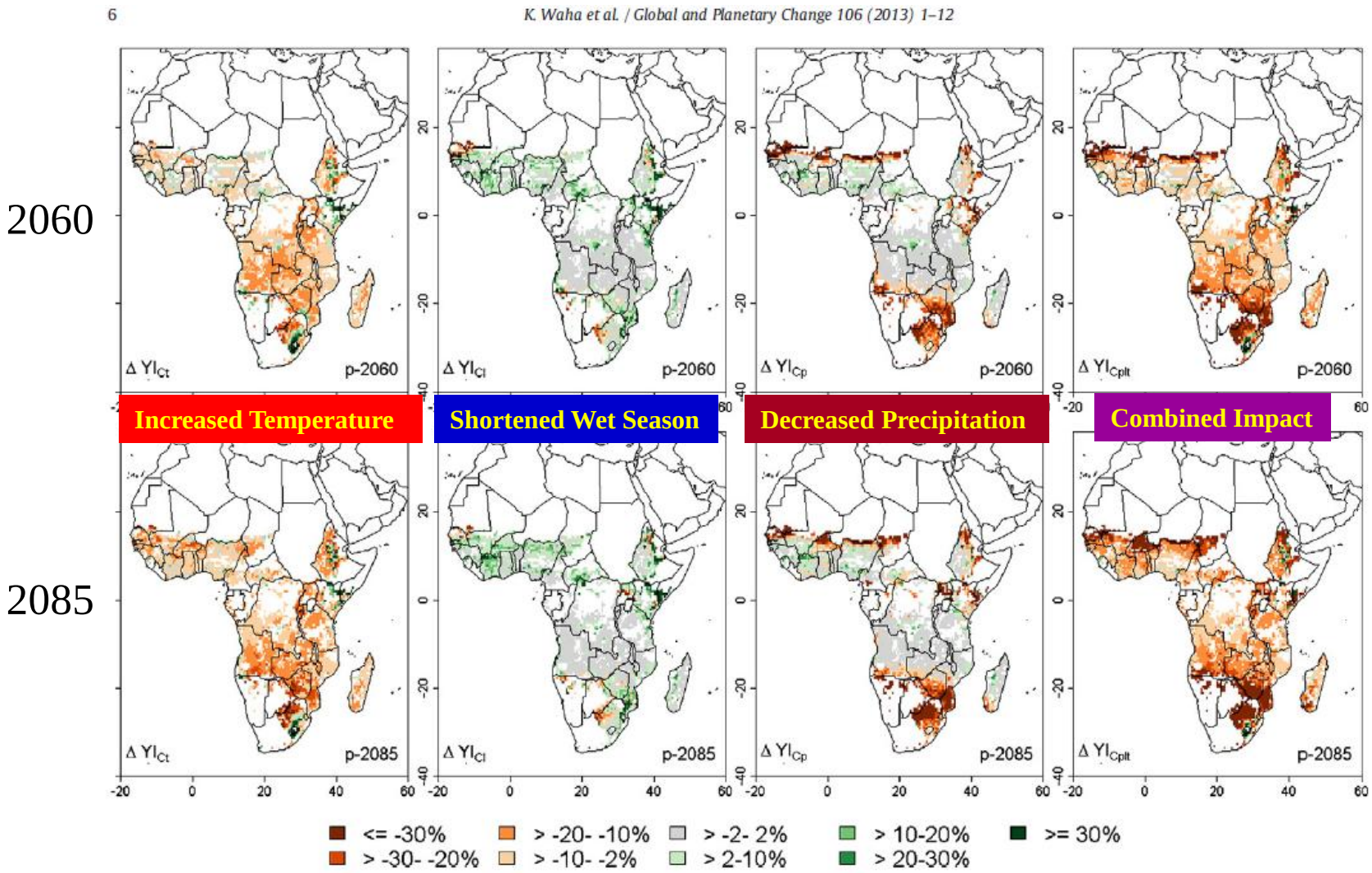
Fig. 3. Change in important agroclimatic variables according to GCM projections in p-2060 (top) and p-2085 (bottom) compared to b-1995 (from left to right): wet season precipitation, wet season length and annual mean temperature. The largest changes in the length and precipitation amount of the wet season per grid cell after removing the outliers and the corresponding temperatures are shown. Dark violet colors in the leftmost and middle panel indicate a reduction of 50% or more. White areas are regions with a bimodal rainfall regime (eastern Africa) or desert areas (southern Africa) where no main wet season could be identified.

Future Scenarios:

In SSA:

- ✓ **Decrease in wet season precipitation.**
- ✓ **Decrease in length of wet season.**
- ✓ **Increased annual mean temperatures.**

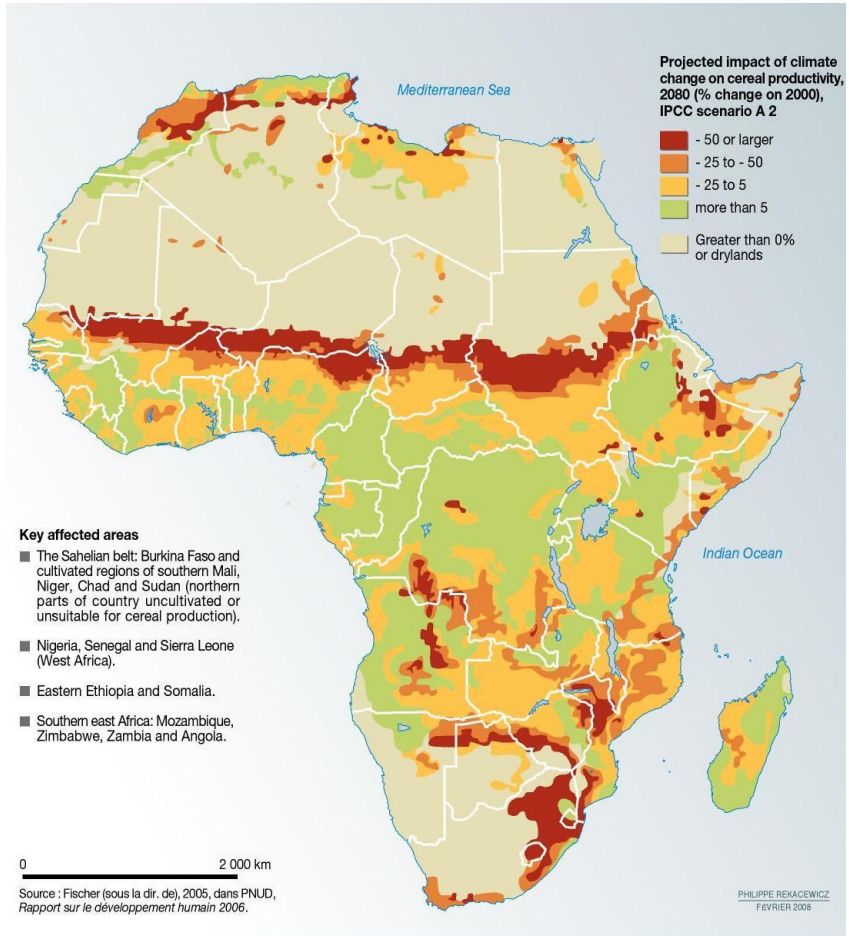
Africa: Climate Change – Maize Yields

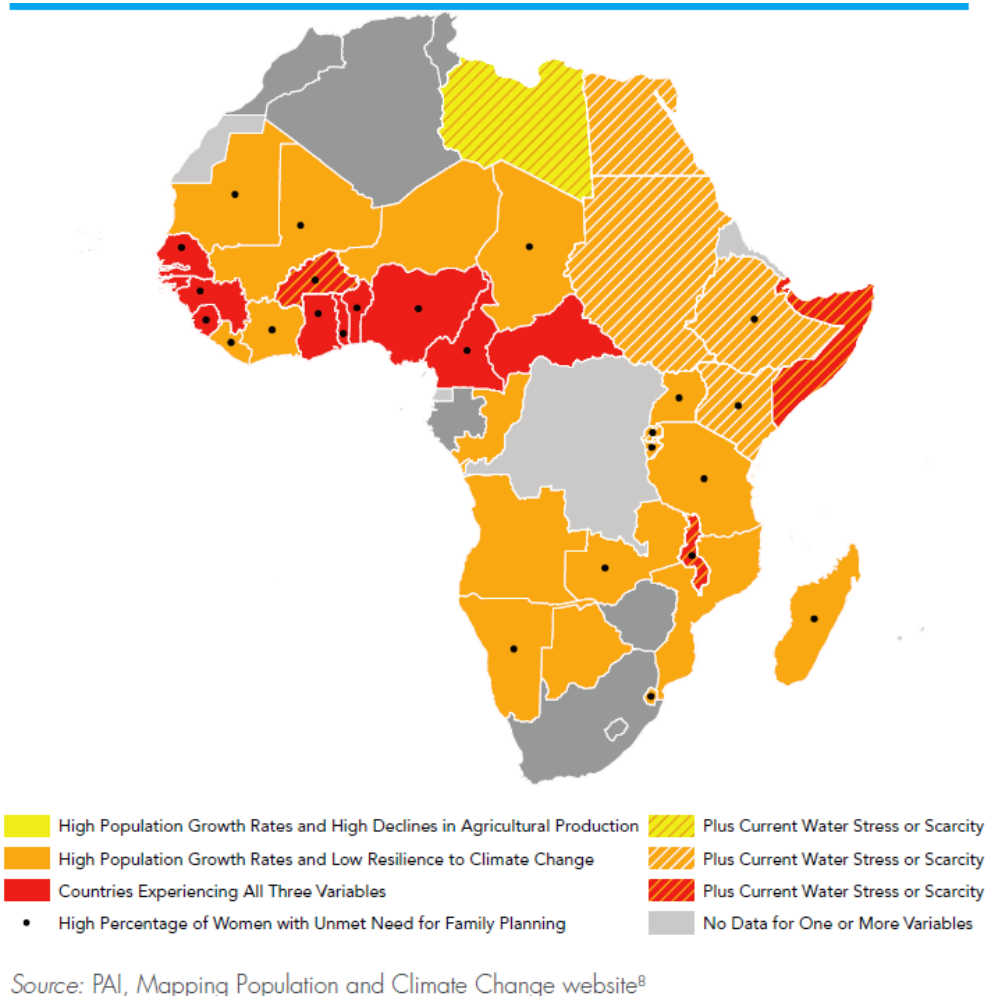


Maize and other grains yield will decrease (> 30%) unless climate smart resilient technologies are adopted.

Crop Yield, Population and Climate Change Hotspots

Cereal productivity in Sub-Saharan Africa under a scenario of the IPCC that shows CO_2 atmospheric concentrations a level at 520-640 ppm by 2050



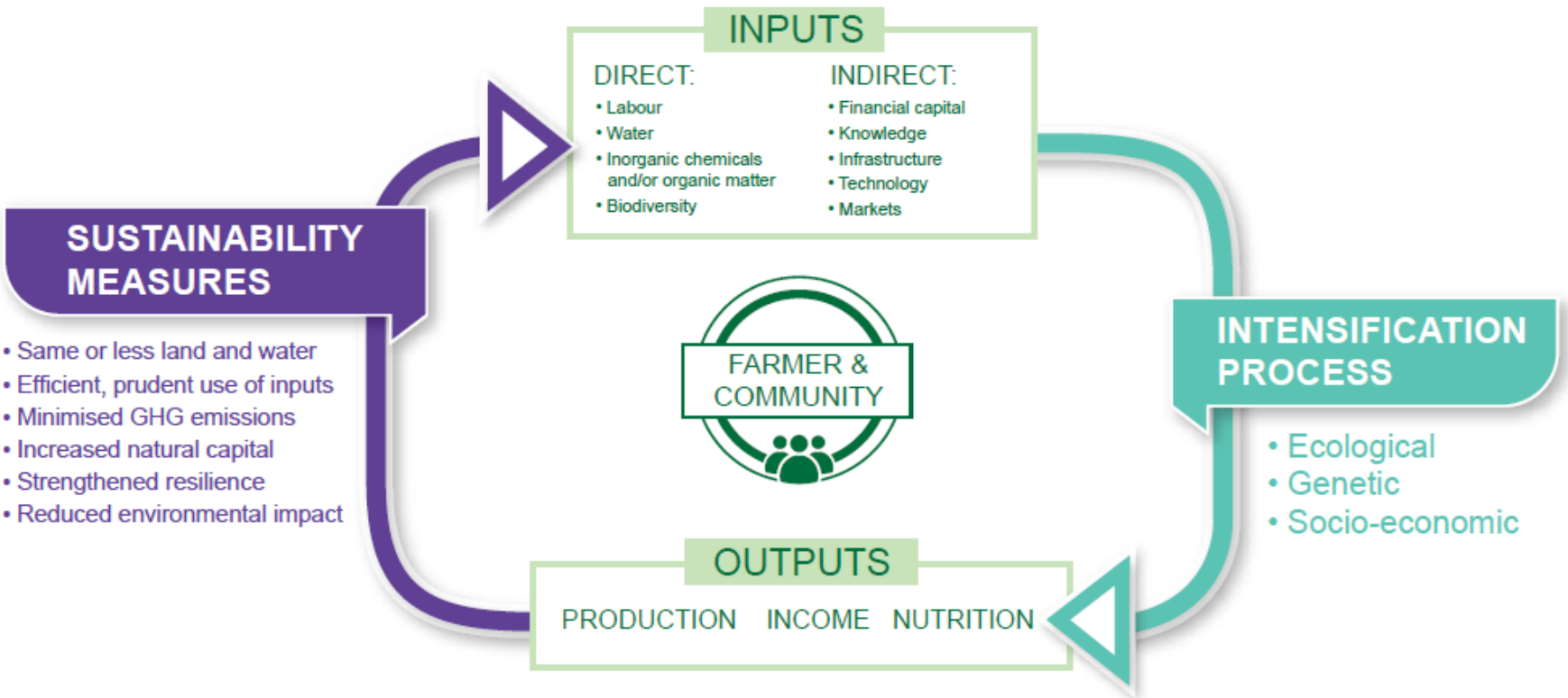


Source: PAI, Mapping Population and Climate Change website[8]

Cereals grain yield will decreases, and SSA will be the hotspot region when all population increase and climate change are combined together.

Sustainable Intensified Resilient Systems

Sustainable Intensification: Frame Work



Production	Income	Nutrition
Definition *Total amount or yields of food per unit input*	**Definition** *Amount of net income generated per unit input*	**Definition** *Human consumption of nutrients per unit input*

The Montpellier Panel 2013. Sustainable Intensification: New Paradigm for African Agriculture. London: Agriculture for Impact.

Sustainable Intensification will help improve productivity and resilience of small holding farmers.

Sustainable Intensification: Components

Socio-Economic Intensification
- Enabling environments
- Developing markets
- Building social capital
- Creating sustainable livelihoods

Ecological Intensification
- Cropping (Farming) systems
- Efficient use of inputs
- Integrated pest management
- Integrated nutrient management
- Effective agricultural practices

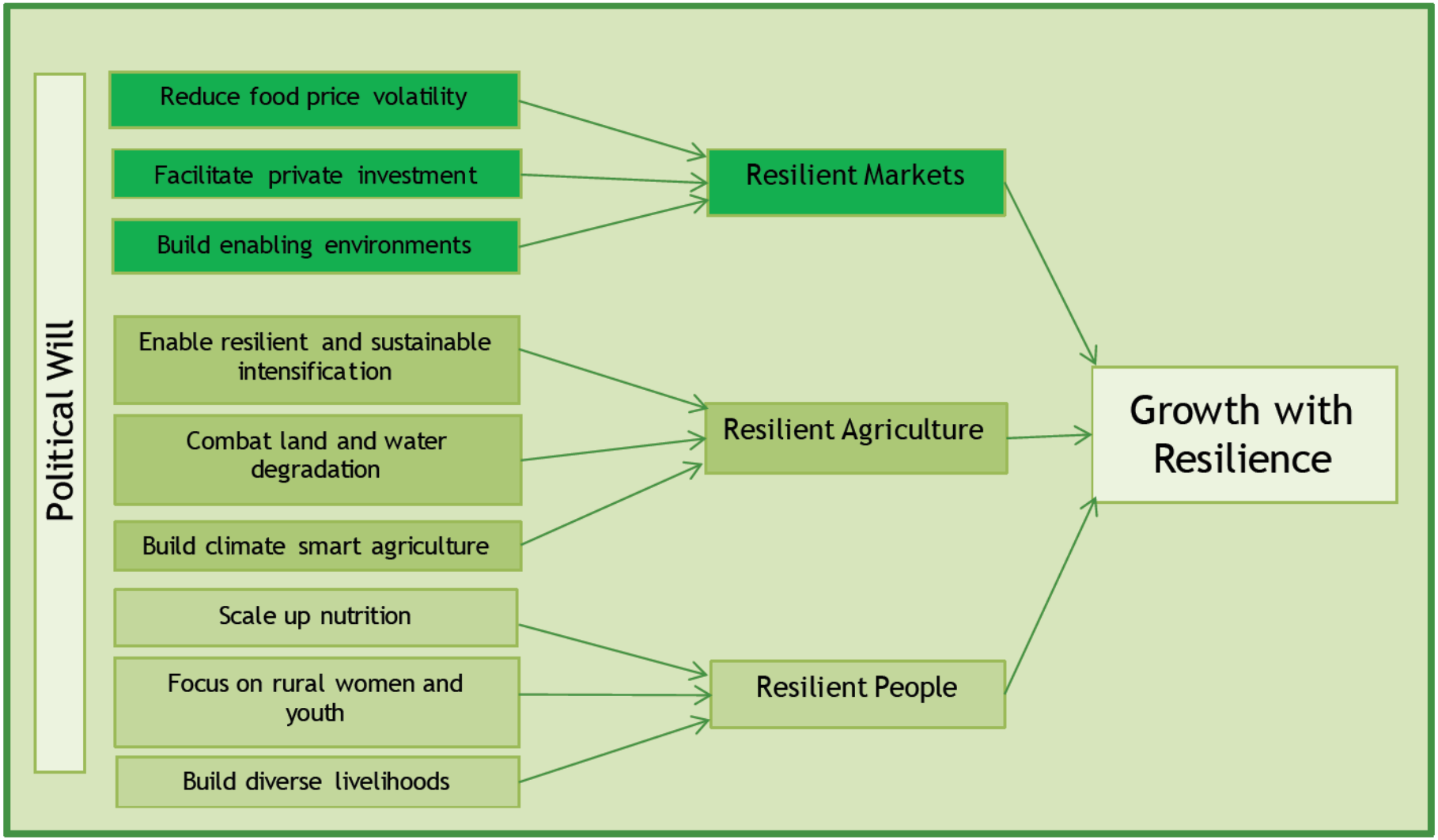
Genetic Intensification
- Higher yield
- Improving nutrition
- Resilient to pest and diseases
- Resilient to climate change
- Diversified cropping systems

The Montpellier Panel 2013. Growth with Resilience: Opportunities for African Agriculture. London: Agriculture for Impact.

Creating Sustainable and Resilient Livelihoods

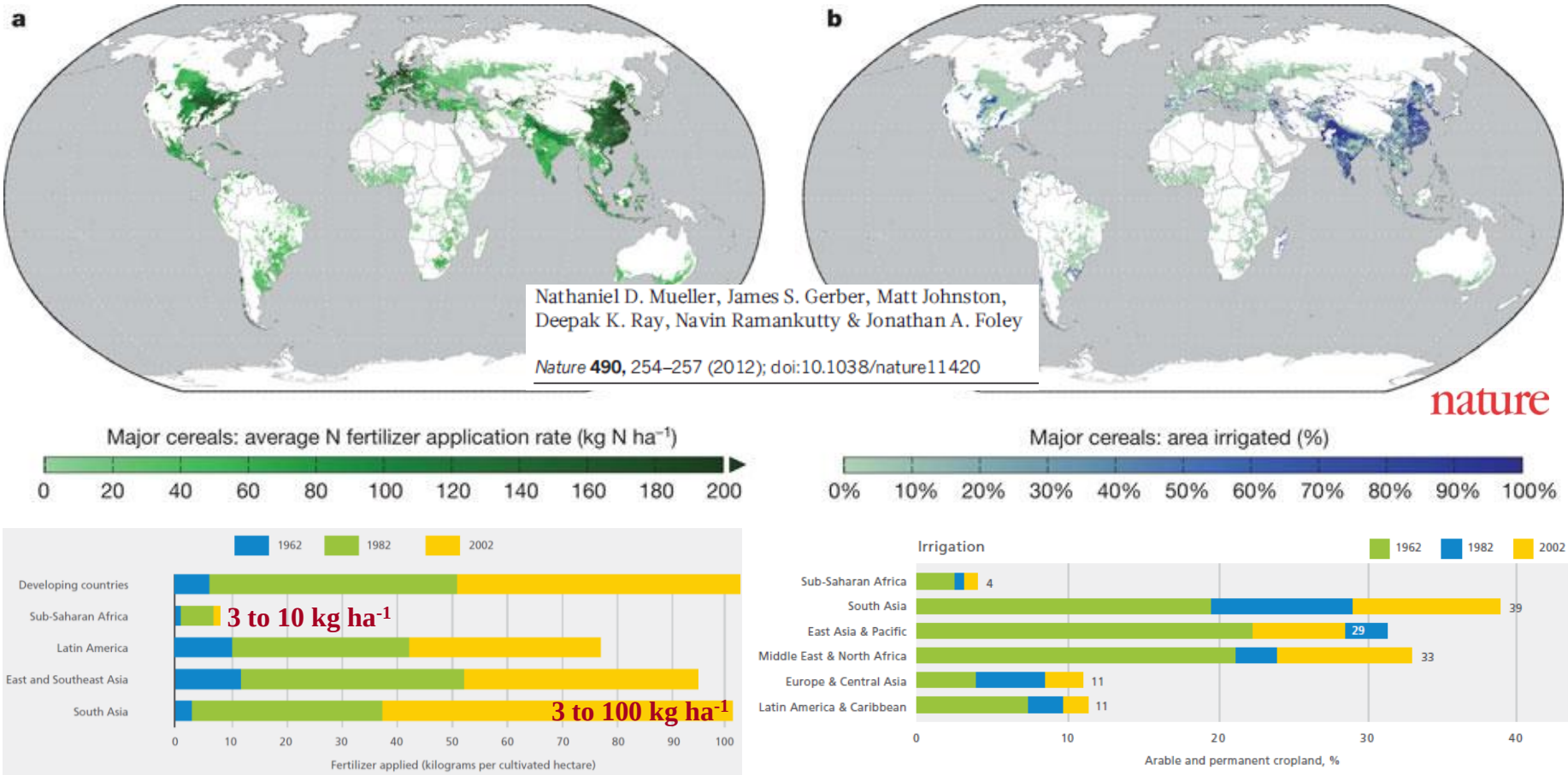
Resilient Systems: Components

Montpellier Panel Recommendations (2012)



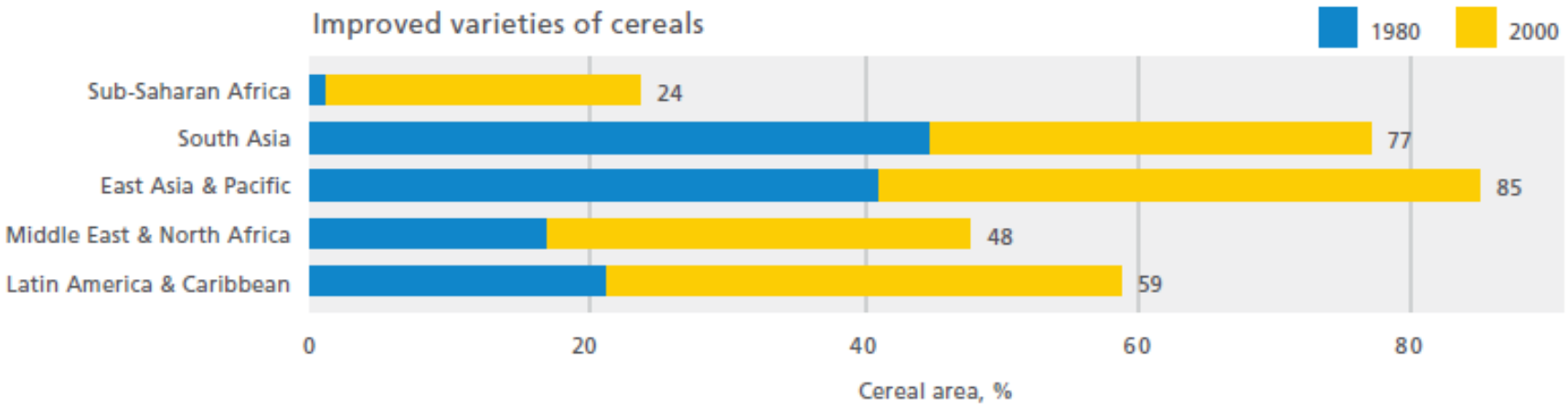
The Montpellier Panel 2012. Growth with Resilience: Opportunities for African Agriculture. London: Agriculture for Impact.

Africa: Challenge and Opportunities
Nutrient Use and Irrigation



Sub-Saharan Arica and South Asia started at same point in 1962, but little progress is made in SSA.

Challenges: Cultivar Adoption and Genetics



Sub-Saharan Arica has relatively low adoption of improved varieties due to lack of extension programs and also strong breeding programs and capacity.

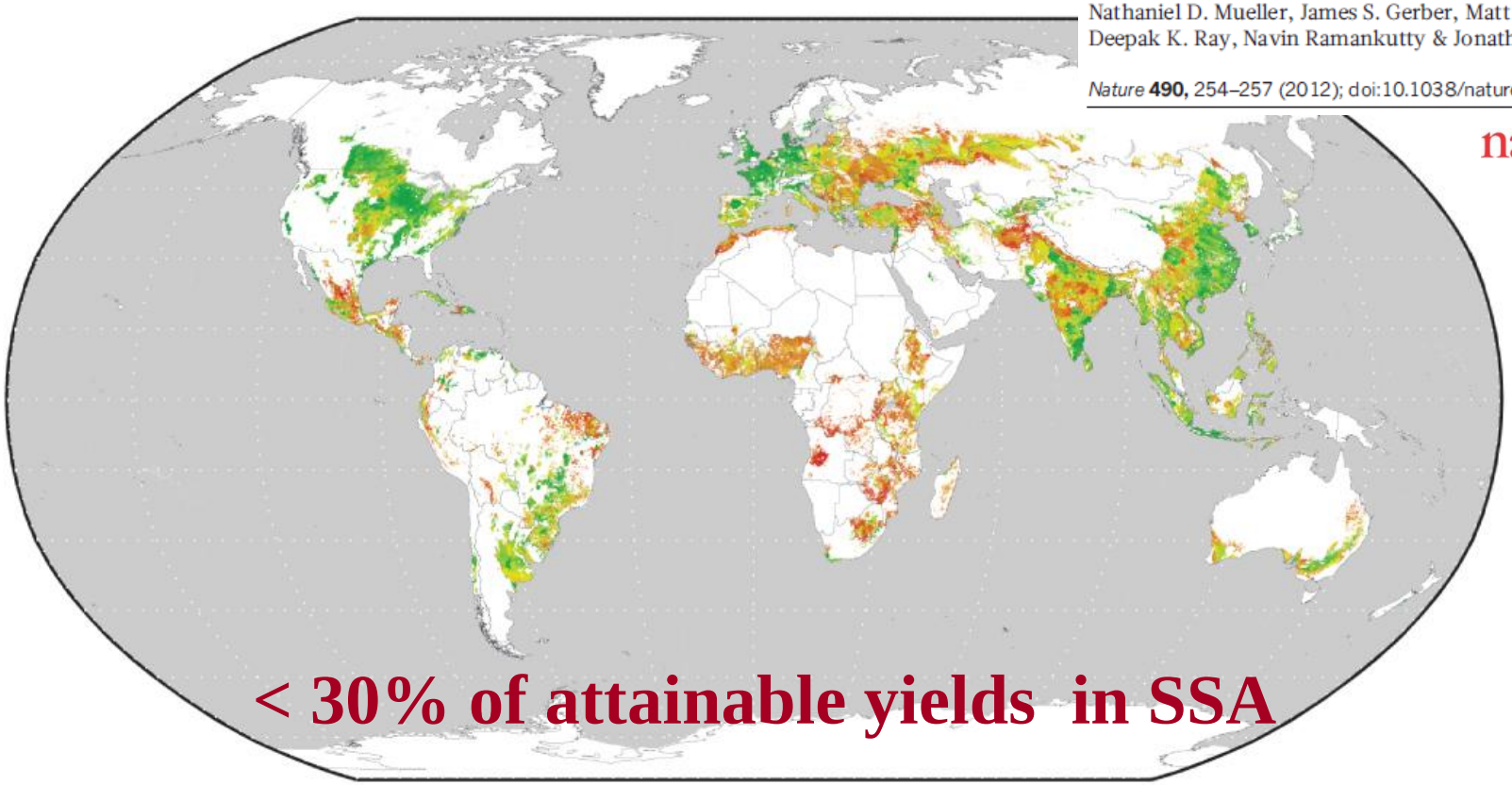
It is improving. Need to invest in Extension Services and Engagement of farmers and seed production and seed distribution systems.

Crop Productivity: Attainable vs. Actual

Nathaniel D. Mueller, James S. Gerber, Matt Johnston, Deepak K. Ray, Navin Ramankutty & Jonathan A. Foley

Nature **490**, 254–257 (2012); doi:10.1038/nature11420

nature



Major cereals: attainable yield achieved (%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

In SSA we have achieved only about 30% of the attainable yields.
This is very low compared to other parts of the world.

Crop Productivity: Attainable vs. Actual

Crops	Reported Yield Range	Good Farmers Field	National Average	Yield Gap	Potential Yield Increase	Approx. Genetic Potential*
	(t ha^{-1})				(%)	(t ha^{-1})
Rice	1.5 – 8.2	5.5	2.3	**3.20**	**139**	**10**
Maize	0.5 – 7.2	5.8	1.6	**4.20**	**262**	**14**
Sorghum	0.8 – 5.5	4.5	1.17	**2.33**	**280**	**10**
Millet	0.5 – 4.5	3.0	1.02	**1.98**	**294**	**7**
Cowpea	0.8 – 2.6	2.1	0.60	**1.50**	**250**	**2.5**
Soybean	0.60 – 2.6	2.4	0.90	**1.50**	**166**	**4**
Cassava	12.5 – 40	28.4	12.5	**15.9**	**127**	**80**
Yam	3.4 – 30	22.0	14.5	**7.5**	**90**	**27**
Sweet potato	10.5 – 30	13.0	7.8	**5.2**	**66**	**15**

*** Genetic potential not corrected for environment**

In SSA (e.g. Ghana) we have opportunities to more than double yield of most cereals and legumes; and by > 60% for tubers.

Objectives of SANREM and INTSORMIL

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- Develop and demonstrate locally available sustainable agricultural production systems for smallholder rain-fed farmers that improves food security, productive capacity and ecosystems services of degraded and productive agricultural lands.

- The new practices, knowledge and technological innovations should address food security, economic and social (including gender) viability, soil quality, water productivity, and other ecosystems services.

Resilient Dryland Cropping Systems

Improve productivity and resiliency of cropping systems for rainfed small holding farmers

Crop Residue

Cover Crop

Minimum Tillage

Crop Rotation

Water Harvesting

Nutrient Management

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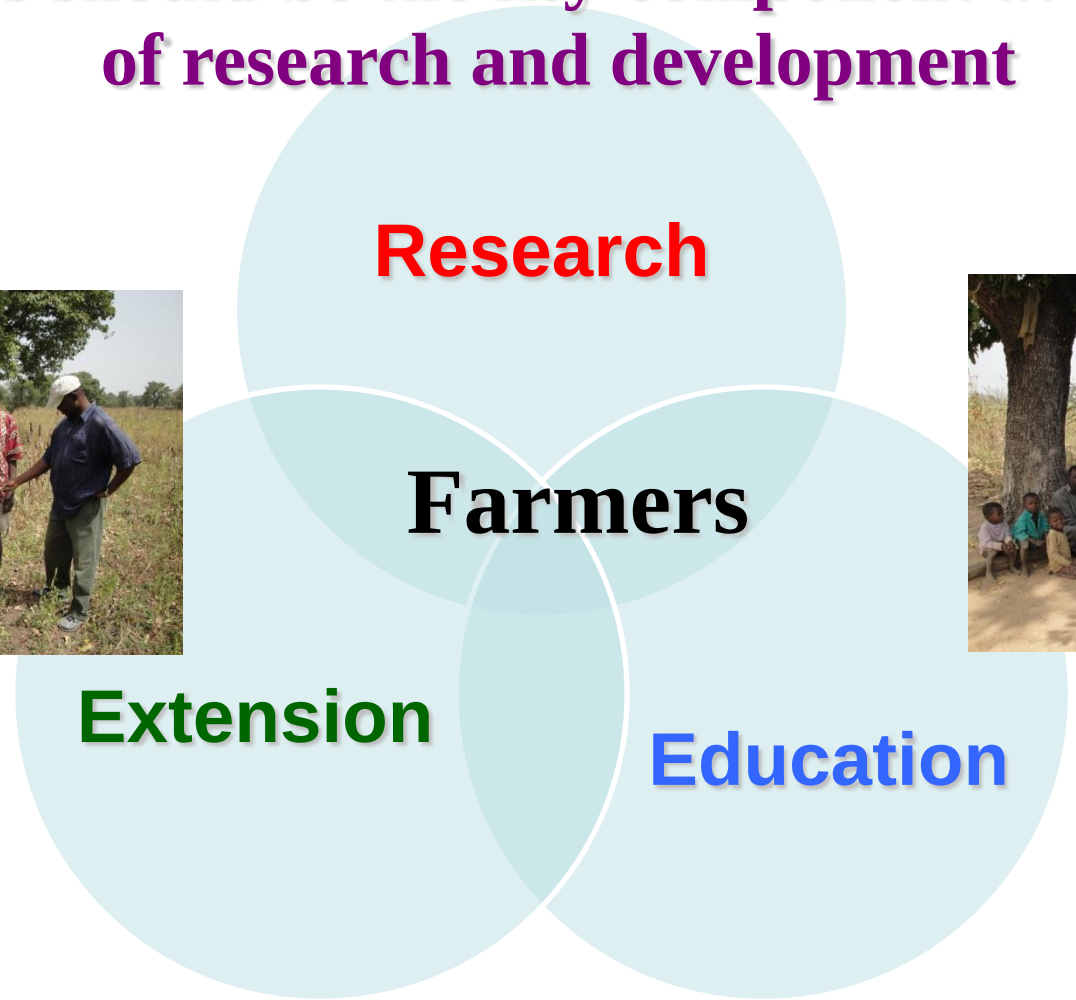
Focus was on above components.

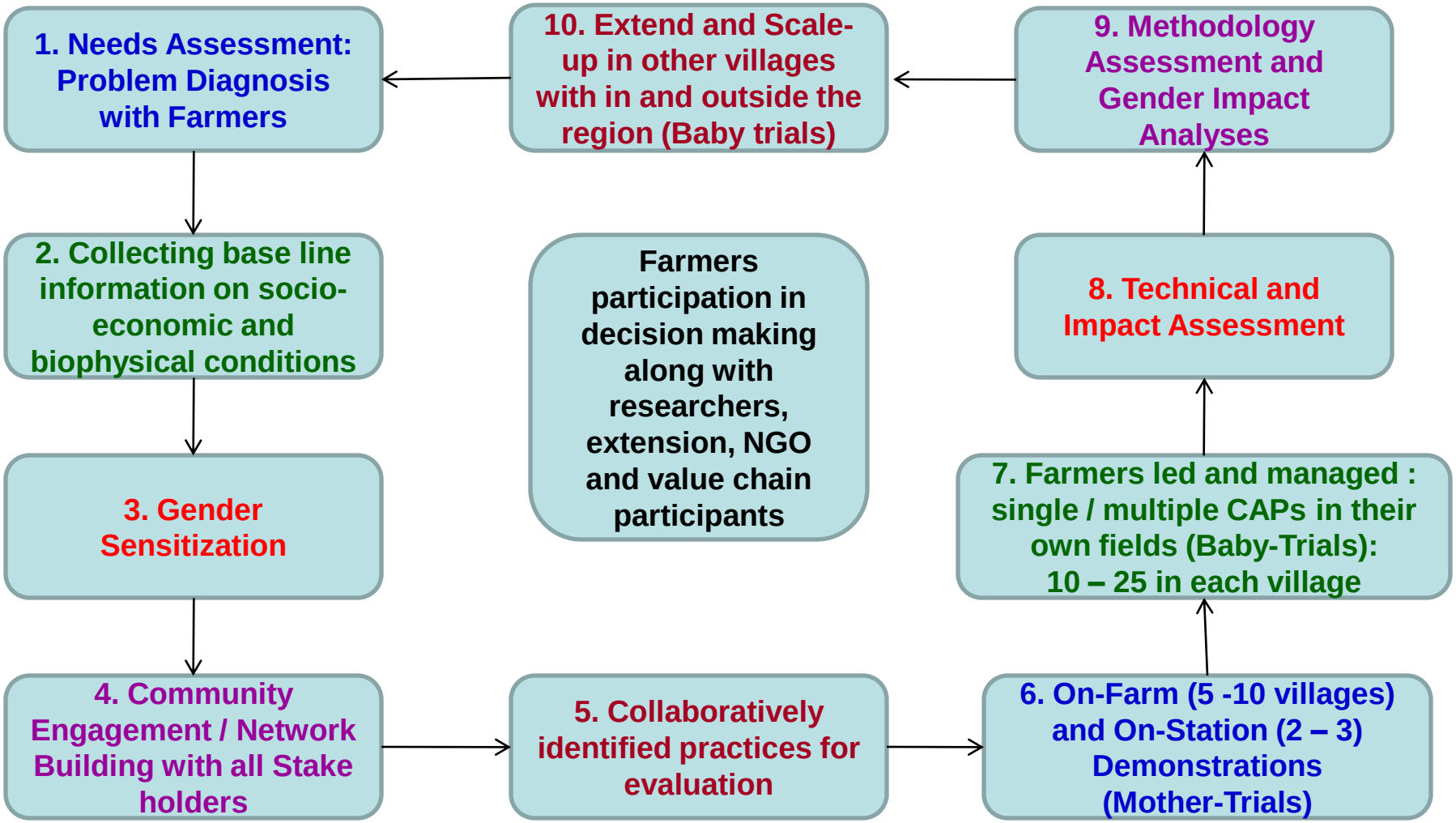
Farmers Driven Research Approach

Farmers should be the key component at all stages of research and development



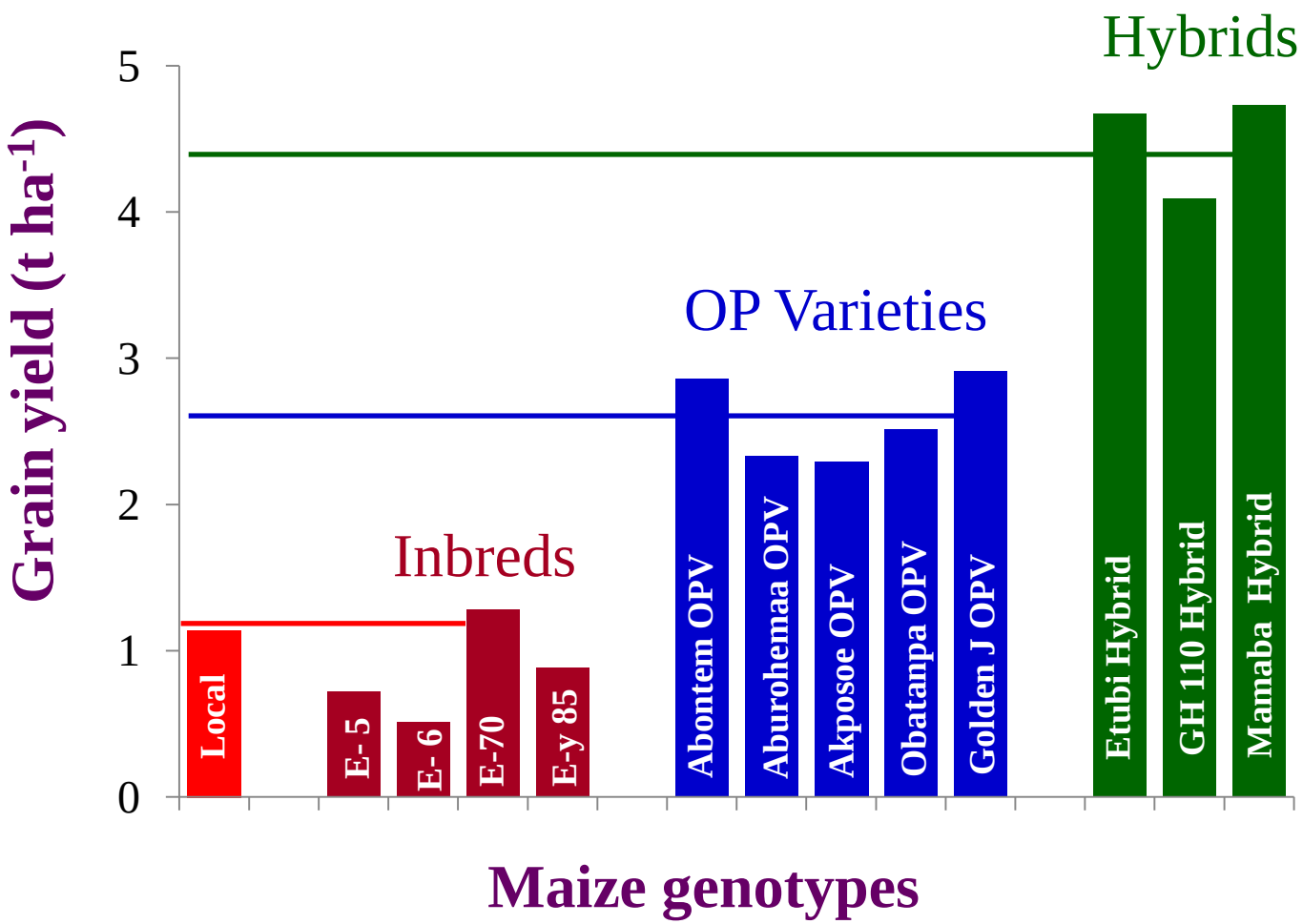
Farmers should feel the ownership of research.

Approach and Road Map



Case Study: Maize – Value Chain – Ghana

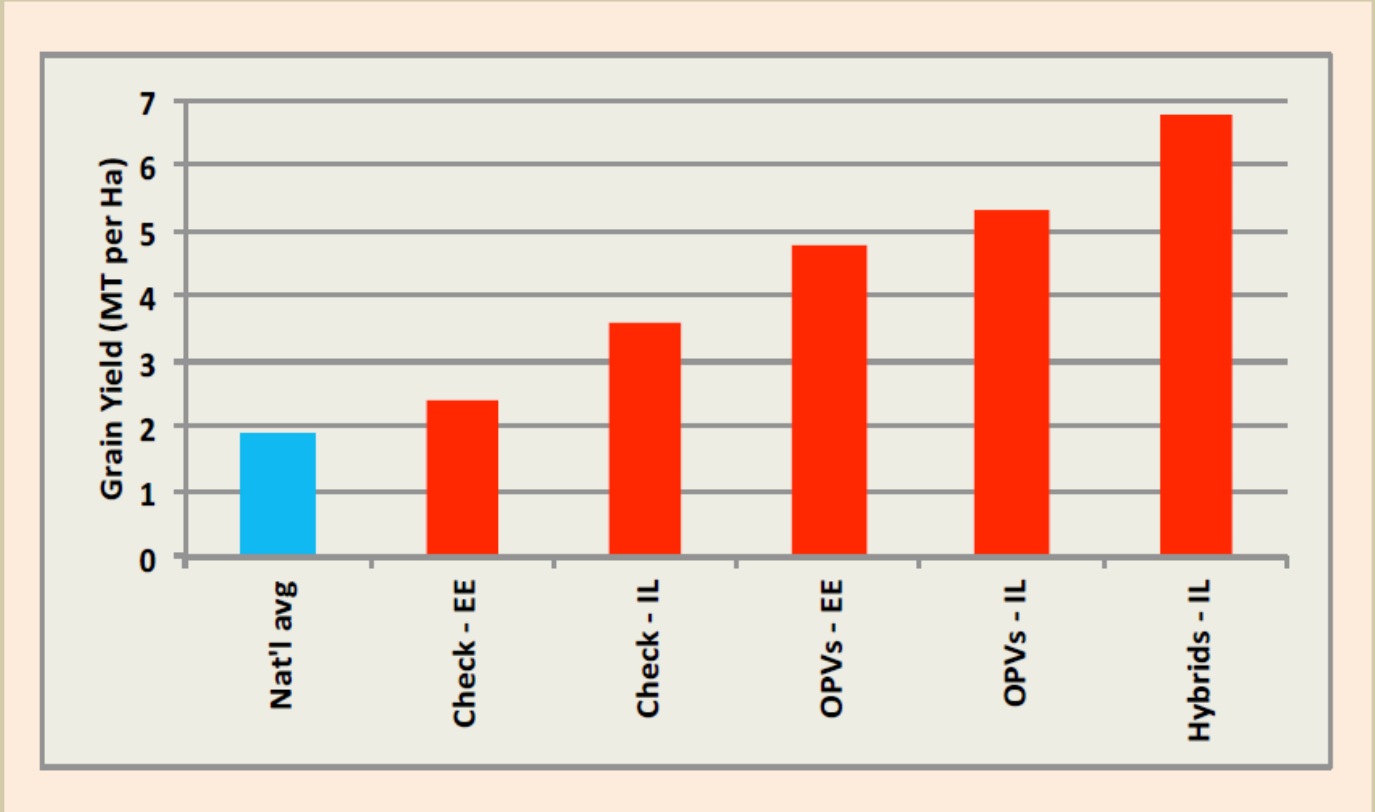
Maize: Improved Genotypes and Hybrids



Source: Kpotor 2012. M.Sc. Thesis, College of Agriculture and Natural Resources, Ghana

Grain yield increased by 400% by hybrids, and by 200% by open pollinated varieties.

Maize: Drought Tolerance / Striga Resistance



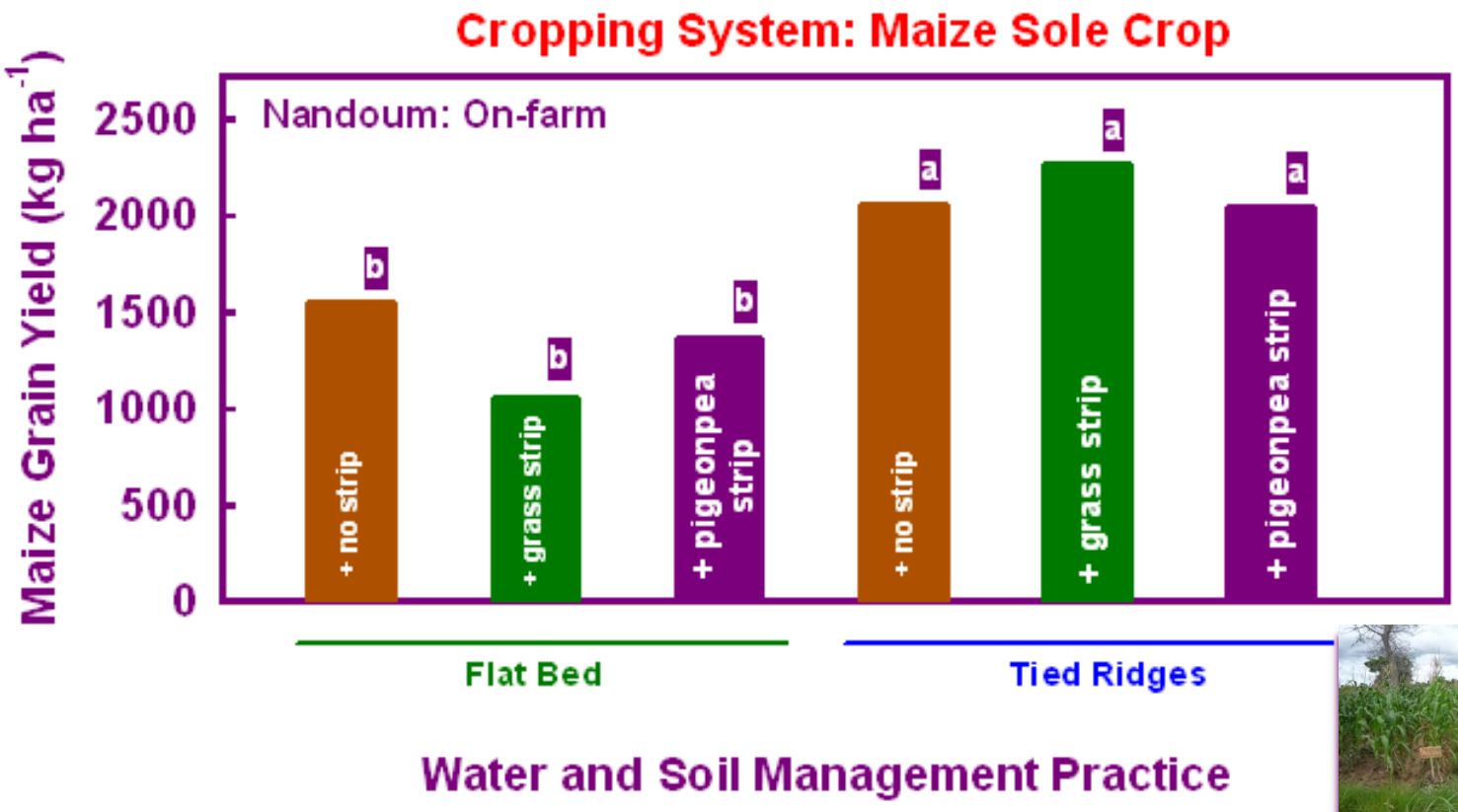
Grain yields of new varieties compared with checks and national average (EE and IL at the end of each data point represent extra-early/early and intermediate/late maturity, respectively)

DT Maize: Volume 2: March 2013

Grain yield increased by 400% by hybrids, and by 200% by open pollinated varieties with drought tolerance and striga resistance.

Maize: Seed Beds and Water Harvesting

Upper West Region

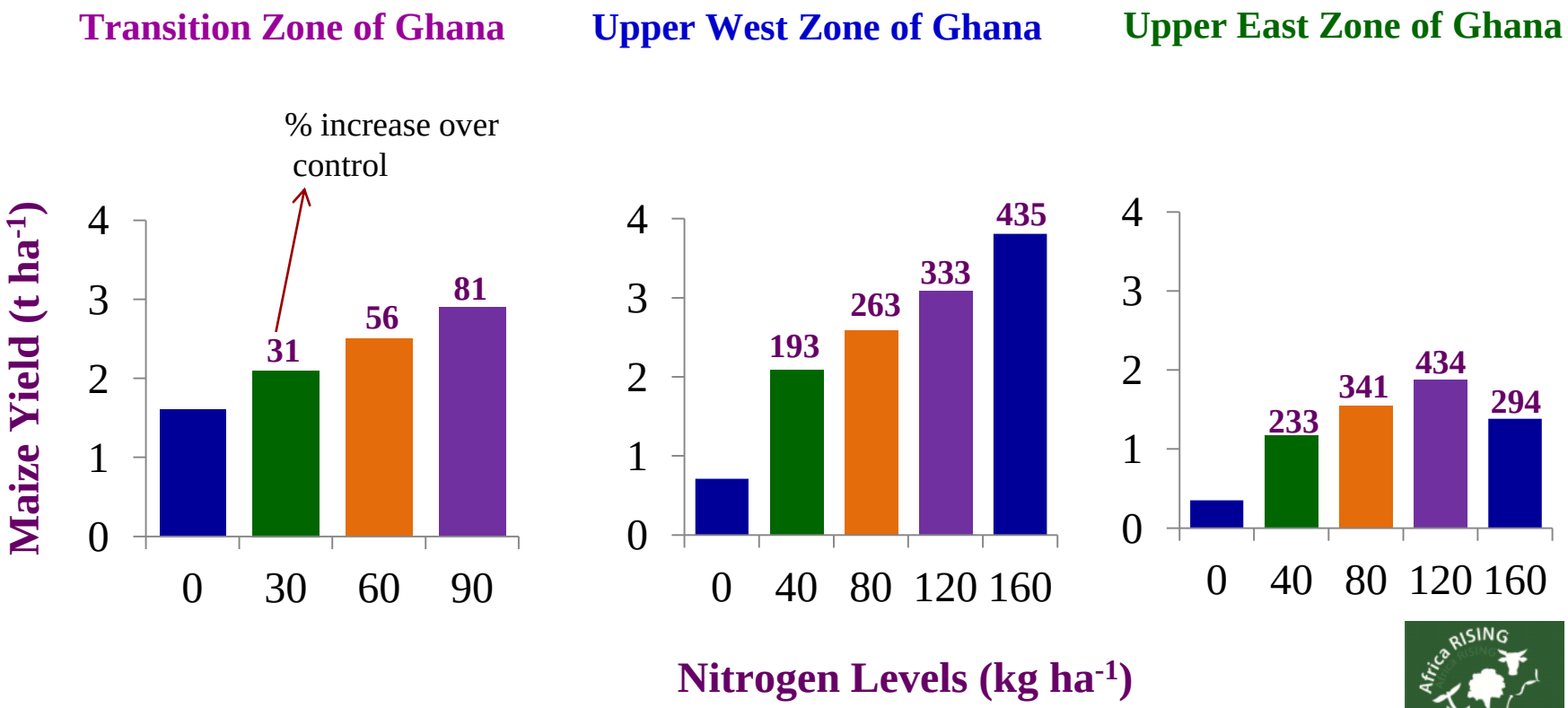


SANREM CRSP

Source: Naab et al. SANREM CRSP Research Activities

Maize planted on tied ridges increased grain yield in all treatments compared to flat bed systems.

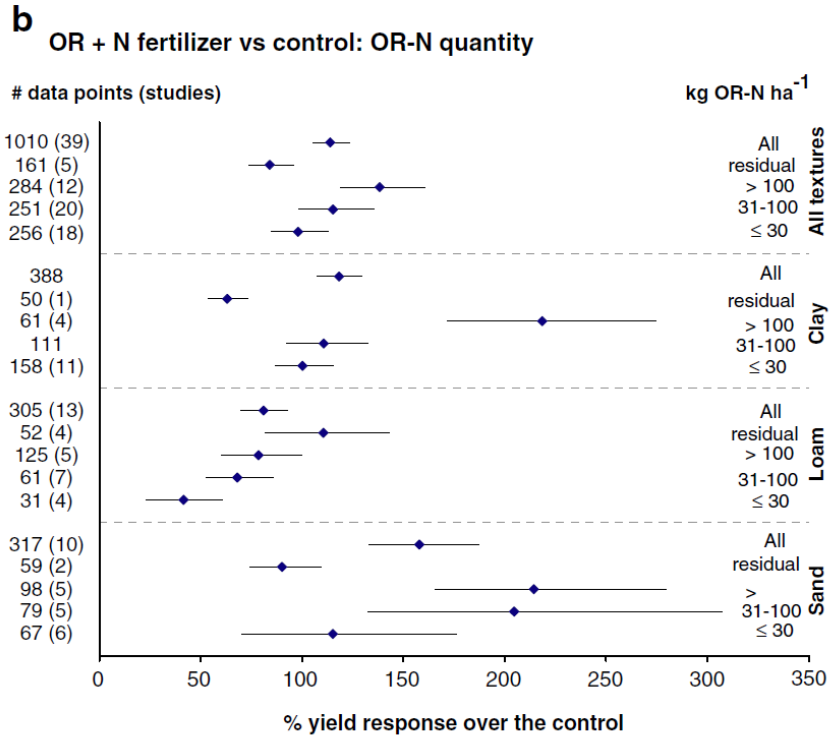
Maize: Response to Nitrogen Fertilizer



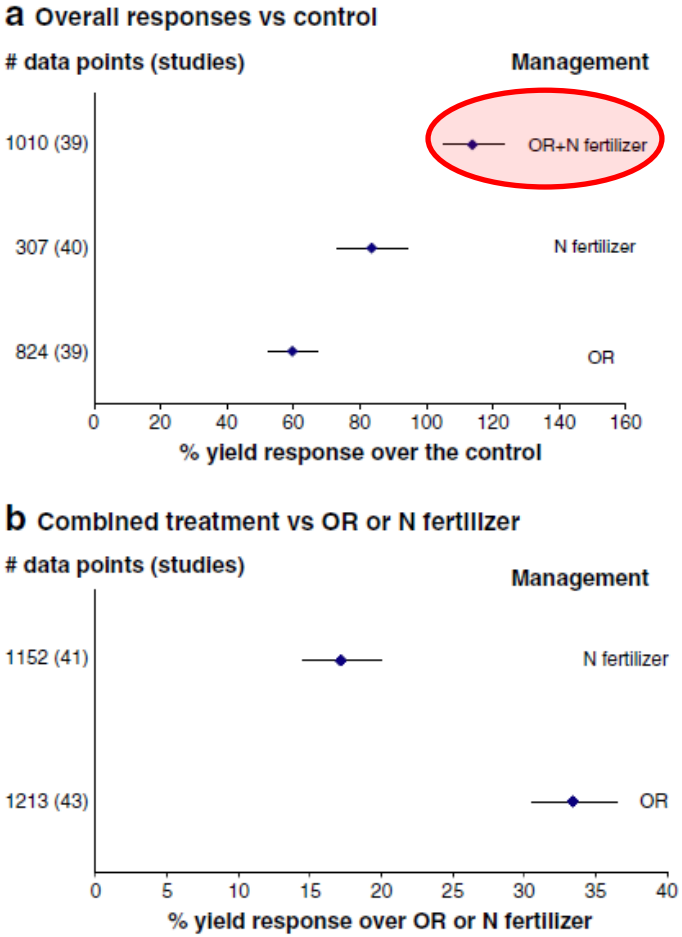
Source: (1) Bonsu P.O. and J.Y. Asibuo. 2013. Int. J. Scientific Technol. Res. 2: 222-227
(2) Annual Report of Africa RISING project - subprojects carried out by CSIR-SARI, 2013.

Fertilizer application of about 80 to 90 kg ha^{-1} of nitrogen can increase grain yield in the range of 80 to 300%.

Maize: Integrated Nutrient Management

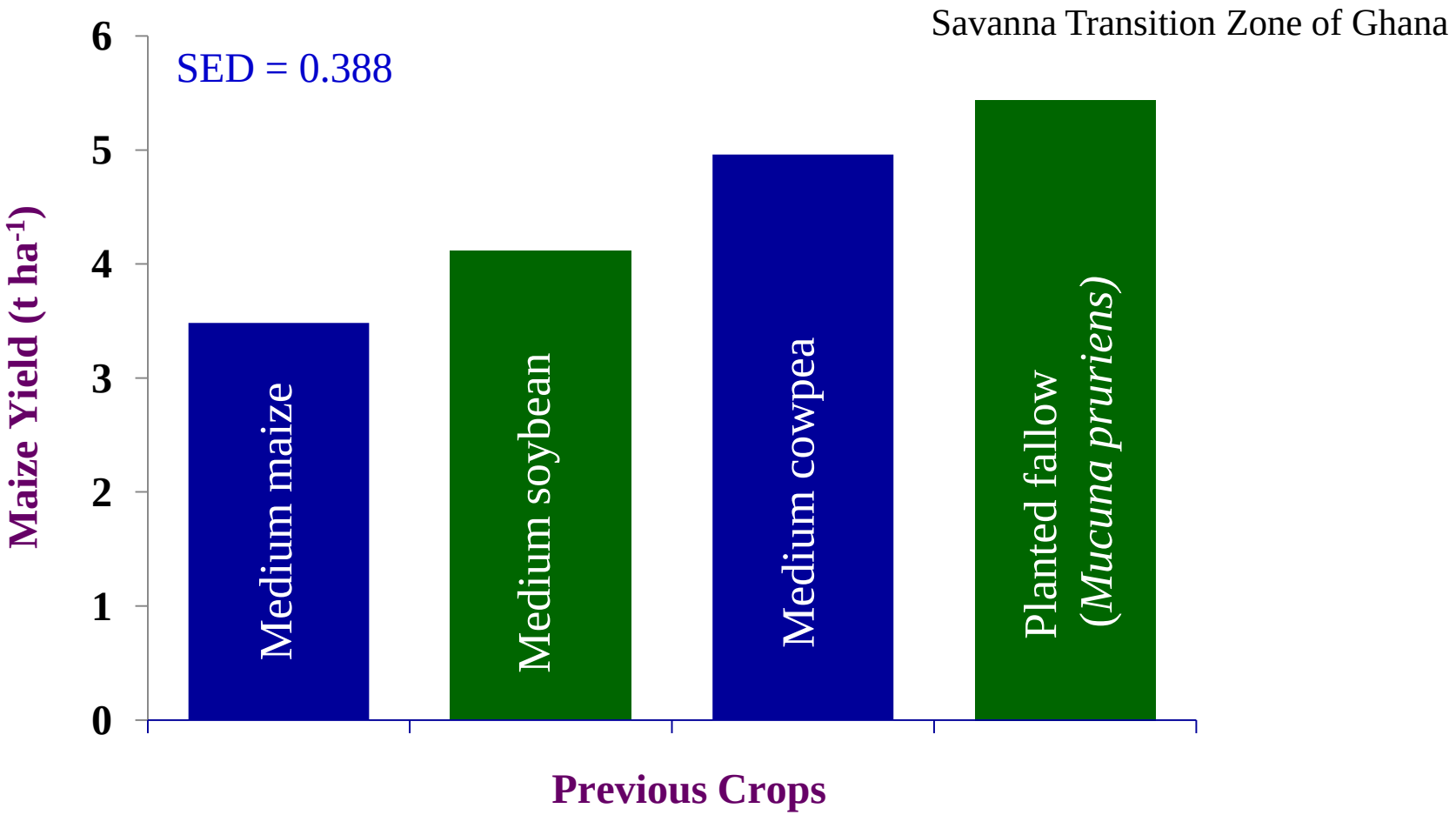


Chivenge et al. (2011). Plant and Soil 342:1-30



A detailed meta-analysis of published papers in SSA on response of maize to inorganic and combination of inorganic and organic sources showed positive responses to combinations (INM).

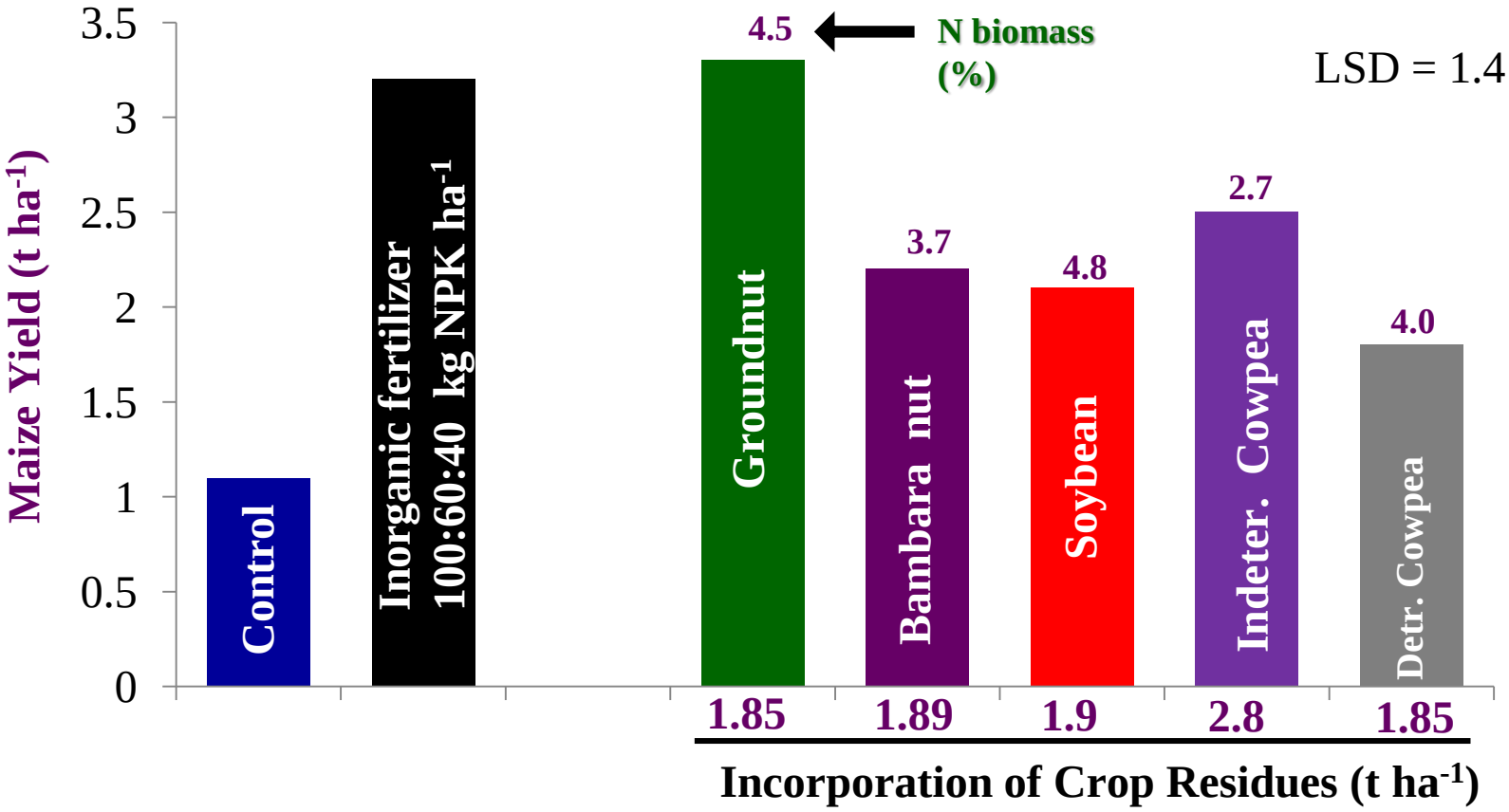
Maize: Response to Previous Crop (Rotations)



Source: Ennln et al. 2004. West African Journal of Applied Ecology 6: 65-74.

Crop rotation with legume (soybean or cowpea) or fallow and Mucuna increased grain yield of maize by about 60%.

Maize: Response to Crop Residue



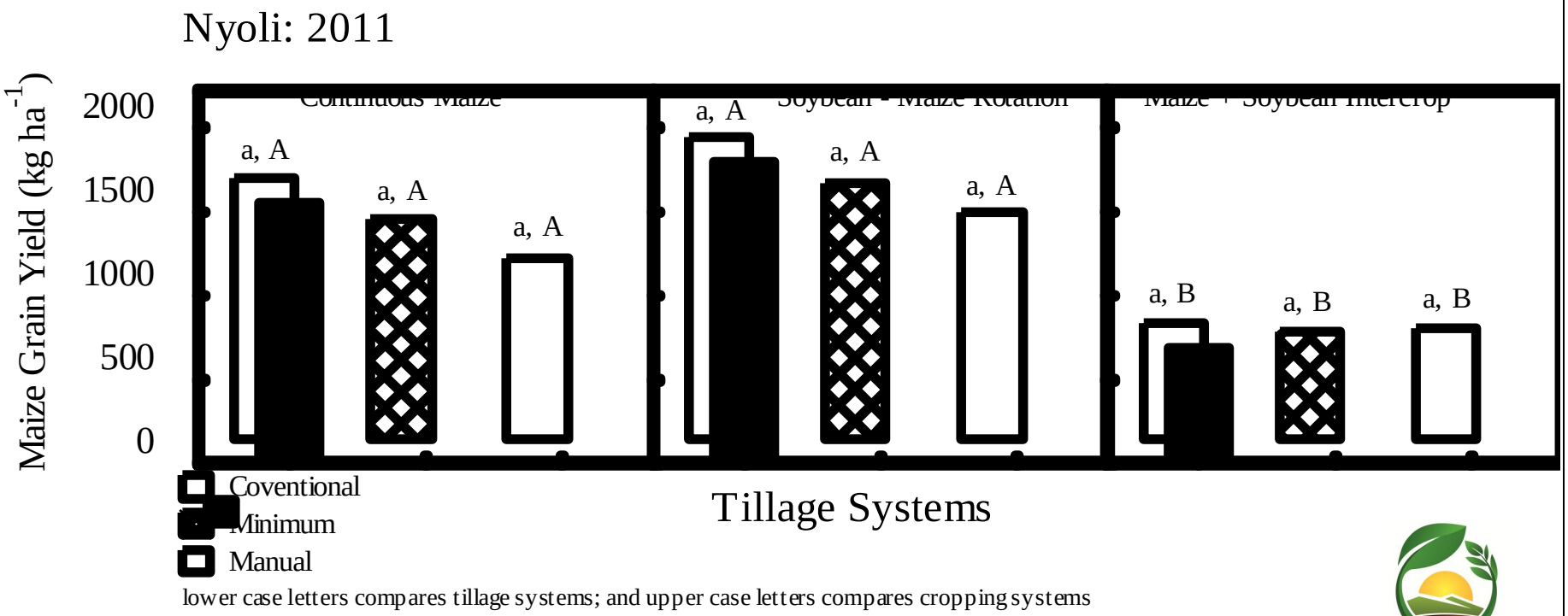
Savanna Transition Zone of Ghana

Source: Nyalemegbe, K.K. and Osakpa, T.Y. 2012. West African Journal of Applied Ecology, 20: 33-40

Rotation and incorporation of leguminous crops / residue provided about 75 to 100% of nitrogen needs, and doubled yields.

Minimum Tillage –Maize – Soybean Systems

Upper West Region



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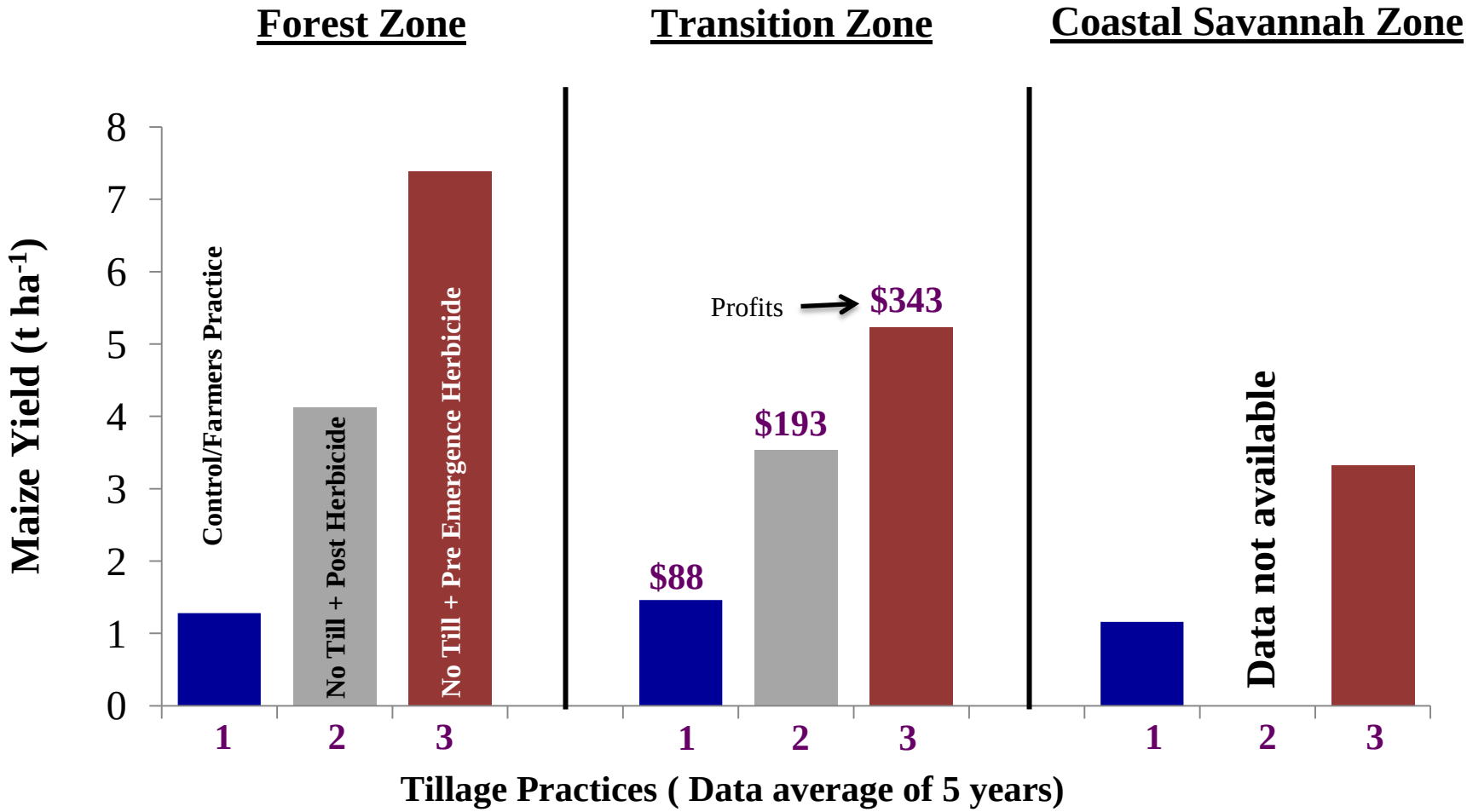
Source: Naab et al. SANREM CRSP Research Activities

Use of minimum tillage in on-farm mother and baby test had similar yields to that of conventional tractor tillage in all cropping systems. Economics showed beneficial response.

Maize: Response to Tillage Practices



Source: Aflakpui et al. 2007. Journal of Plant Sciences 2: 68-74.

Minimum tillage with improved management (fertility and herbicide) increased yield (>300%) and also had economic benefits.

Case Study: Ghana - Sorghum and Millet

Sorghum: Tillage – Genotype - Fertilizer

Treatments	Stover (kg ha^{-1})	Grain (kg ha^{-1})
Tillage System		
Conventional Tillage	3797 a	1379 a
No Tillage	3161 a	1641 a
Varieties		
Kapala	2218 a	1941 a
Dorado	2555 a	1694 a
Local (Chere)	5663 b	895 b
Fertilizer Rate (N kg/ha)		
0	1973 a	912 a
30	4112 b	1395 a
60	3832 b	1462 a
90	3632 b	2276 b
120	3848 b	1506 a

Tillage: No difference

Genetics: >100 % Increase

Nutrients: >100 % Increase

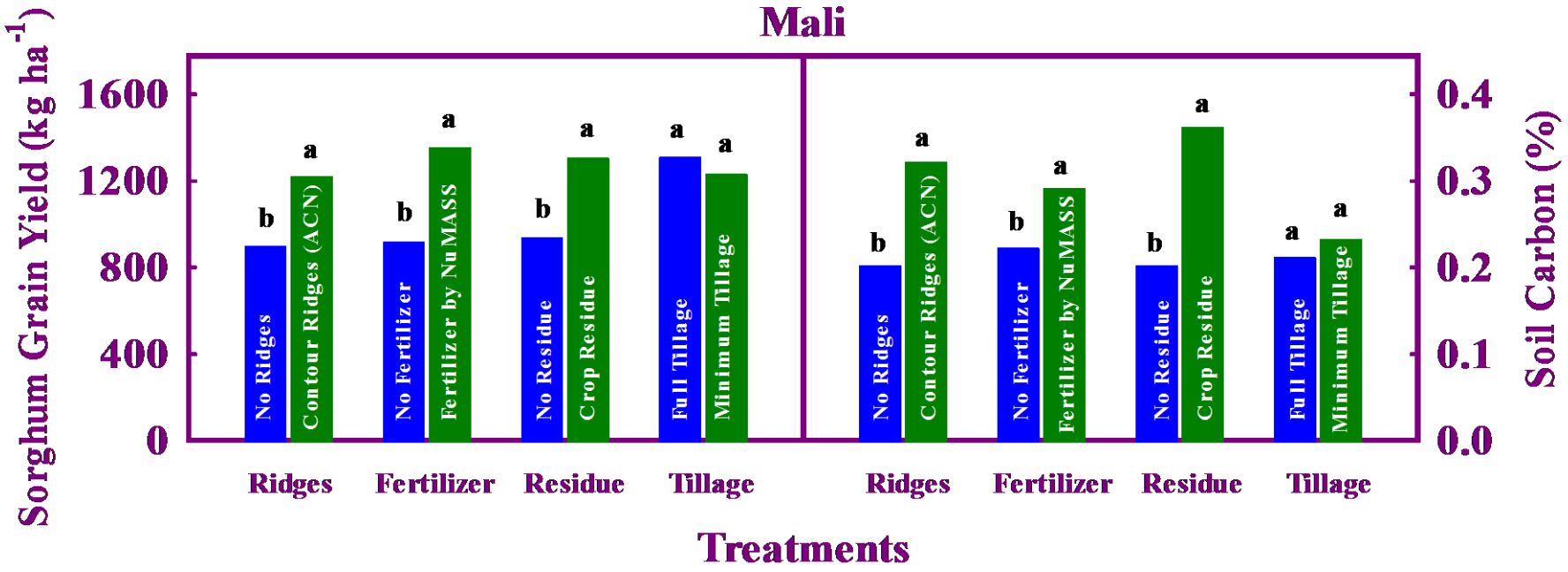
Naab et al. INTSORMIL Project

Sorghum on various managements had higher yields (>100%).

Intensive Crop Management – Long Term (~3 to 5 yrs)

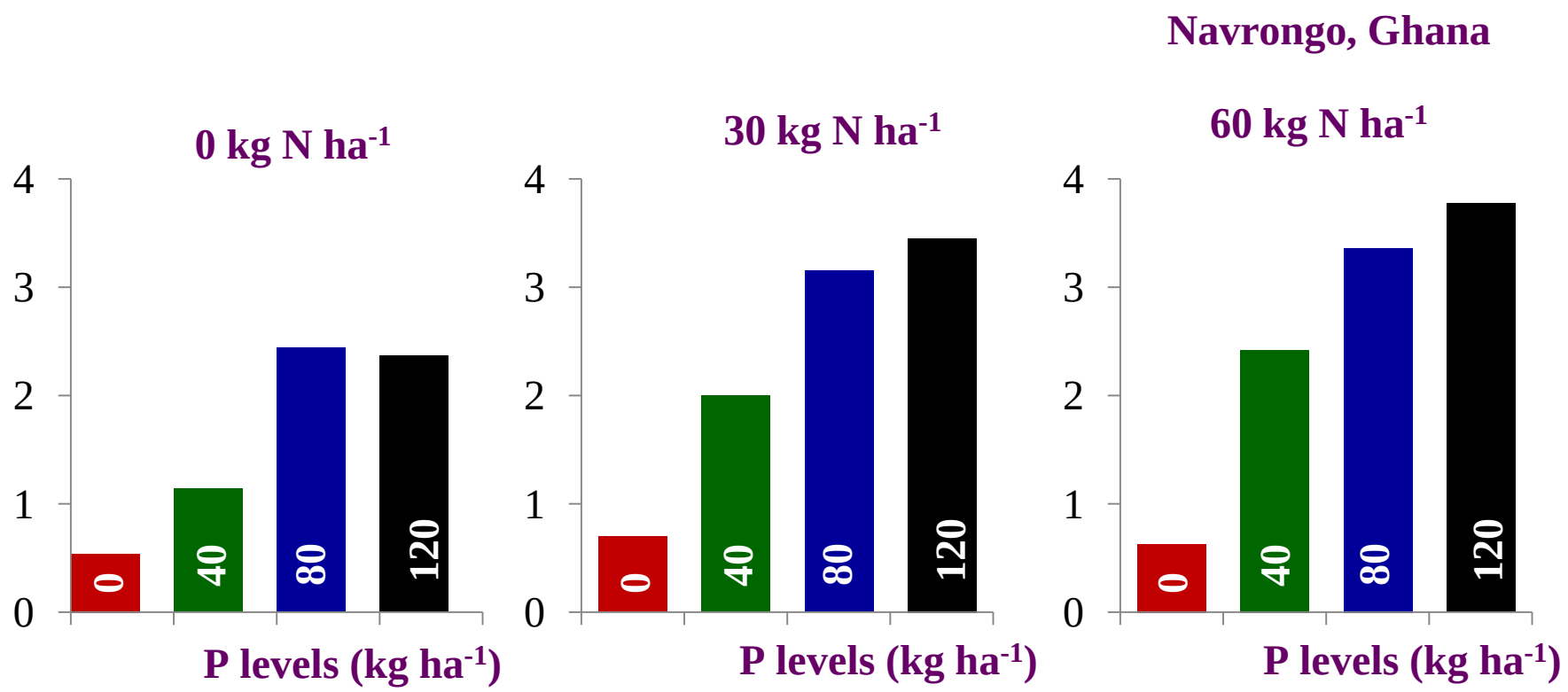
Short-Term Experiment (about 3-5 years

Doumbia et al.



Use of contour ridging (ACN), inorganic fertilizer and crop residue increased crop yields (>40%) and soil carbon. Tillage practice did not influence yield and soil carbon.

Sorghum: Response to Nitrogen and Phosphorus

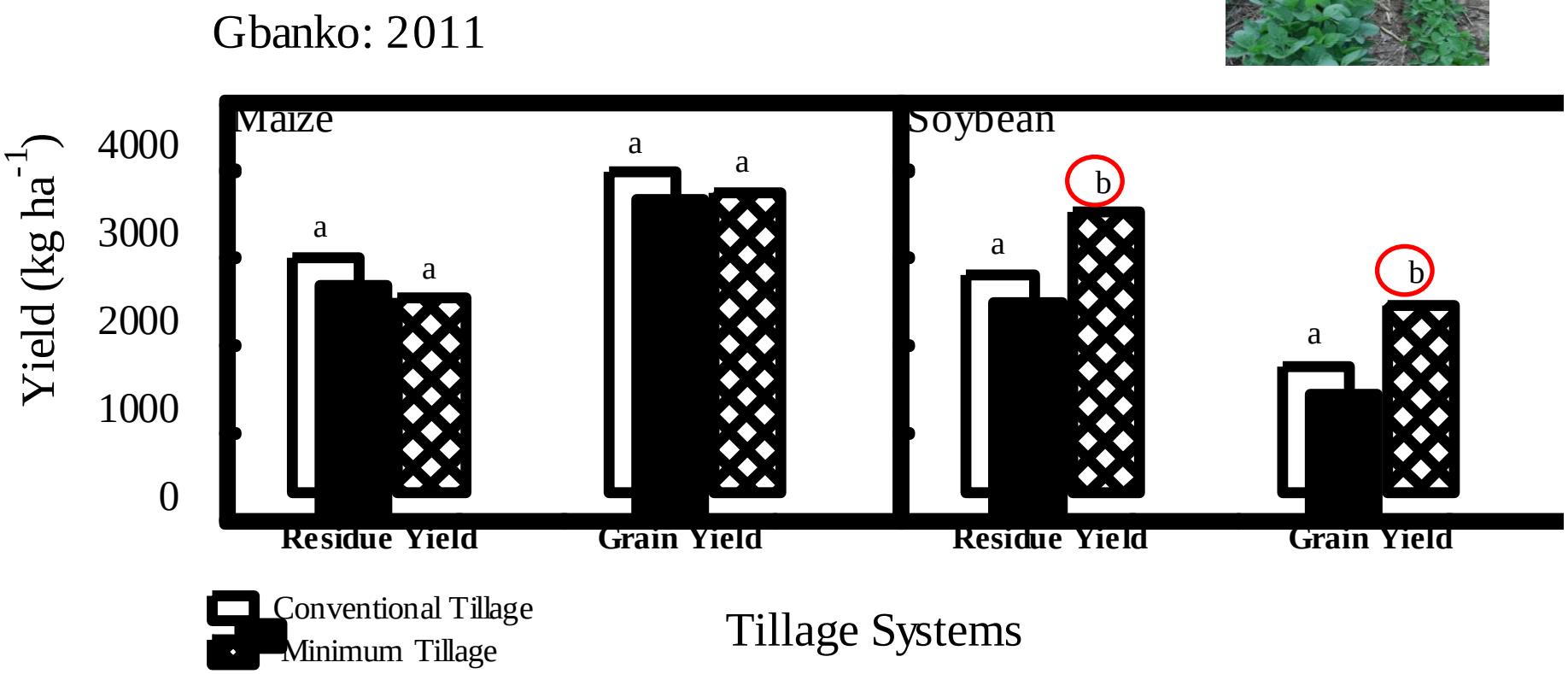


Source: Erlangung des Grades 2007. Doctoral Thesis Spatially explicit modeling of sorghum production on complex terrain of a semi arid region in Ghana using APSIM. Submitted to Rheinischen Friedrich-Wilhelms-Universität zu Bonn.

Application of nitrogen and phosphorus significantly increased grain yield of sorghum. N = ~80% increase; P = ~400% increase.

Soybean

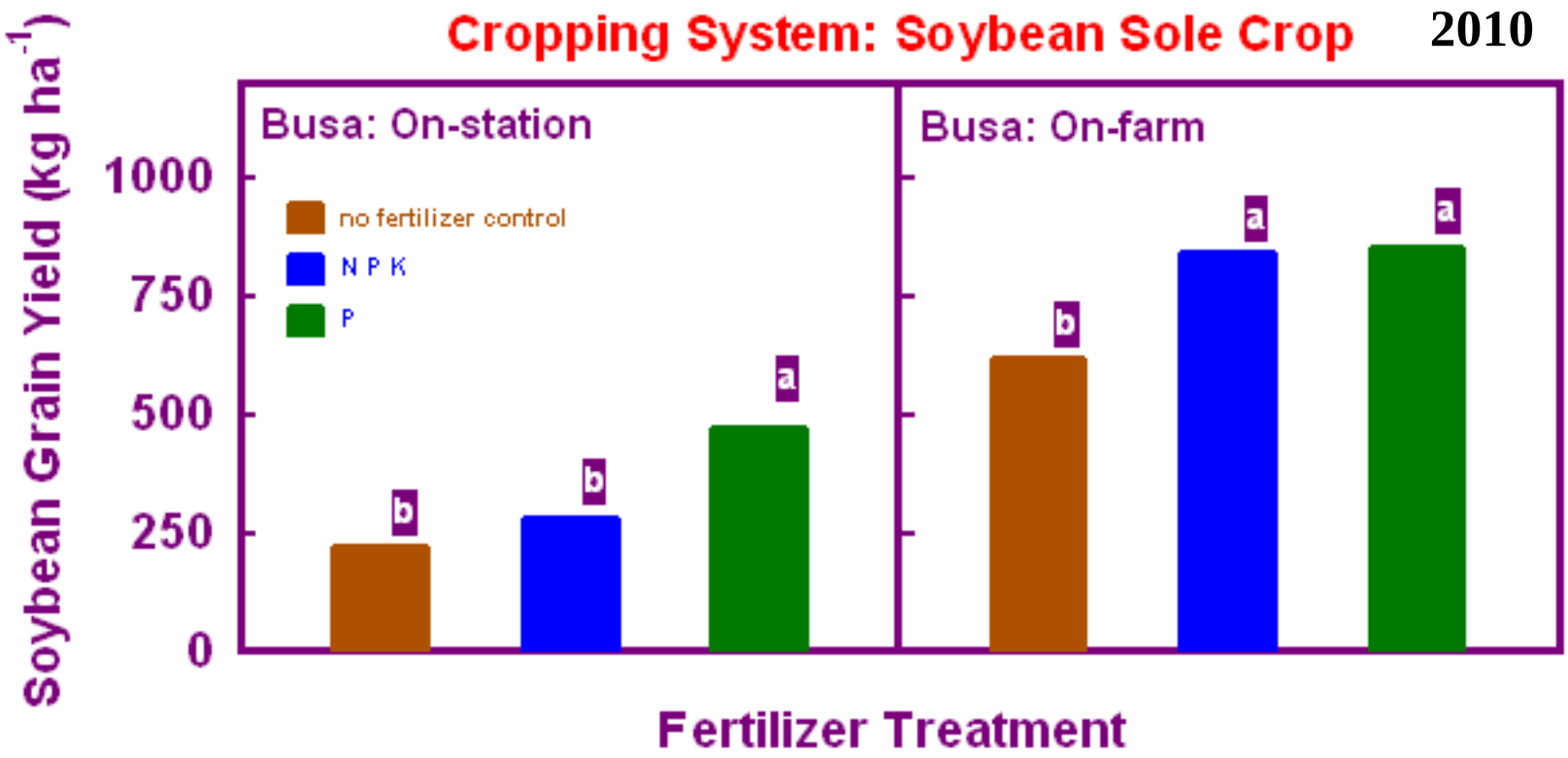
Soybean: Minimum Tillage : Maize - Rotation



No difference in tillage systems for maize residue or grain yield.

Minimum tillage improved soybean residue and grain yield (30%).

Soybean: Phosphorus Nutrition

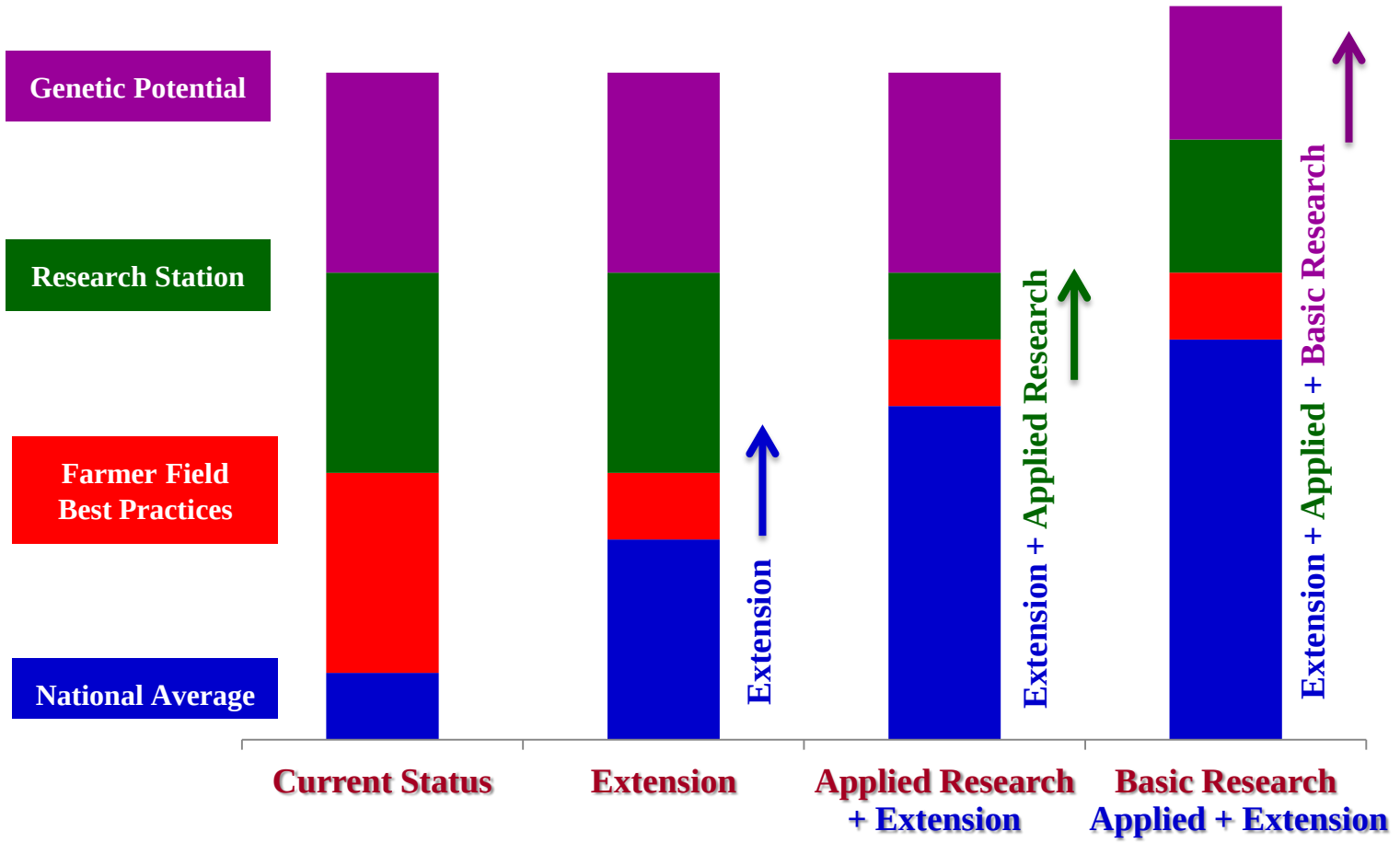


Application of P (26 kg/ha) increased grain yield of soybean (>30%) in all tillage systems and crop rotations.

NPK (37:16:31 kg/ha)

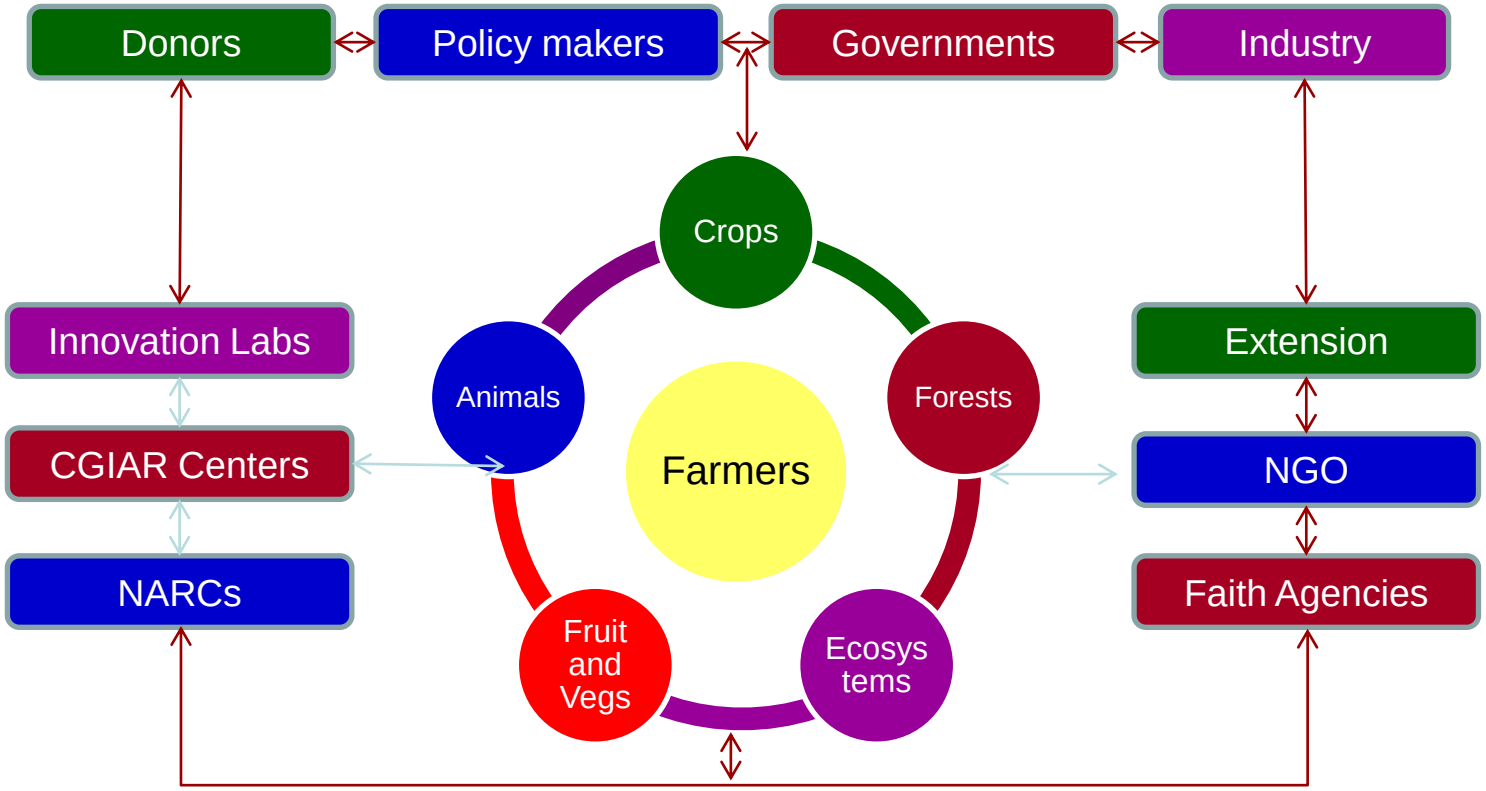
Remarks and Conclusions

Various Yield Gaps and Approaches



Different yield gaps can be achieved by improving extension services, facilitating inputs and market opportunities, and enhancing research capacity and international partnerships and cutting edge genetics and improved efficient technologies.

Integrated Collaborative Programs



We Need to Build Integrated Programs; and
Not Short Term Individual/Independent Projects

Conclusions

- **There are opportunities to more than double (~200%) yield of major cereals and legumes in through use of intensive sustainable and climate smart technologies.**
- **Engagement of farmers and value chain partners is critical.**
- **NARS should develop sustainable programs and not be contained with limited short-term projects. Capacity building should be integral part.**
- **Research and donors should increase communication and work as team and complement each others programs.**

Acknowledgements

- **Farmers**
- **Savanna Agricultural Research Institute, NGOs, MOFA**
- **Ghana: SARI: J.B. Naab and R.A.L. Kanton (SARI) and their team.**
- **Mali : IER, M. Doumbia, S. Traore, M. Kone, O. Samake, P. Sissoko**
- **KSU: S. Staggenborg, C. Rice, D. Mengel, K. Garret, A. Jumponen, K. Roozeboom, N. Lilja, and D. Presley.**

Ghana

Mali

Questions

“You can’t eat the potential yield, but need to raise the actual by combating the stresses”

Norman E. Borlaug
(Nobel Peace Laureate)

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