Notes on soil health, legumes and participatory action research

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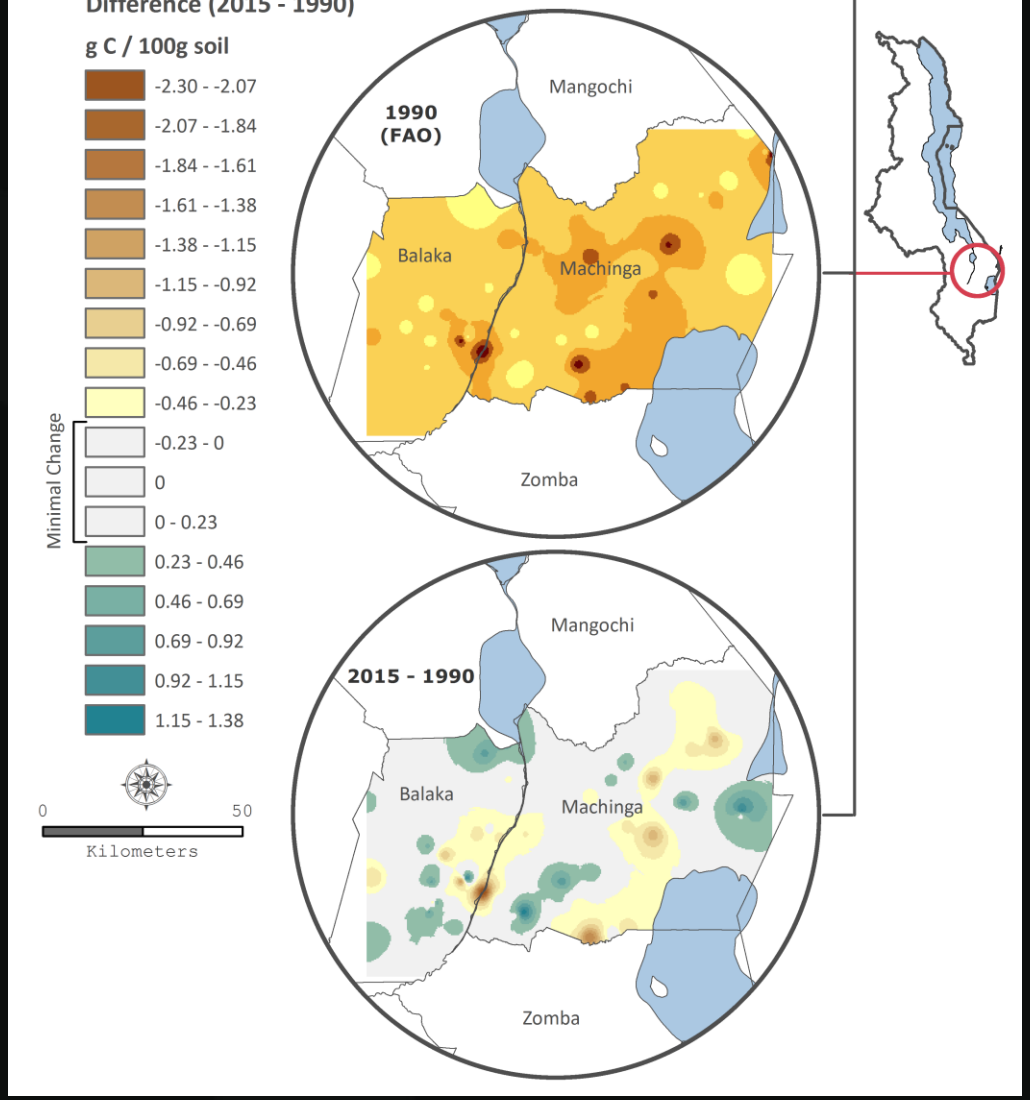
Sustainability challenges

Malawi intensively cultivated fields



Mpeketula et al 2019

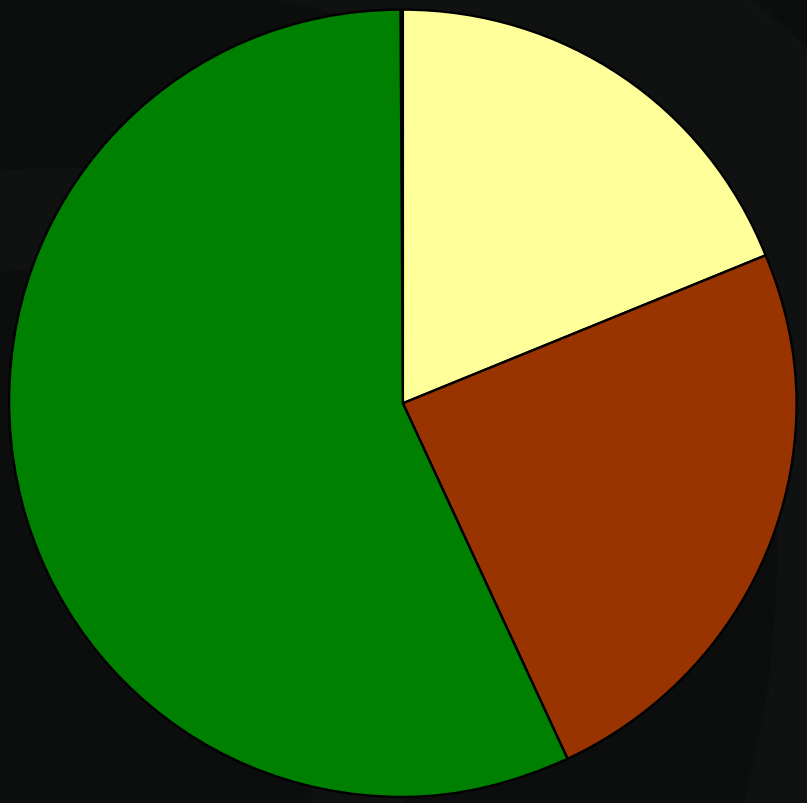
Soil health

Legume diversity

Future pulses

Soil organic matter pools

Soil health



- ACTIVE: Recent OM inputs and soil organisms
- SLOW: Organic compounds derived from active pool, protected
- STABLE: Physically protected humus, extremely recalcitrant

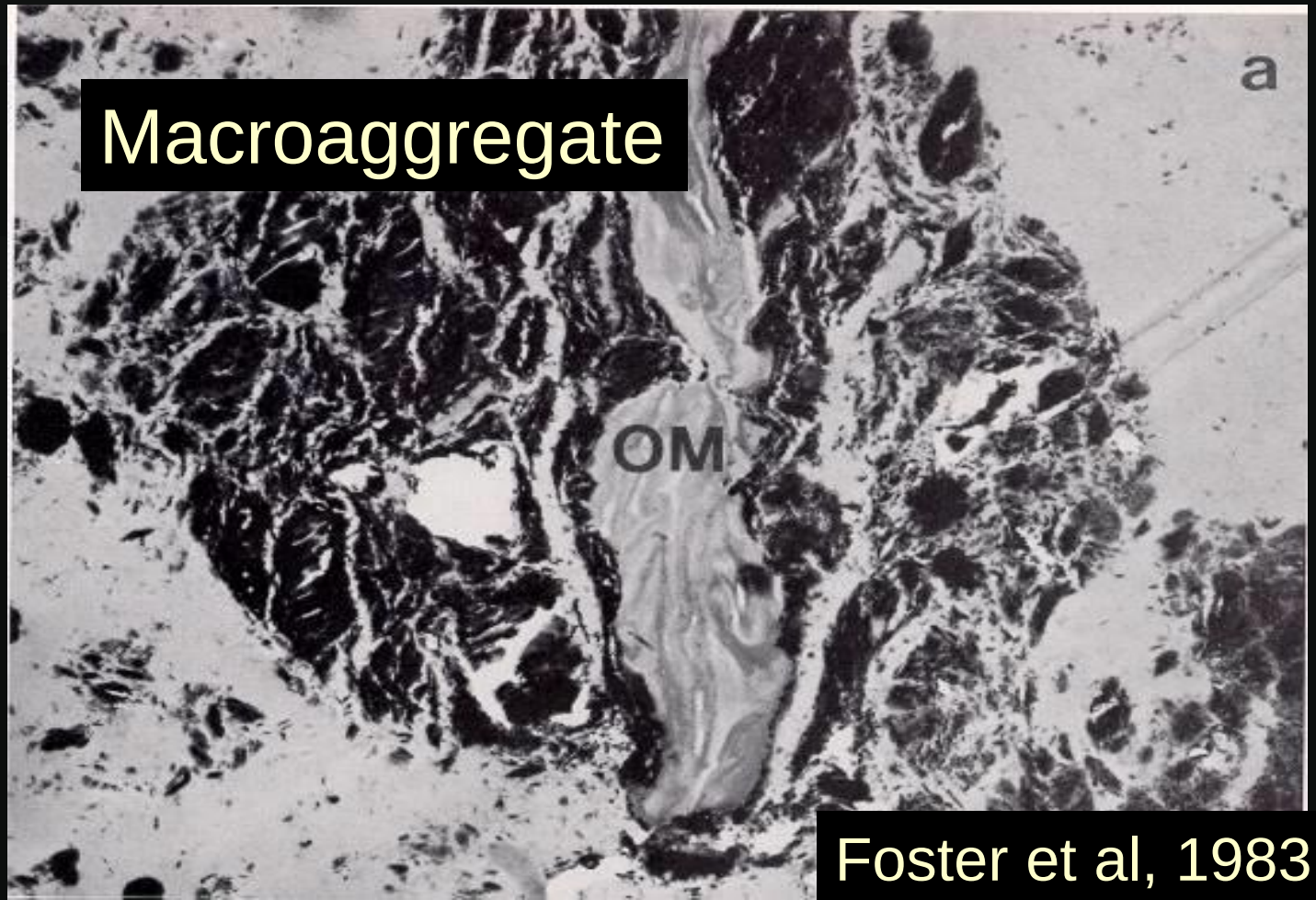
How to build soil organic matter?

Soil health

Quantity?

Soil health

Aggregates = Soil org. matter sandwich



Foster et al, 1983

Pigeonpea aggregates

Soil health

Soil fraction	Total Nitrogen (mg N/kg)		Organic Phosphorus (mg P/kg)	
	Maize	Pigeonpea	Maize	Pigeonpea
Bulk Soil	1734	1686	90	82
Aggregates				
Macro	1405	1524	84a	98b
Micro	974a	1323b	29a	77b
Silt+Clay	2102	2056	157	134

Garland et al., 2018

Soil health

SOIL CARBON SEQUESTRATION

Maize roots - 30 to 45%

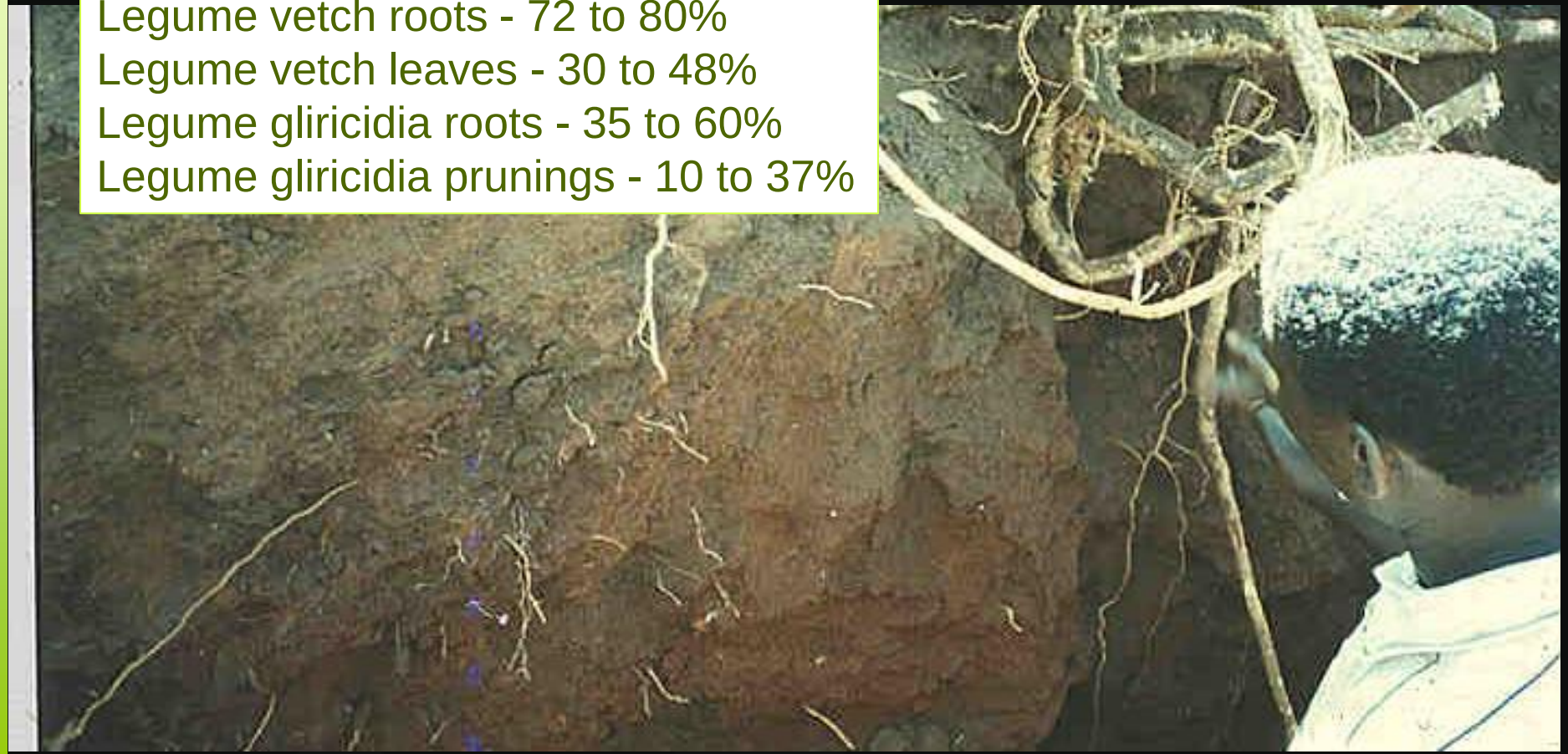
Maize leaves - 10 to 28%

Legume vetch roots - 72 to 80%

Legume vetch leaves - 30 to 48%

Legume gliricidia roots - 35 to 60%

Legume gliricidia prunings - 10 to 37%



Soil amelioration

Belowground biomass assessment: 1.1 T/ha

Pigeonpea roots

0 - 20 cm

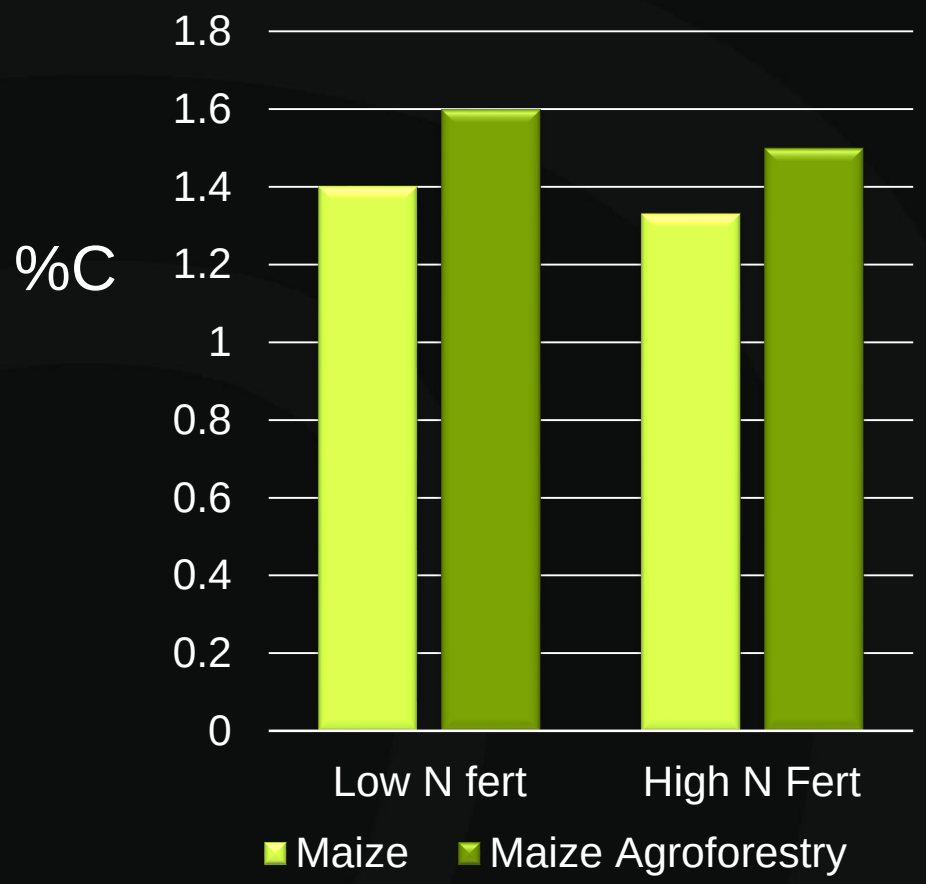
20 - 40 cm

40 - 60 cm

Gwenambira, 2015

Agroforestry and soil C

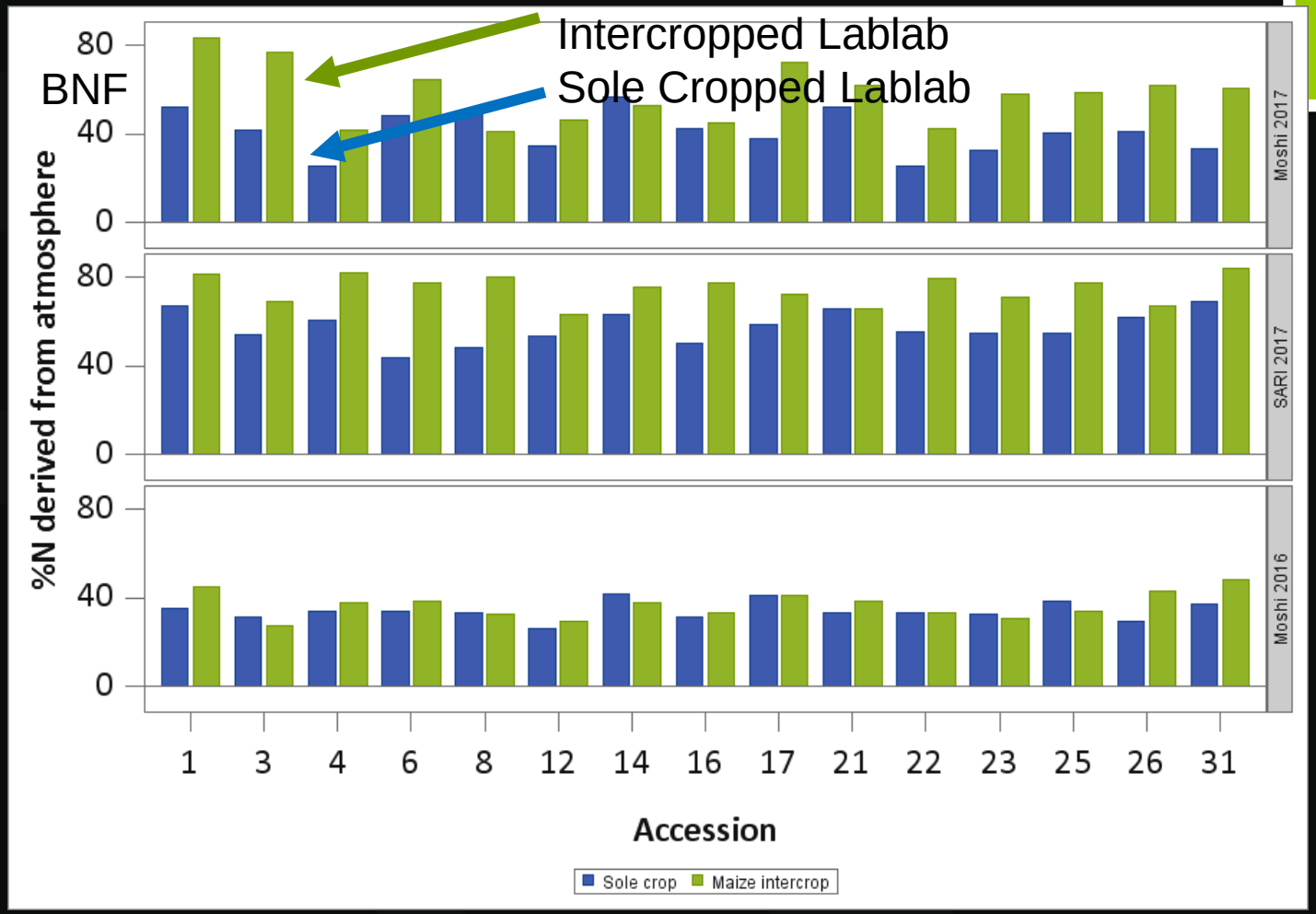
Soil health



Beedy et al., 2010

Intercrops

Lablab N fixation



Alison Nord et al 2018

Not all legumes are alike

Legume diversity

Legume diversity

Pulse: Food, Income

Perennial: Soil Fertility

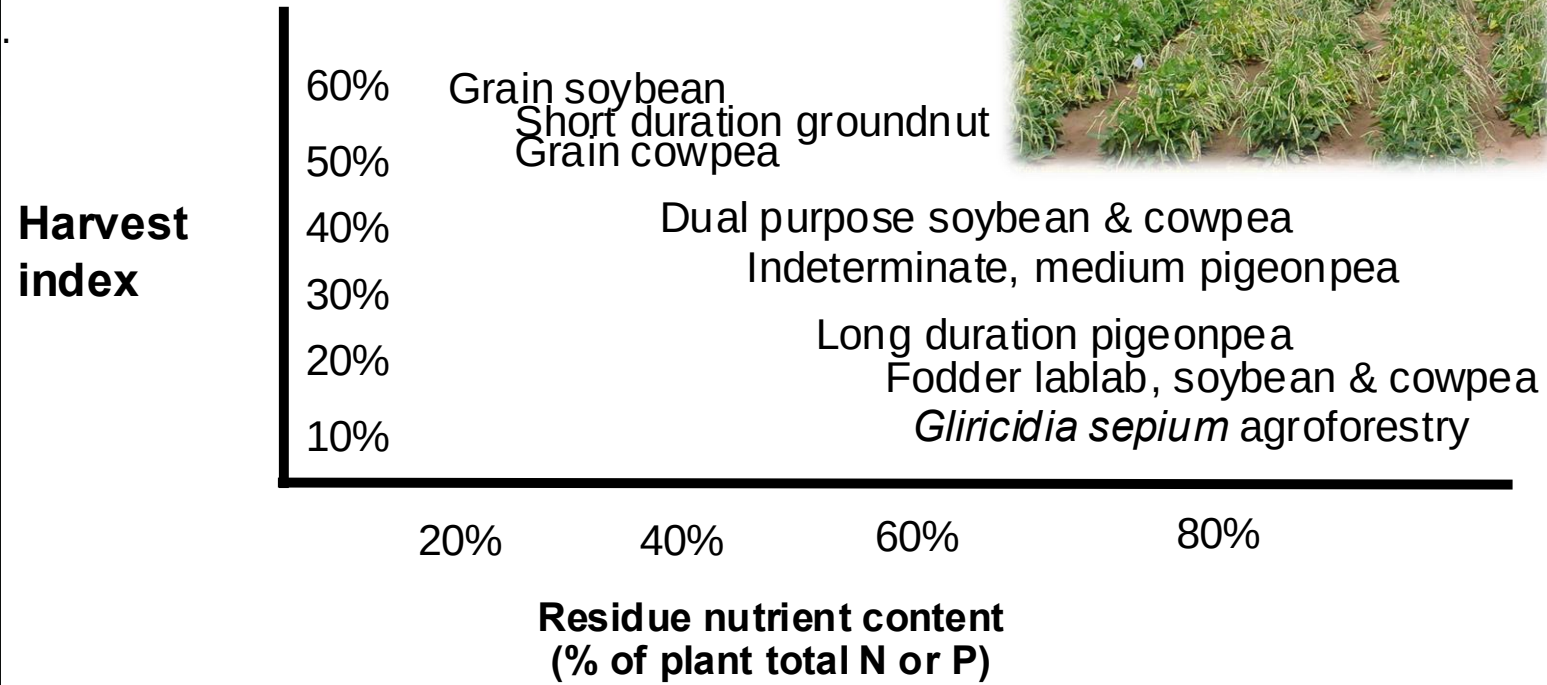
Maize-pulse System

Maize rotated with good agronomy groundnut: Double row

Maize-pulse System

Maize rotated with good agronomy groundnut: high fertilizer response

Tradeoffs: more grain less nutrition



Multipulse

Legume diversity

Pigeonpea
(*Cajan cajanus*)

Multipulses: vines, shrubs

Legume diversity

Pigeonpea
(*Cajan cajanus*)

Climbing bean
(Phaseolus vulgaris)

Runner bean
(*Phaseolus coccineus*)

Lablab
(*Lablab purpureus*)

Legume diversity

Multipulses for Heat

Pigeonpea

Drought tolerant
Excellent intercrop, ratoon
Not flood tolerant
Pod, grain, fodder

Lablab

Drought tolerant
Excellent relay intercrop
Prefers fertile soil
Grain, veg leaf, fodder

Mucuna

Poor soil tolerant
Excellent relay intercrop
fodder

Multipulses for Cool

Climbing bean

Requires stakes/support
Prefers fertile soil
Very high yielding
Pod, grain, veg leaf, fodder

Runner bean

Requires stakes/support
Tolerant of cold, disease
Pod, grain, fodder
Need short day tolerance, larger seeds

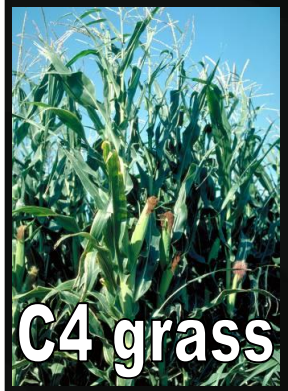
Plant trait tradeoffs

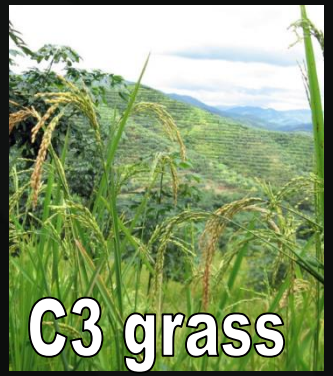
Crop Diversity

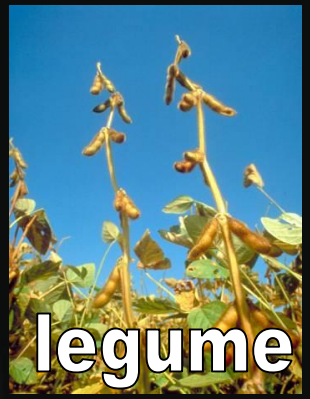
High

Relative Growth Rate

Low







Low-Nutrient

High-Nutrient

Tissue Quality

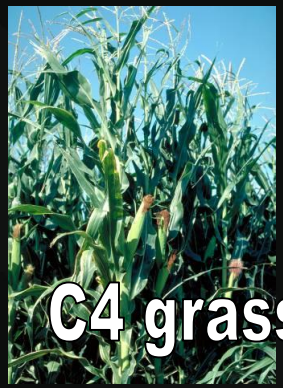
Plant trait tradeoffs

Crop Diversity

High

Relative Growth Rate

Low



+

Low-Nutrient

High-Nutrient

Tissue Quality

Intercrop diversification

Crop diversity

Maize (or Sorghum) + pigeonpea shrub (complementary plant growth habit)

Slow growth of pigeonpea minimizes competition
pigeonpea keeps growing, late season rainfall = pods

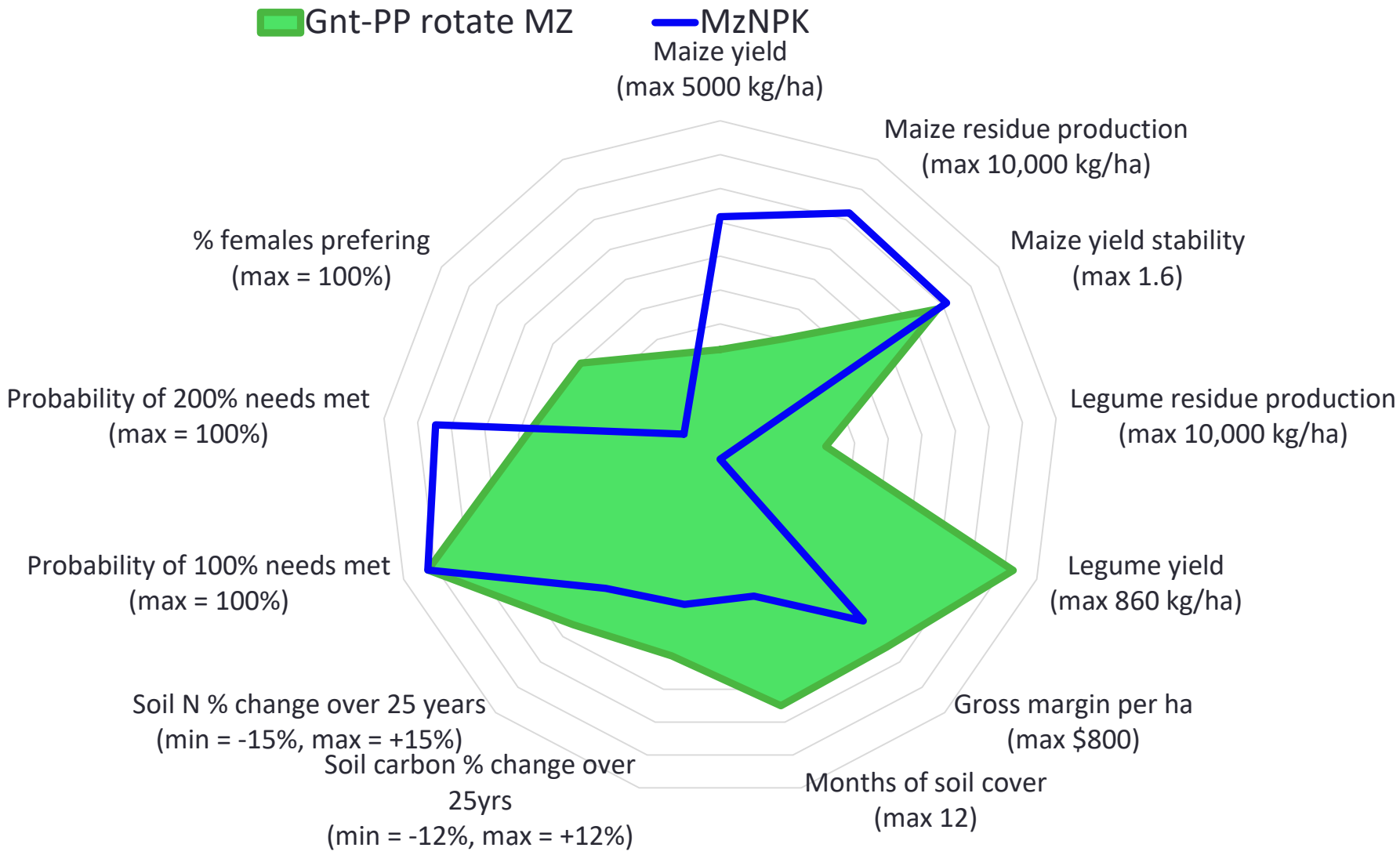
Intercrop diversification

Crop diversity

Groundnut understory + pigeonpea shrub (complementary plant growth habit)

Harvest groundnut, pigeonpea keeps growing, late season rainfall = pods

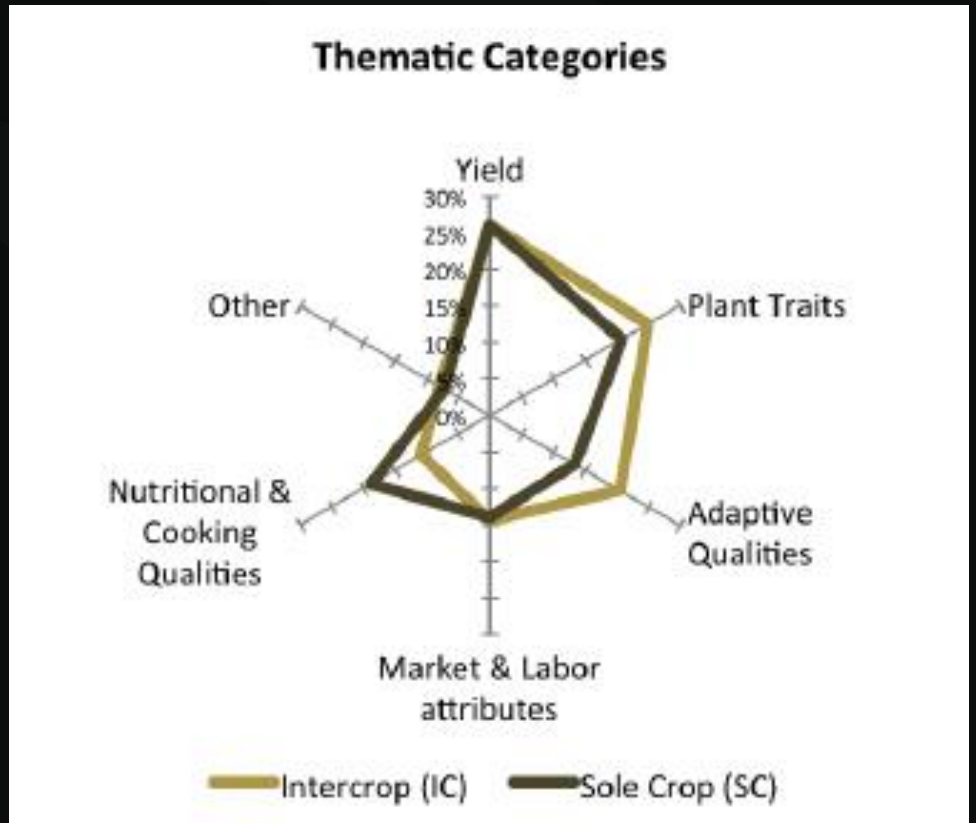
Doubled up legume rotation (DLR)


Gnt-PP rotate MZ
MzNPK
Maize yield
(max 5000 kg/ha)
Maize residue production
(max 10,000 kg/ha)
Maize yield stability
(max 1.6)
Legume residue production
(max 10,000 kg/ha)
Legume yield
(max 860 kg/ha)
Gross margin per ha
(max $800)
Months of soil cover
(max 12)
Soil carbon % change over
25yrs
(min = -12%, max = +12%)
Soil N % change over 25 years
(min = -15%, max = +15%)
Probability of 100% needs met
(max = 100%)
Probability of 200% needs met
(max = 100%)
% females prefering
(max = 100%)

Participatory bean breeding

Future pulses

- **Varieties with shade tolerance traits**
- **Varieties with cooking qualities**



Isaacs et al., 2018

Bean innovations

Future beans

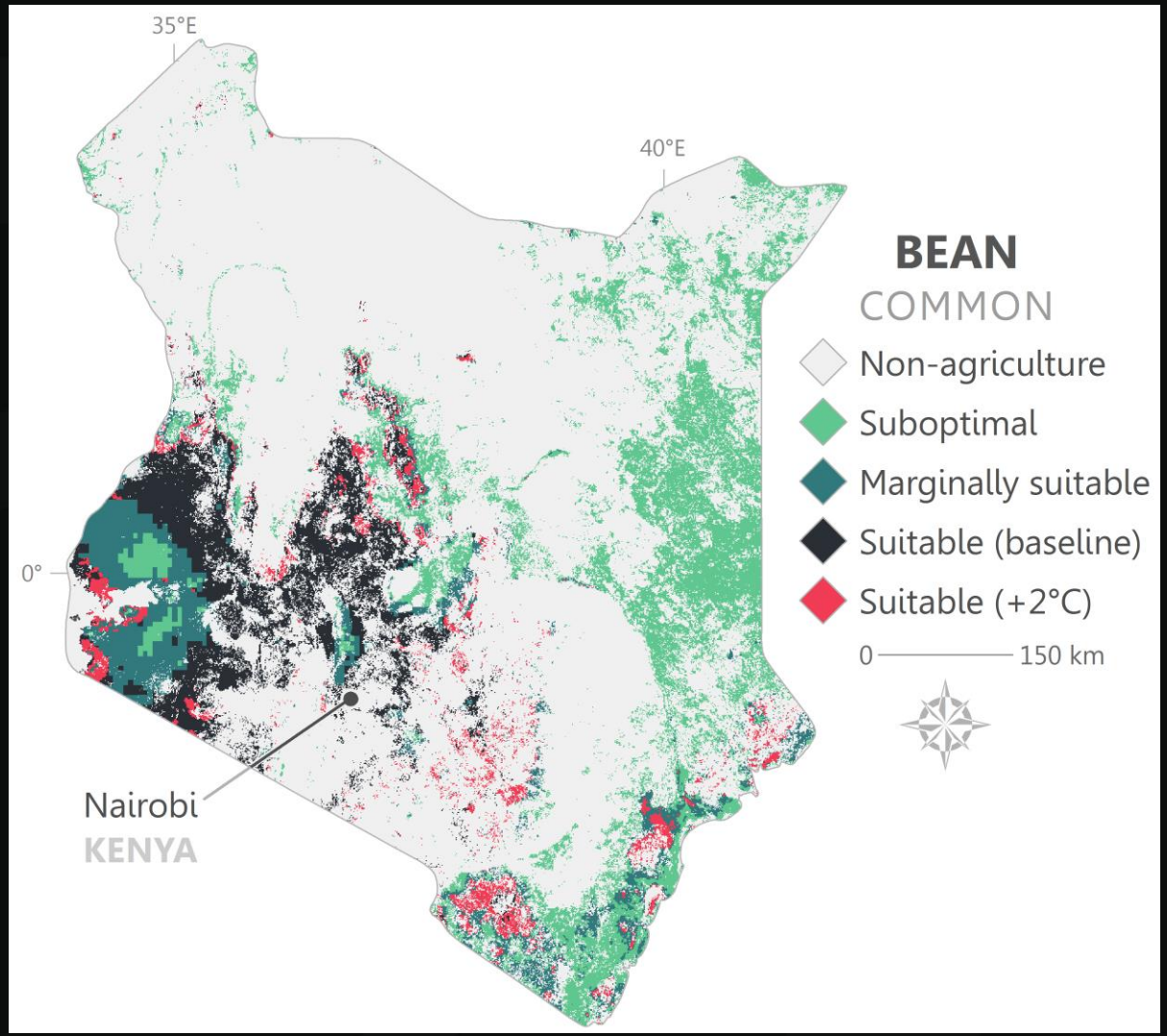
(Genetics)

Cooking time

Cichy et al., 2017

Future beans

(Systems)



Kenya suitability niche mapping for current bean varieties and future heat tolerant varieties (+2°C)

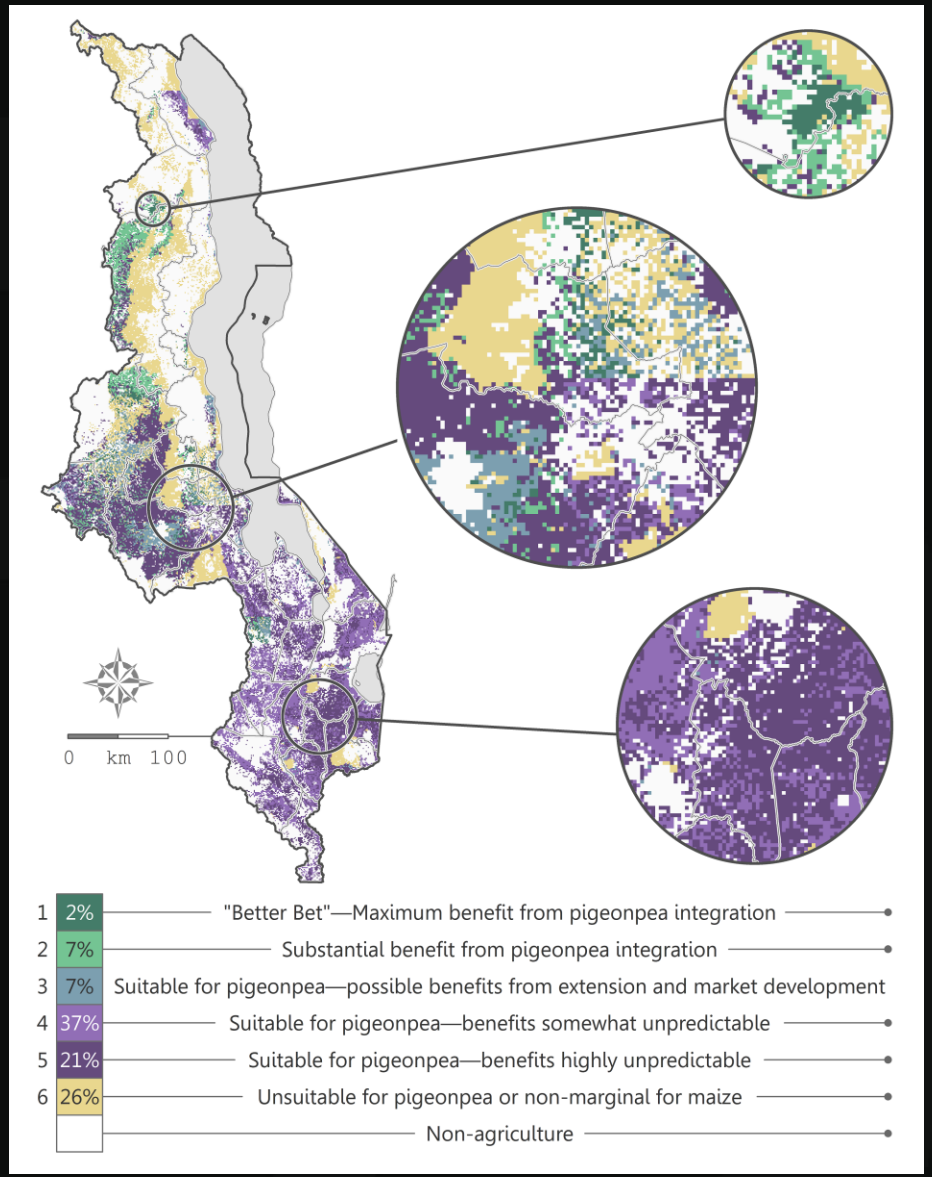
Snapp et al., 2019

Future pulses

Pigeonpea is underexploited

- Pigeonpea-maize intercrop
- Pigeonpea-maize ratoon
- Pigeonpea-groundnut a doubled up legume rotation (DLR) released by the Malawi government as a multipurpose technology

Future pulses

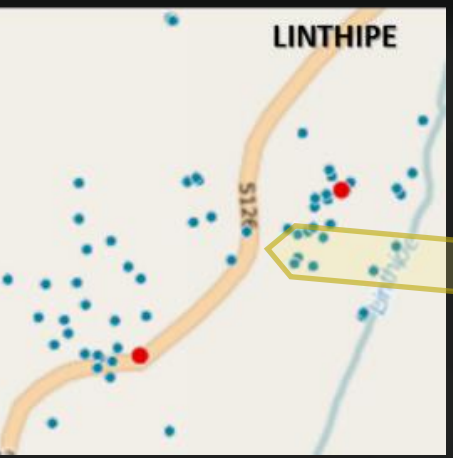


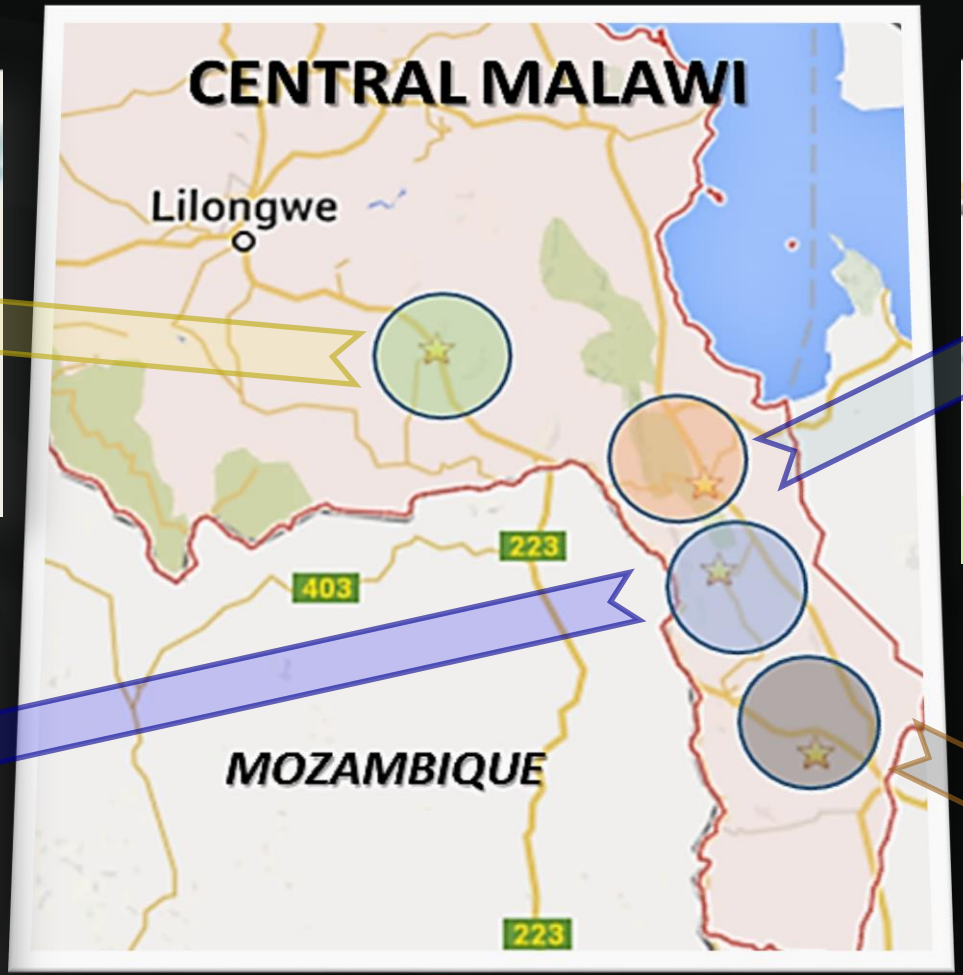
Pigeonpea niche

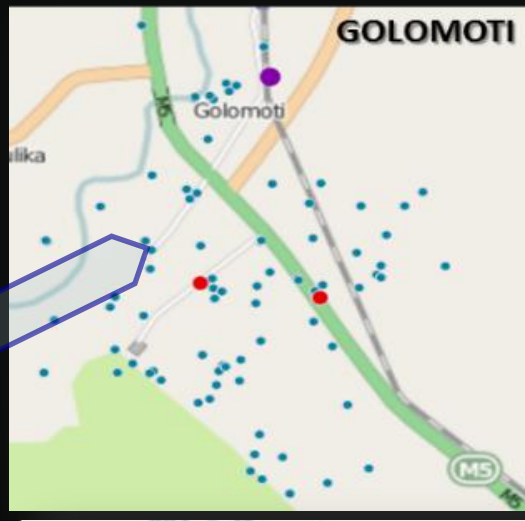
- Under exploited
- Under invested

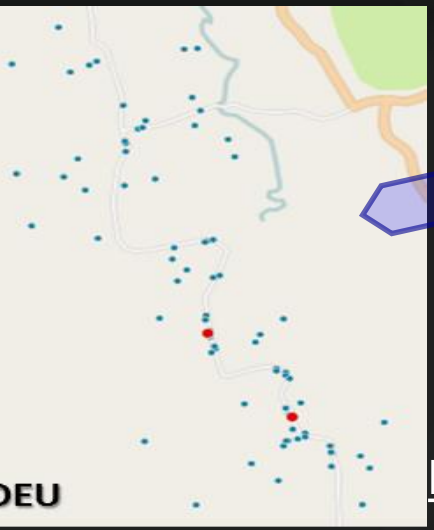
Peter et al., Prof Geo 2017

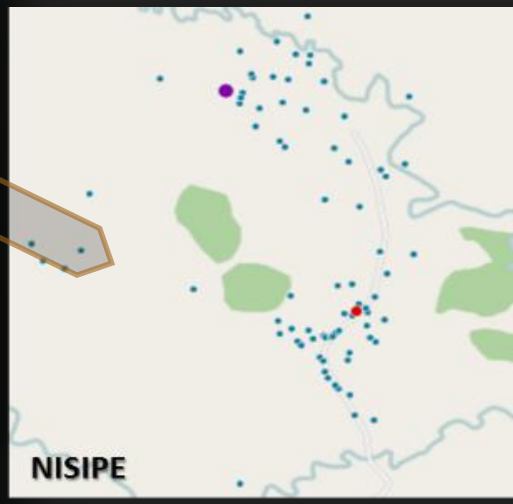
Africa RISING Farmer Participatory Research



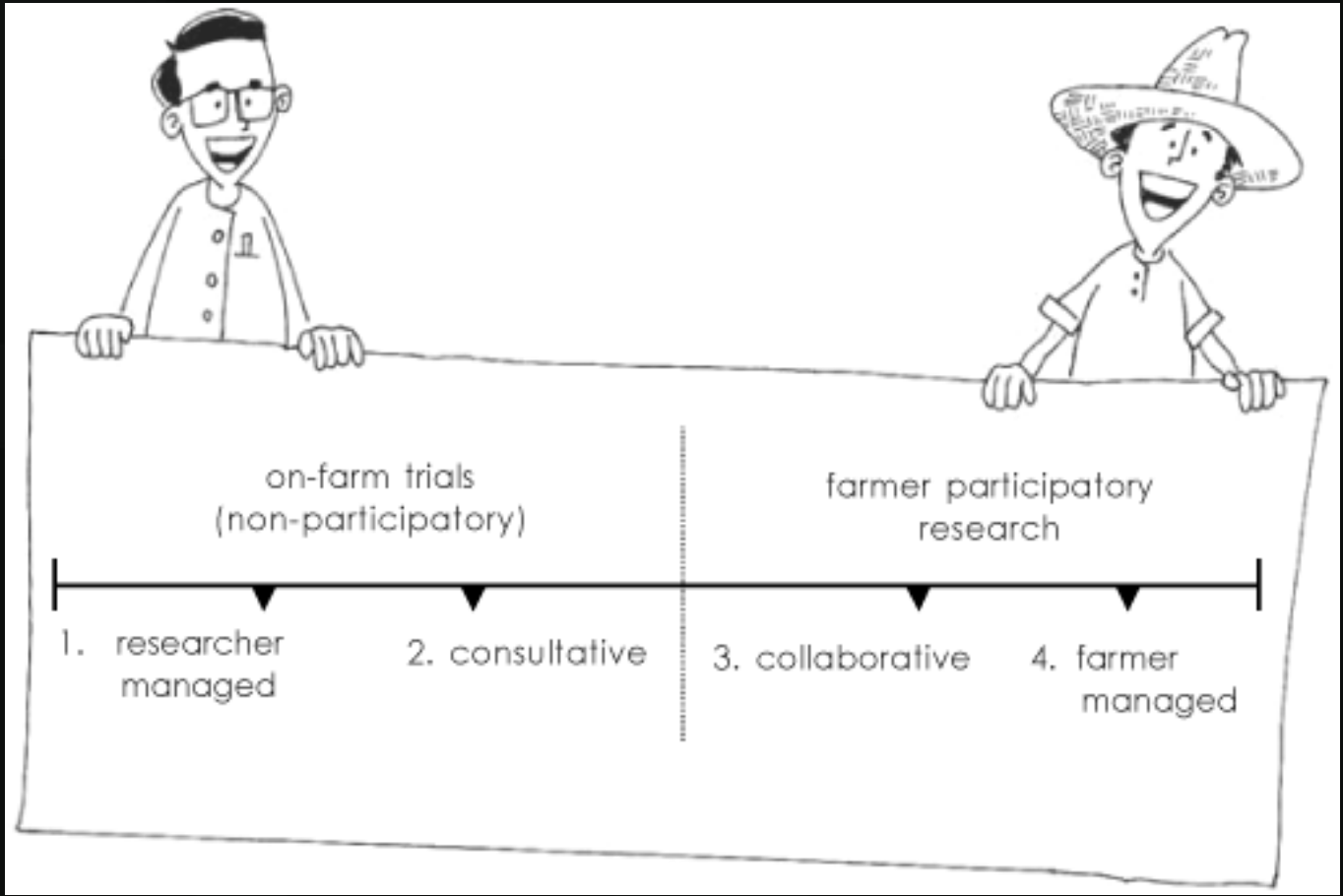








http://globalchangescience.org/eastafricanode



Researcher-Farmer Continuum (Adapted from Biggs 1989)

Continuum of participation in research

Contractual

-farmers hired to run experiments

Consultative

-farmers consulted about design & interpreta-tion

Collaborative

-regular interaction throughout process

Collegial

- researchers strengthen farmers' informal inquiry

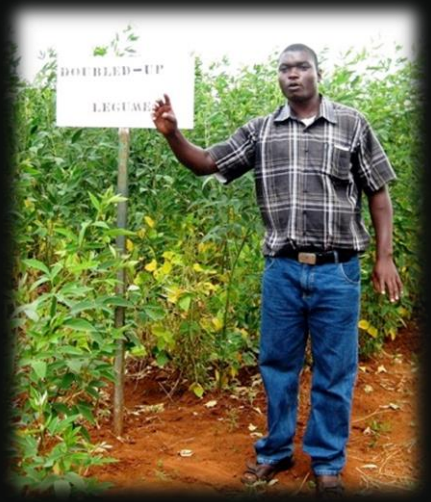
Adapted from Biggs 1989 and Buhler et al. 2005

PAR

Plan

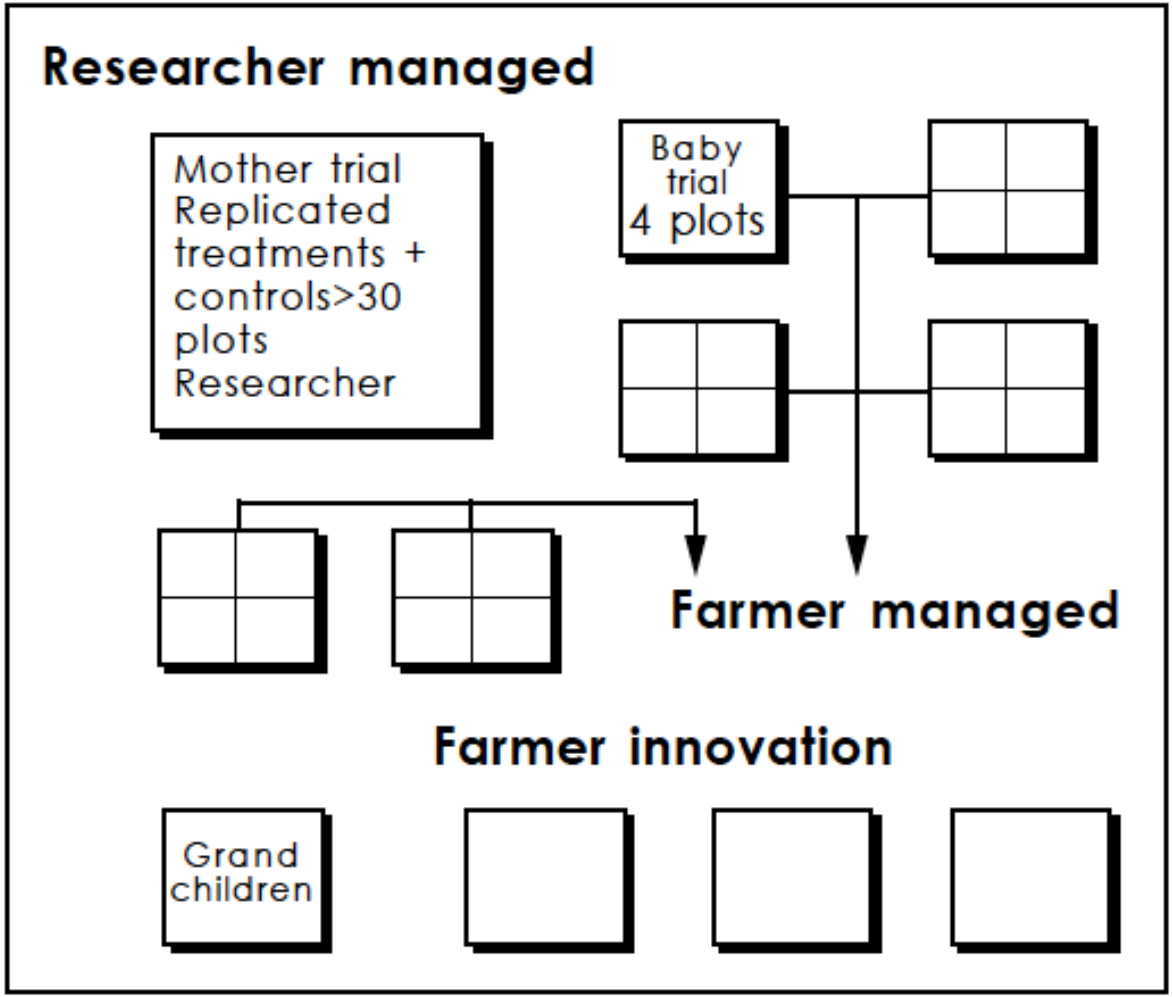
Act

Reflect



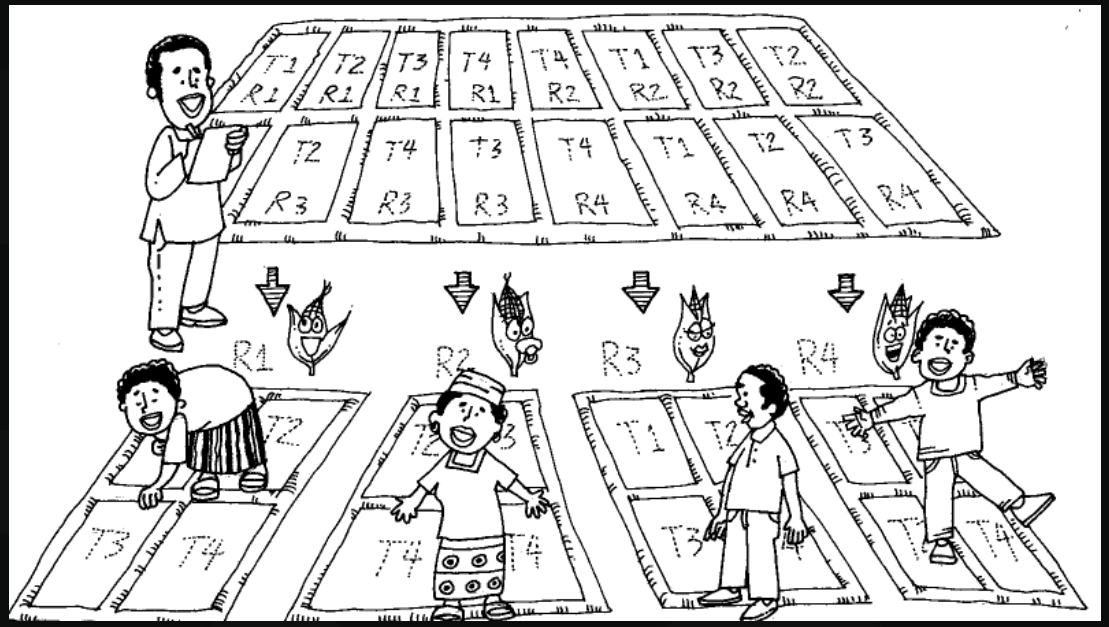
‘Mother and baby’ trial design

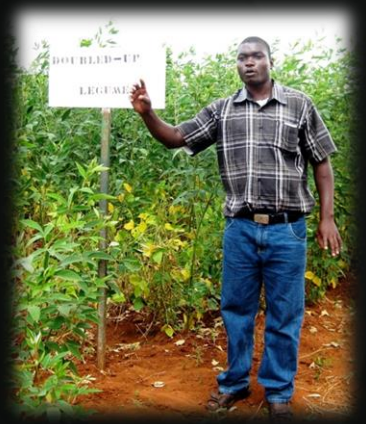
PAR



Snapp, 1998

PAR


T1 R1
T2 R1
T3 R1
T4 R1
T4 R2
T1 R2
T3 R2
T2 R2
T2 R3
T4 R3
T3 R3
T4 R4
T1 R4
T2 R4
T3 R4
R1
R2
R3
R4



Farmer ranking ‘pairwise’

PAR

Farmer name: _____ Gender: _____ Location: _____

Farmer expert: Yes ____ No_____ Farm size: _____(acres farmed)

Market: Local _____ Wholesale_____ Major crops:_____

Ranking of technologies		Fill in with letter of technology which is better (for example: if the farmer thinks that A. local variety is better than C. new variety 2, fill in A in the square). There should be one letter in each square.			
		A	B	C	D
A	Farmer variety				
B	New variety 1				
C	New variety 2				
D	New variety 3				

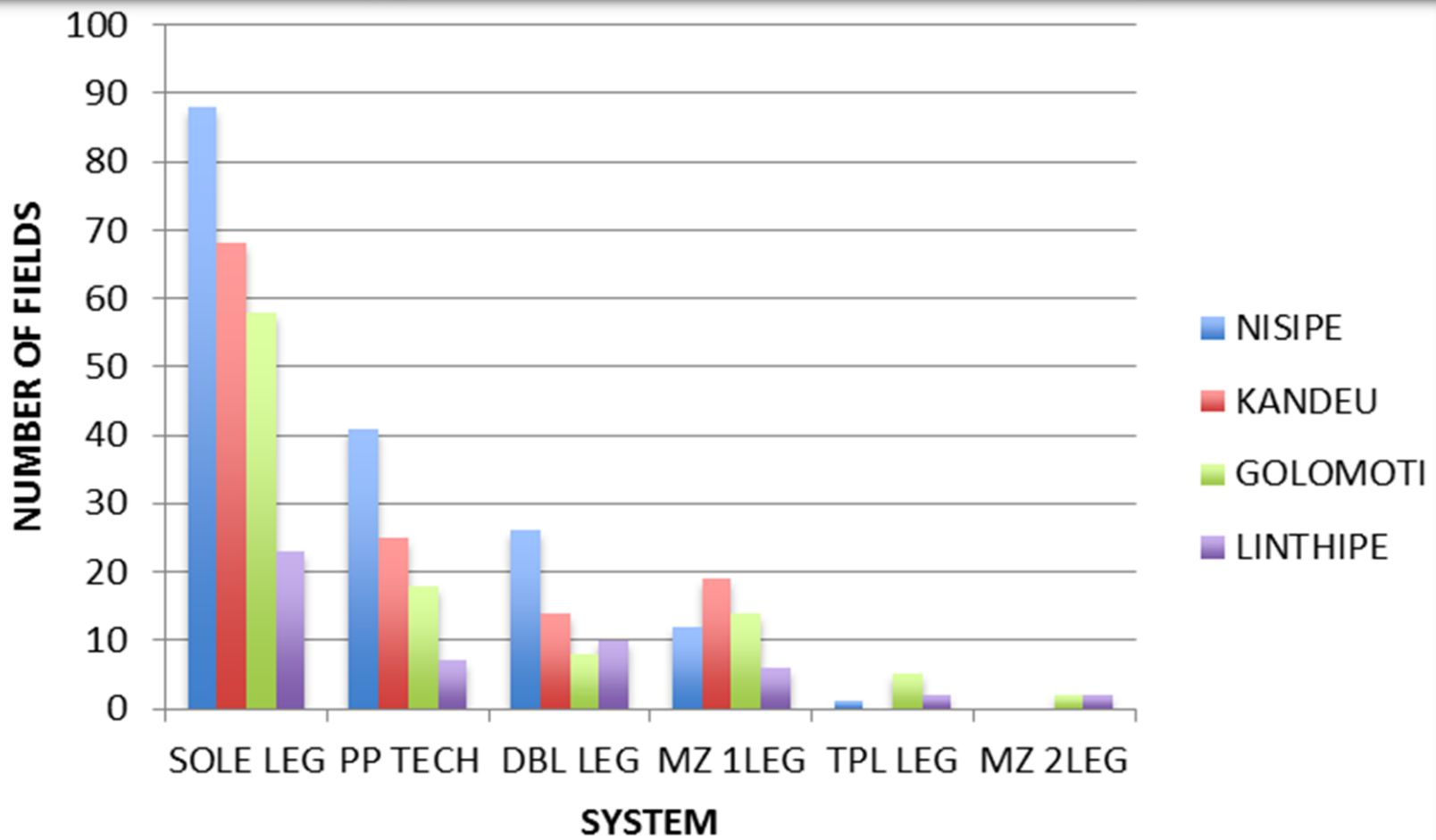
(Snapp et al., 2002)

PAR

Understanding variation

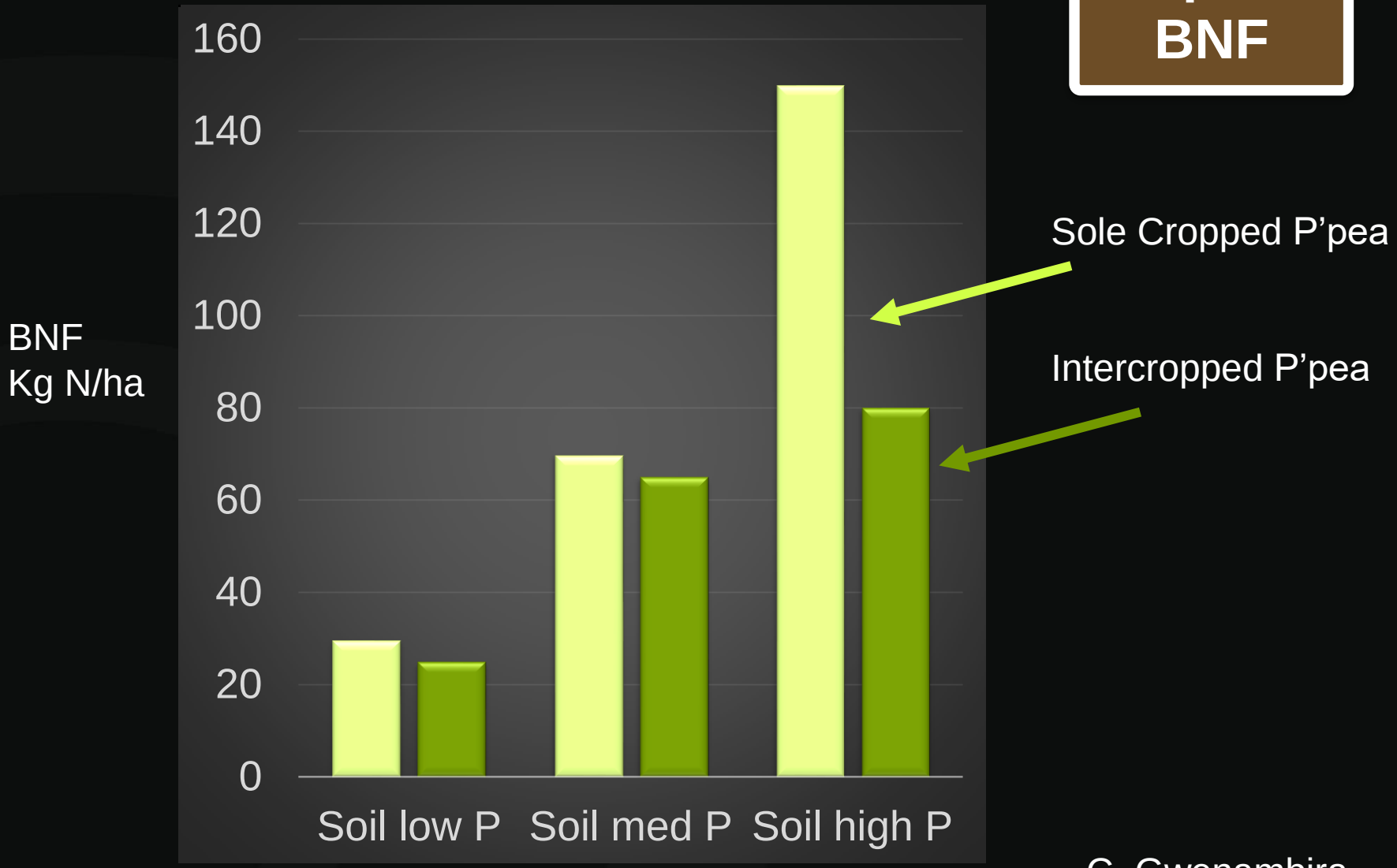
	Female	Male
Variety 1 positive	+ Cooks easily + High yielding	+ High yielding
Variety 1 negative	- Poor taste	- Disease susceptable
Variety 2 positive	+ Good for local dish	+ High market price
Variety 2 negative	- Requires fertilizer	- Low yield

Farmer Expts



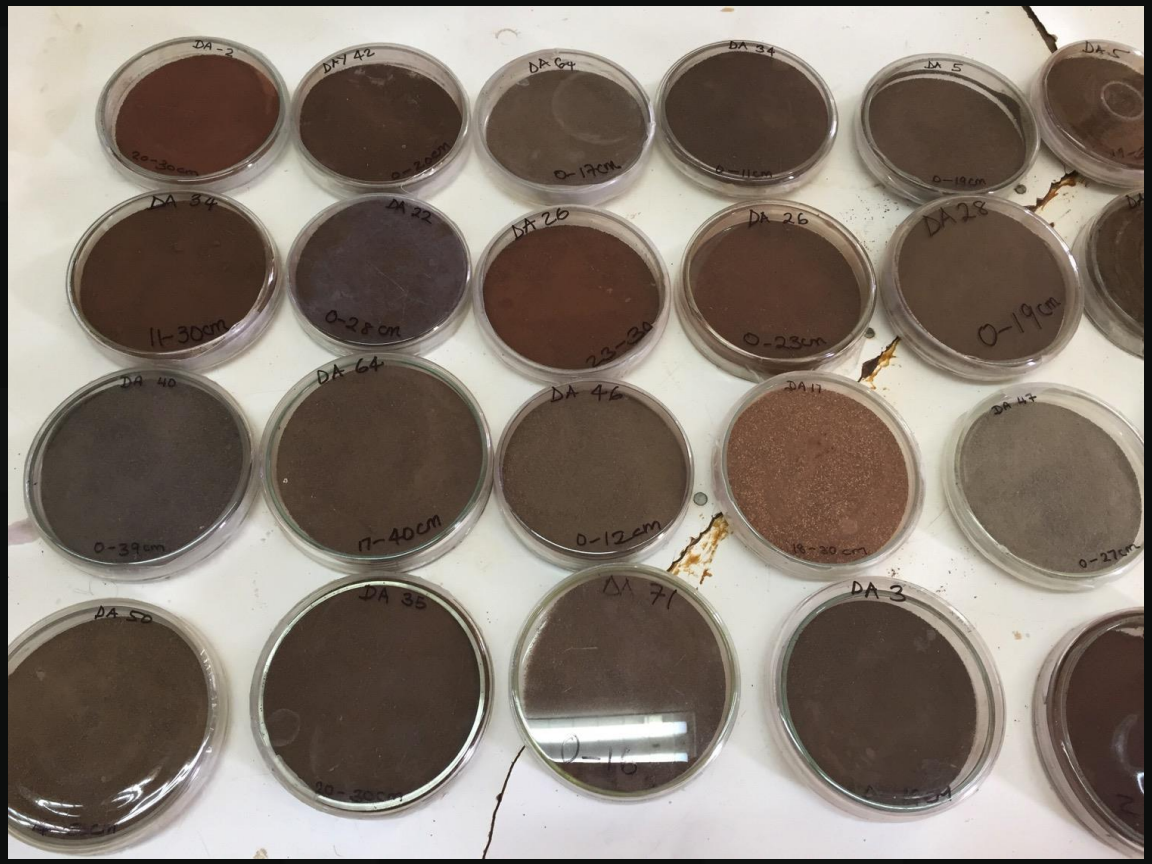
Doubled up legume rotation (DLR)

Ppea BNF



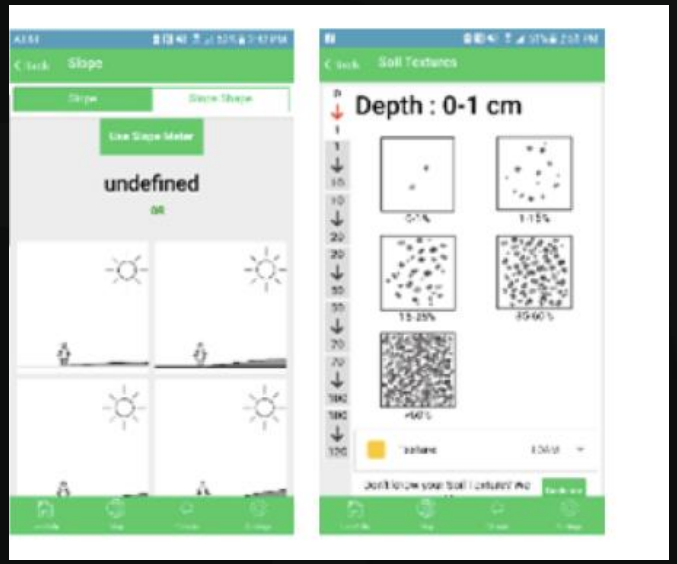
C. Gwenambira

Soil health



Soils vary – where are legumes needed?

Targeting through soil app



Multipulse Systems

LandPKS App → ID soil → Hyper local recommendation → Try out → Disseminate findings → LandPKS App

Mobile phone app connected to global Databases, soils, climate

A system for sharing/interpreting data

- Ferric Luvisols, compaction layer
- Recommendation: Pigeonpea DLR + fertilizer

Pulse future

Targeting thoughts

Farmers linked to markets, good soils:

- Grain legume rotations, fertility/rhizobia
- Cool areas: climbing beans

Farmers with few resources or poor soils/striga:

- Doubled up legume rotation (Ppea+gnut)
- Multipulses (lablab, long season cowpea)
- Biomass for livestock, mulching vegetables

A multipulse future?