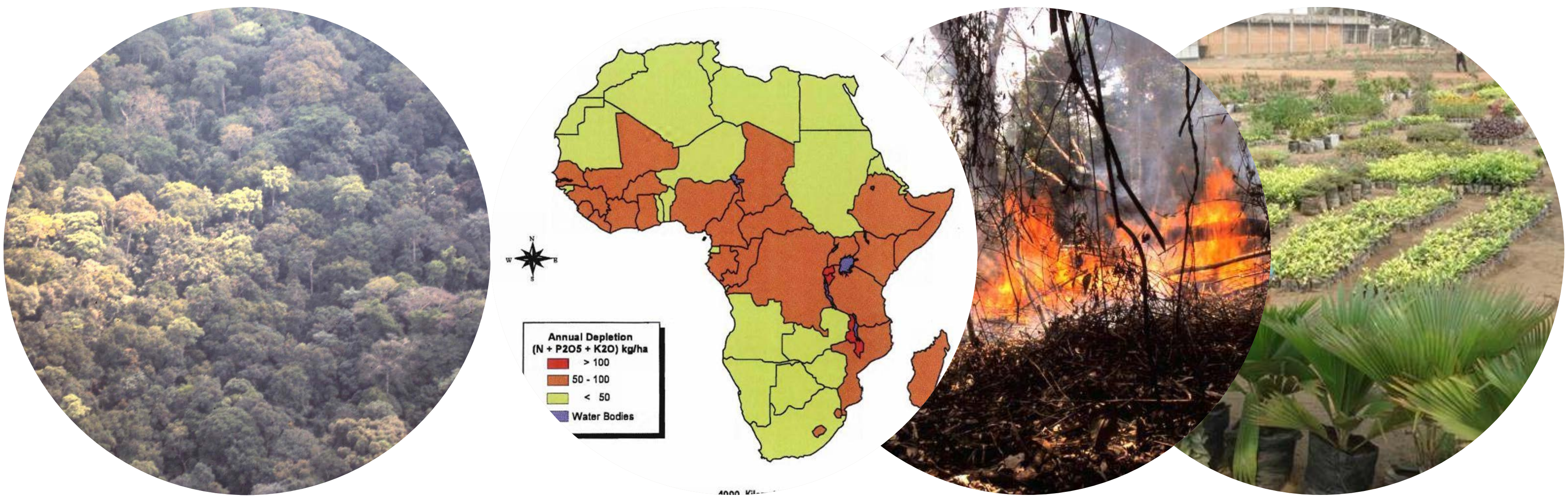
Soil nutrient management

ISRIC WSA course

21 May, 2015, Henk van Reuler



WAGENINGEN UR
For quality of life

Content

- Introduction
- Main soil properties
- Soil and Plant analysis
- Africa
- Case study
- Integrated Soil Fertility Management
- Concluding remarks

Introduction

- Soil quality
- Soil fertility

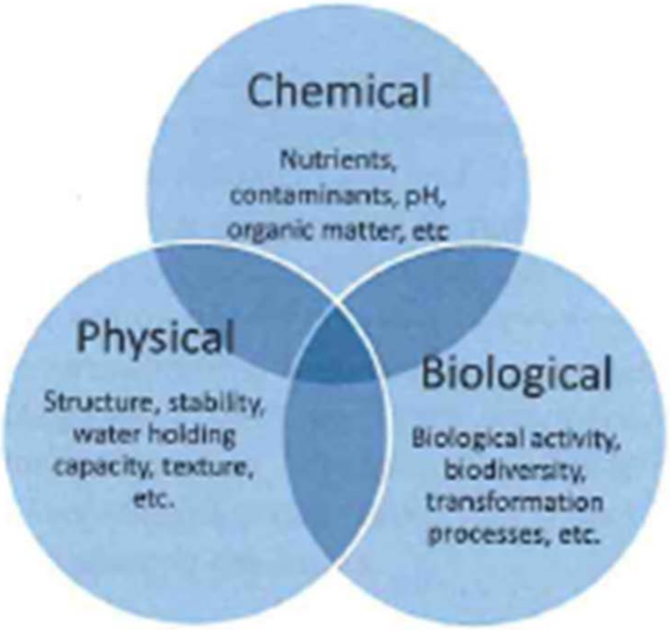
Introduction

- Soil quality is the capacity to function
- Soil quality is how well soil does what we want it to do
- Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation

Introduction

- Soil fertility is the capacity
 to sustain biomass production

  - Physical soil fertility
  - Chemical ,,
  - Biological ,,



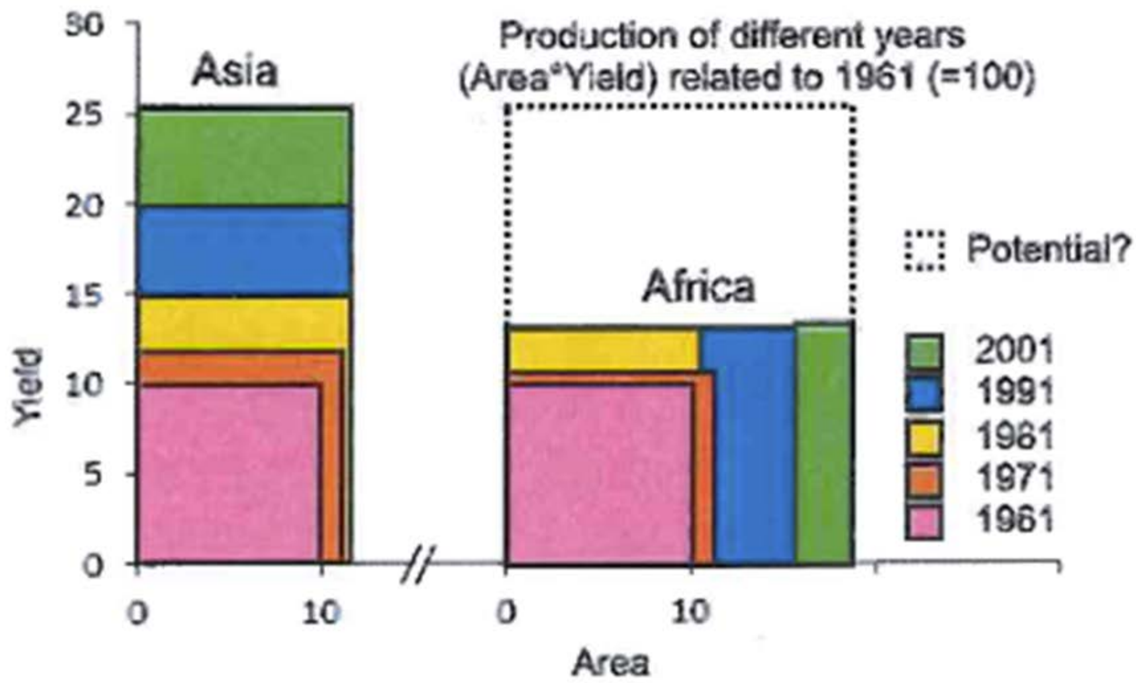
Chemical soil fertility can relatively easily be changed

Introduction

- Chemical soil fertility
  - Storage, retain and release of nutrients in relation to crop growth

- Soil properties
  - SOM, pH, CEC and base saturation, clay content, type of clay, weatherable minerals, biological activity

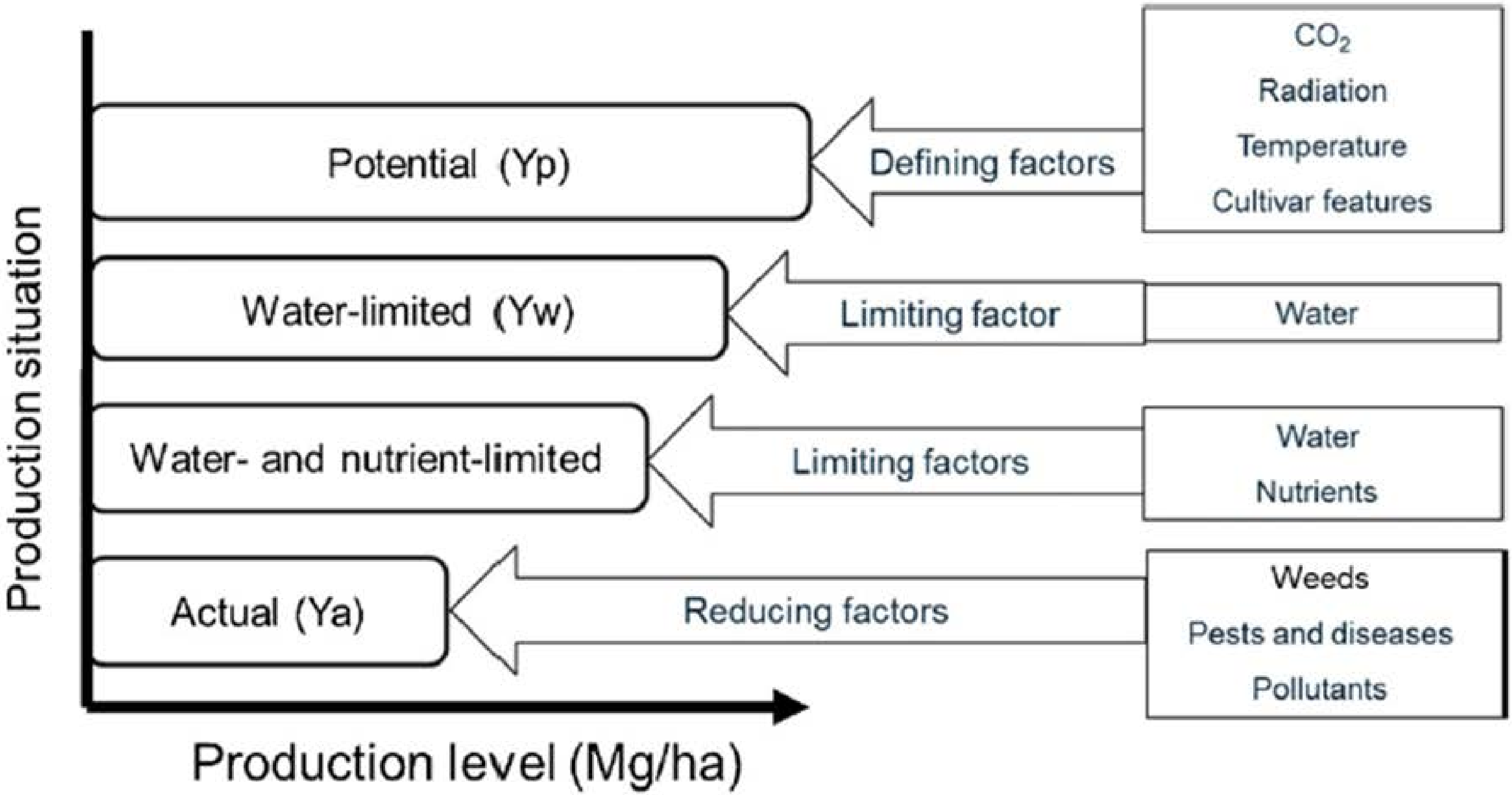
Introduction



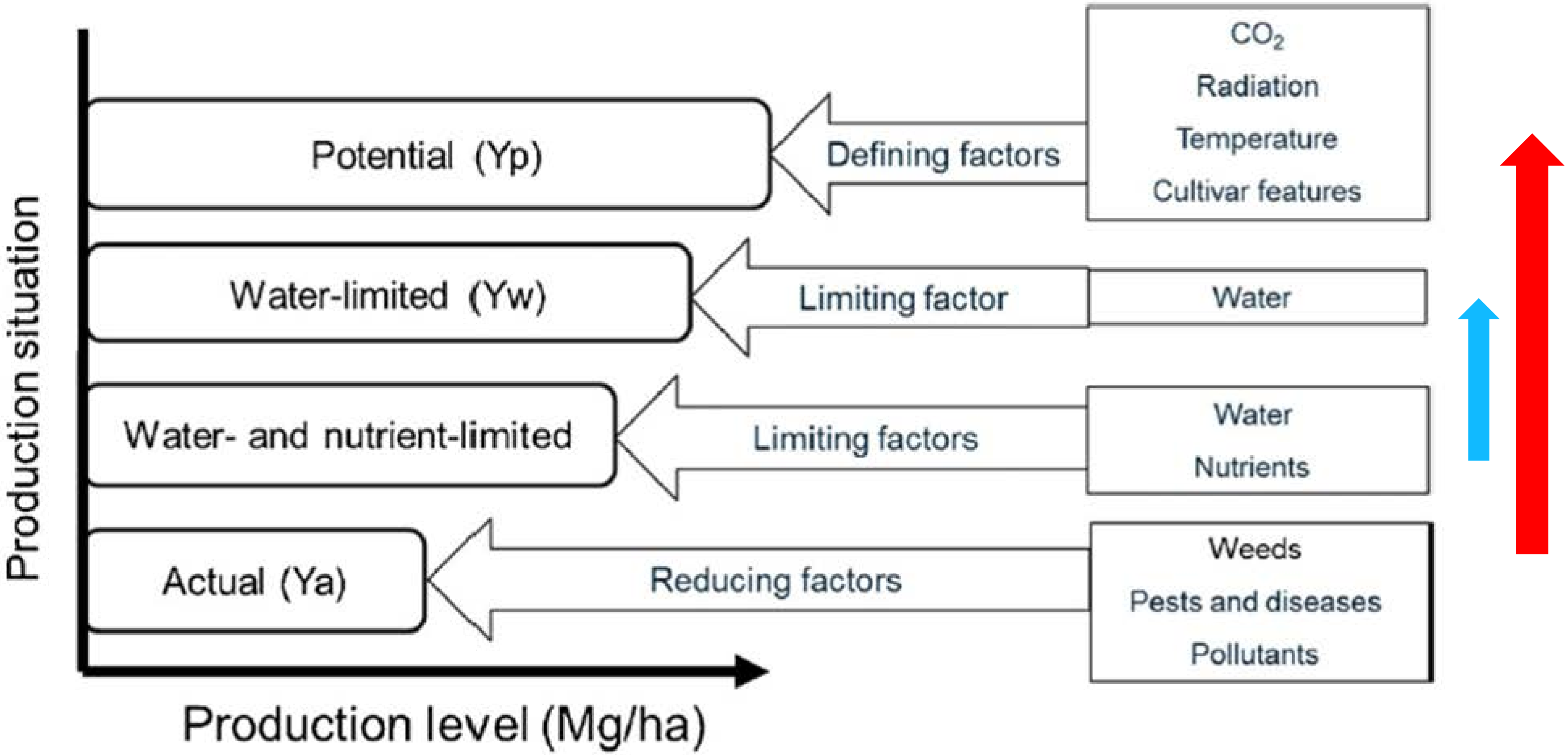
Intensification Asia versus expansion in Africa

(De Jager, 2013)

Introduction



Introduction



WAGENINGEN UR
For quality of life

Introduction

General transition stages in nutrient management.

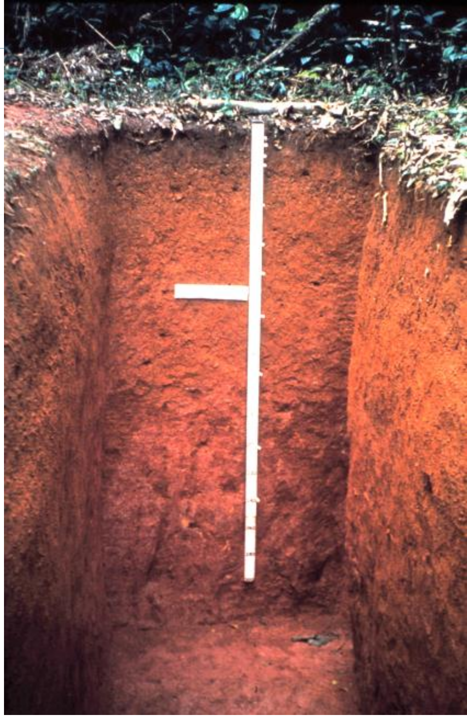
Stage	Description	Examples
I	Traditional extensive systems	Traditional systems in remote areas of Africa and Southern America; Europe before the Middle Ages
II	Intensifying systems	Most smallholder systems in Africa and Asia; Europe during the Middle Ages
III	Input based systems	Commercial farms in Asia, Africa and South America; Europe and USA
IV	Regulating systems	Europe and USA since 1980's
V	Balanced systems	Niche areas of pioneer farms, organic farming, agro-ecological approaches

(Van Beek et al.,2014)

Inherent soil fertility levels of major soil groups

LOW	MODERATE	HIGH
Arenosols	Regosols	Fluvisols
Planosols	Andosols	Gleysols
Acrisols	Calcisols	Vertisols
Ferralsols	Greyzems	Kastanozems
Podzols	Luvisols	Chernozems
Alisols	Podzoluvisols	Phaeozems
Plinthosols	Nitisols	Cambisols
	Lixisols	
	Histosols	(FAO, 1993)

Main soil properties



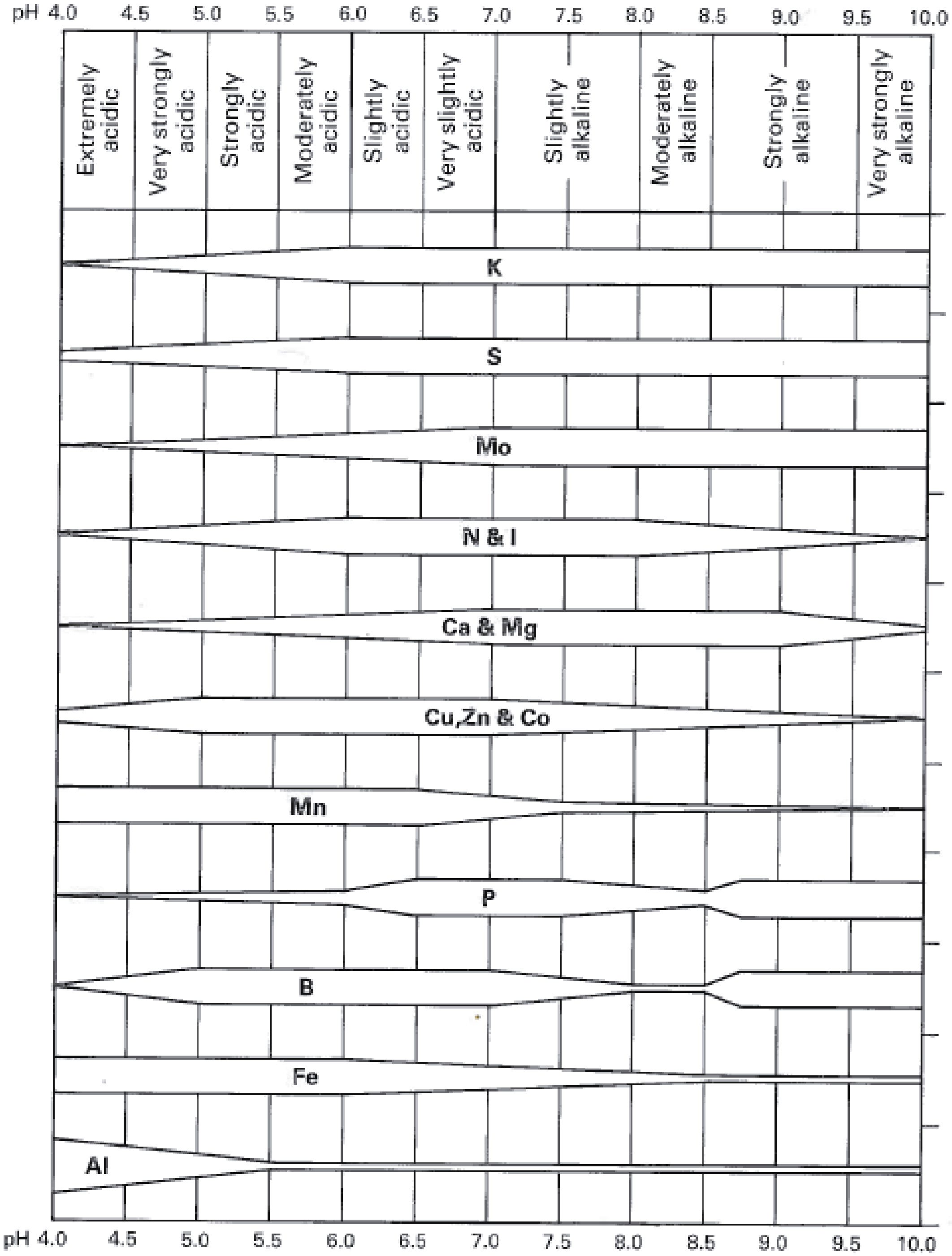
- Most tropical soils are old
    - Presence of volcanoes
- Good physical properties
- Chemical properties
    - Low nutrient reserve — <10% weatherable minerals in the sand and silt fraction
    - Low pH — exchangeable Al
    - Low CEC — mainly kaolinite
    - Al/Fe oxides — P fixation
    - SOM

WAGENINGEN UR
For quality of life

Main properties

Sanchez and Logan (1992)

- Tropical soils vary in their chemistry and fertility
- 43% of the tropics are covered by Oxisols and Ultisols
- Main difference management because of different climate, crop species and socioeconomic conditions



Notes:

K: Deficiencies liable at low pH.

S: Some reduction at low pH, but S bacteria still active.

Mo: Similar to K.

N & I: Bacterial fixation curtailed below about pH 5.5.

Ca & Mg: May be deficient in acidic soils. Non-available at very high pH.

Cu, Zn & Co: May be toxic in acidic soils and deficient where pH › 7.0.

Mn: Similar to Cu, Zn & Co.

P: Liable to be fixed by Fe, Al, Mn at low pH; insoluble forms at high pH, also Ca inhibition.

B: Over-liming may cause deficiency. Toxicity dangers at very high pH.

Fe: Similar to Cu, Zn & Co.

Al: Liming to pH 5.5 recommended to avoid toxicity dangers at low pH.

(Truog,1948)

Main properties

TYPE	LATTICE	NUTRIENT RESERVES	CEC at pH 7 me/100 g clay
Kaolinite	1 : 1	Low	< 10
Illite	2 : 1	K	15 – 40
Montmorillonite	2 : 1	Mg, K, Fe etc.	80 – 100
Organic matter	-	-	about 200

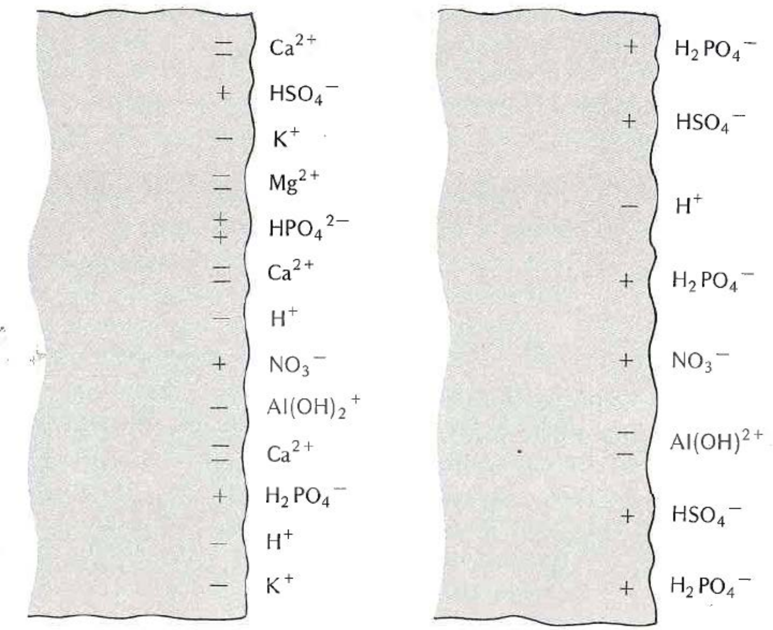
(Landon,1984)

Main properties

TYPE	LATTICE	NUTRIENT RESERVES	CEC at pH 7 me/100 g clay
Kaolinite	1 : 1	Low	< 10
Illite	2 : 1	K	15 – 40
Montmorillonite	2 : 1	Mg, K, Fe etc.	80 – 100
Organic matter	-	-	about 200

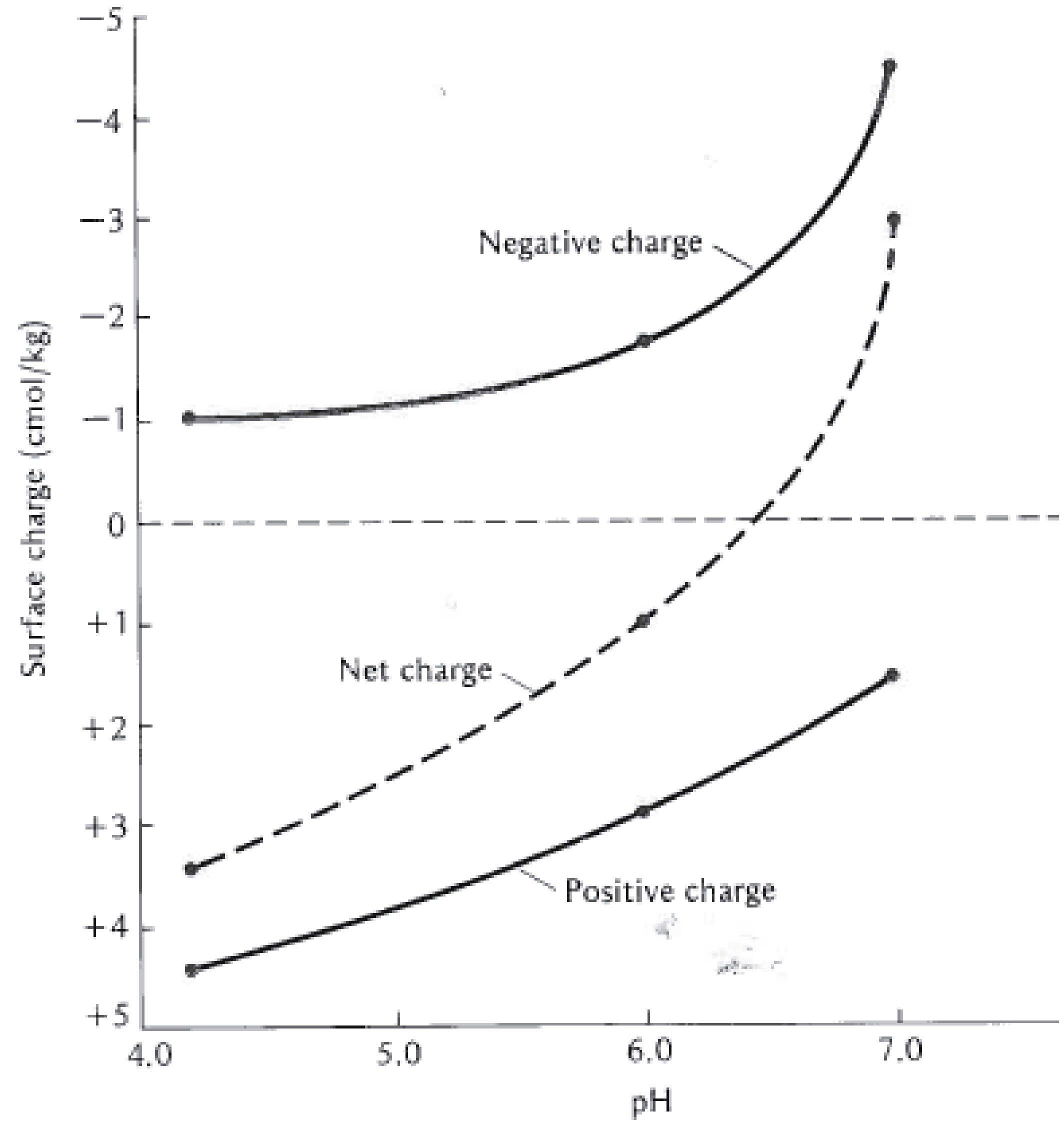
(Landon,1984)

Main properties



(a) 1:1-type silicate clay particle

(b) Iron/aluminum oxide particle

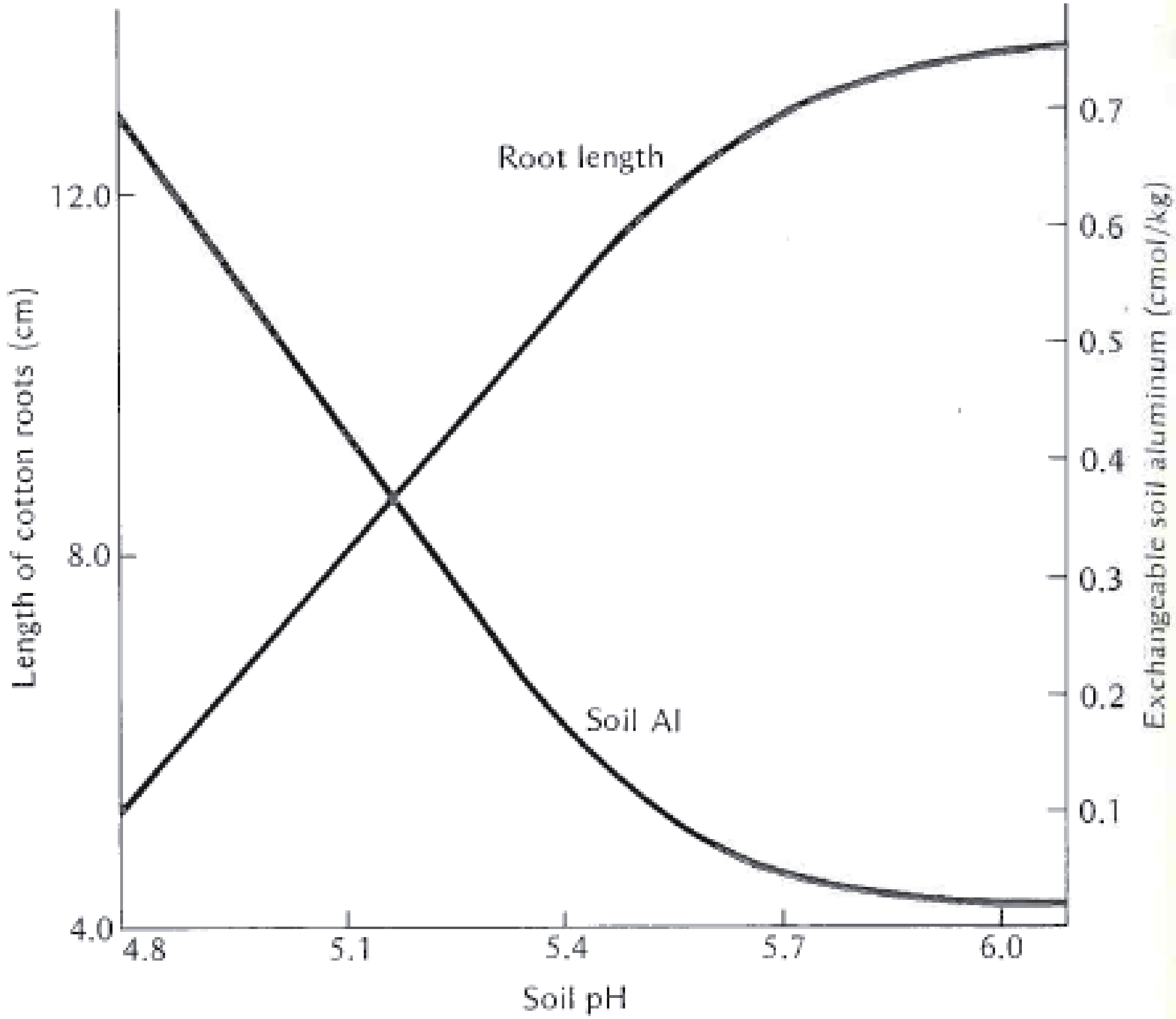


(Van Raij and Peech,1972)

$$\rangle Al{-}OH_2^+ + H_2PO_4^- \rightarrow \rangle Al{-}H_2PO_4 + H_2O$$

Soil solid — Soil solution — Soil solid — Soil solution

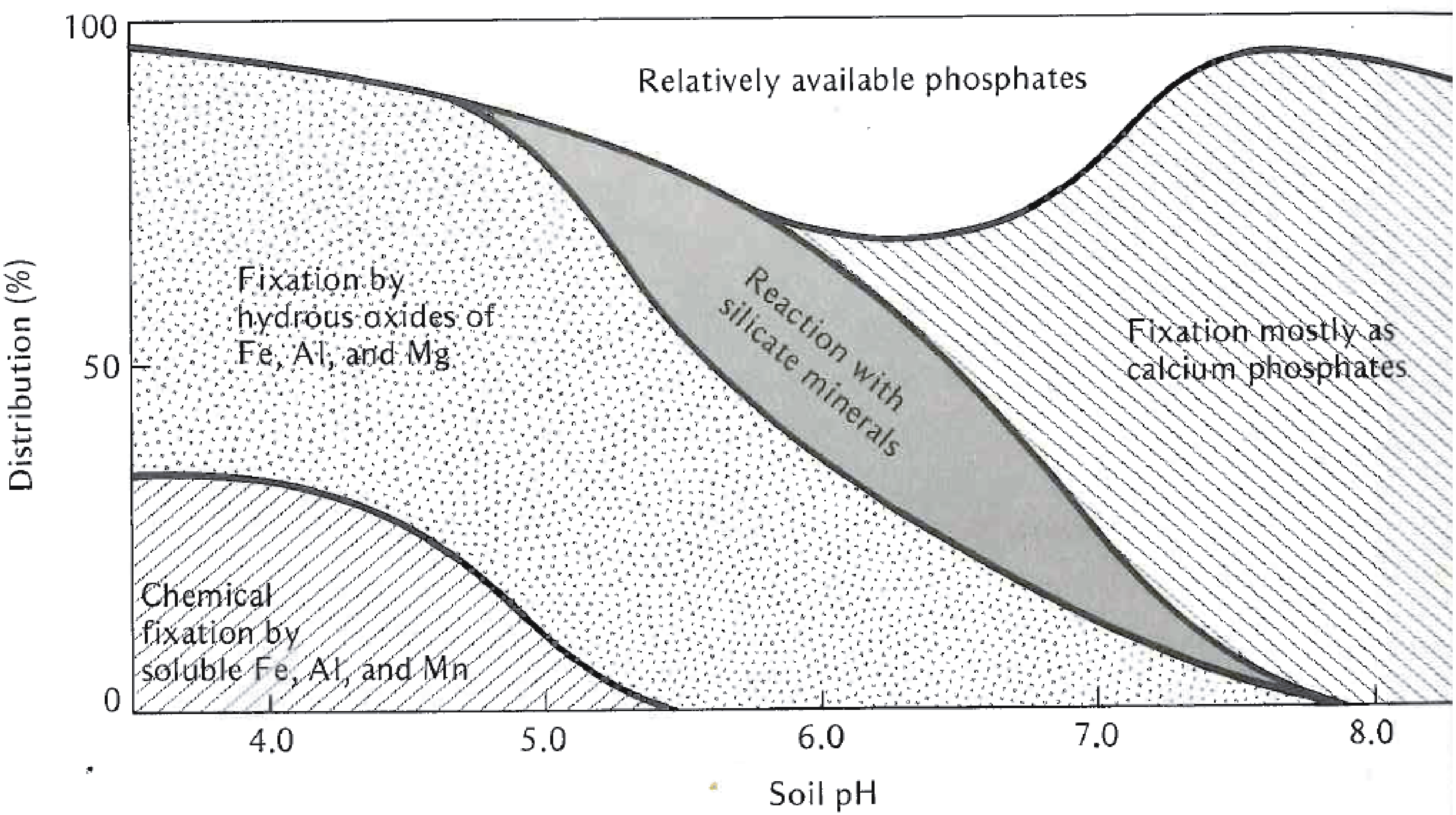
Main properties



- Al toxicity pH< 5.3

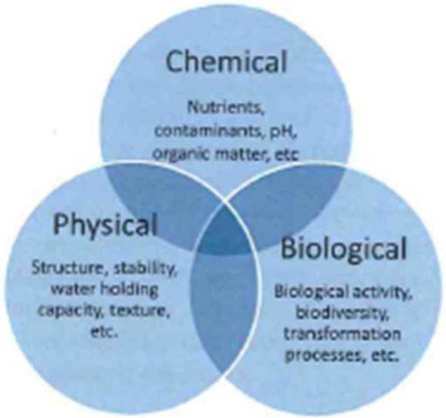
(Adams and Lund, 1966)

Main properties



(Brady,1984)

Main properties

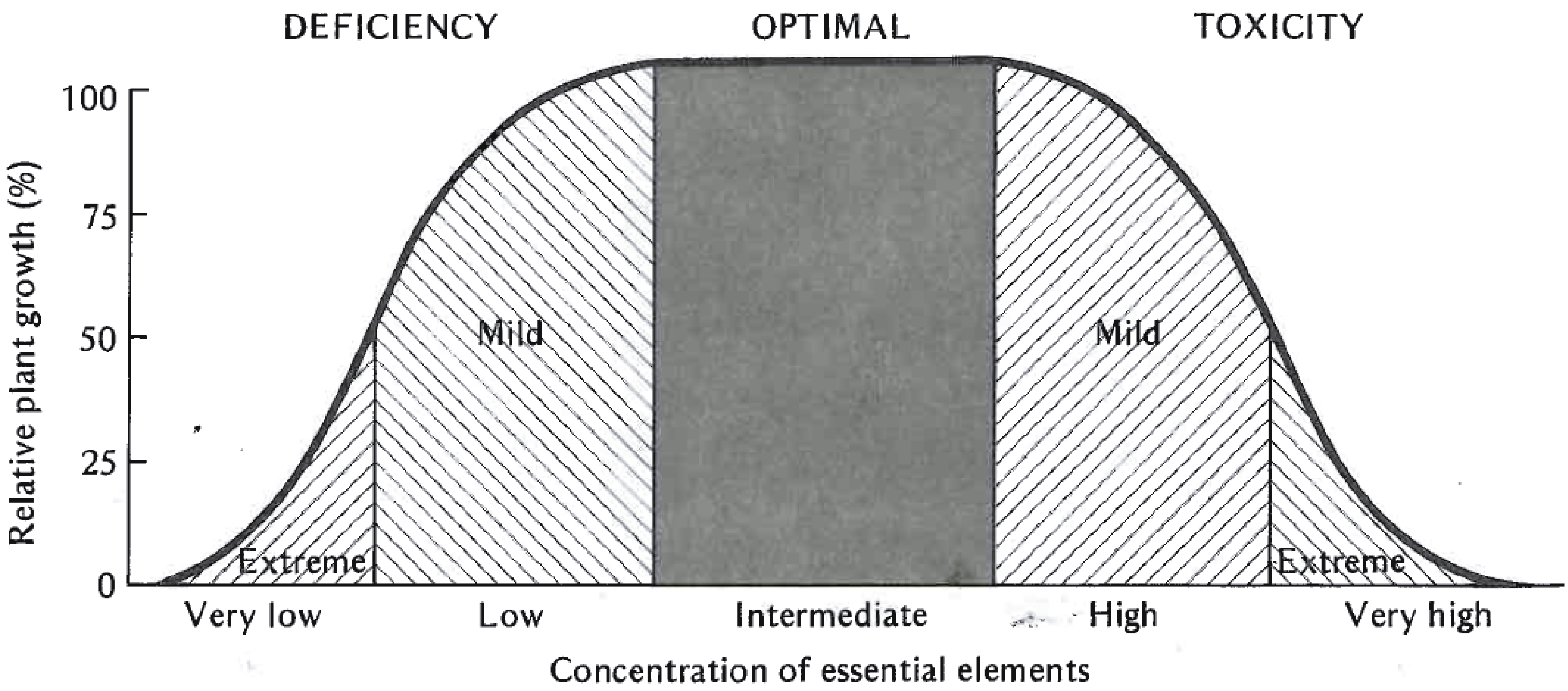


Soil organic matter content (SOM)

- Physical -, Chemical – and Biological soil fertility
- SOM equilibrium of input and decomposition
- Climate, soil, topography and time
- Humid tropics: high production – high decomposition
- No major differences in SOM tropical – temperate soils
- Increase of SOM requires annual application of very high amounts of organic materials

WAGENINGEN UR
For quality of life

Soil and Plant analysis



Soil and Plant analysis

- Chemical soil analysis
  - Available plant nutrients
  - Correlation with crop yield
    - Annual crops
    - Perennial crops
  - Methods adapted to local/regional conditions
  - E.g. P-$CaCl_2$, P-water, P-Olsen, P-Bray, P-Mehlich,…, P-total
  - Basis for fertilizer guidelines
- Errors
- Exchange programmes for quality control

Soil and Plant analysis

- Plant analysis
    - Total analysis
        - Total plant
        - Harvested product
        - Leaf analysis
- Replacement of exported nutrients
- Exchange programme for quality control

Soil and Plant analysis

Recovery fraction – part absorbed of nutrient applied

(+P uptake – P0 uptake) / P application rate

Common fractions or %

0.5 or 50% for fertilizer-N; 0.1 or 10% for fertilizer-P

Measures

N Split application

P Localized application

Soil and Plant analysis

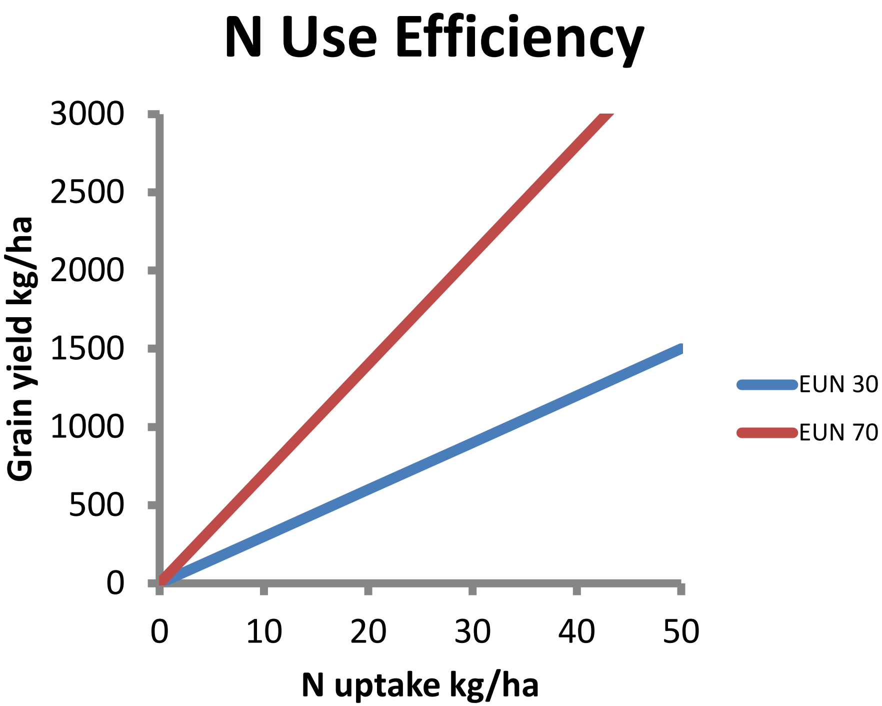
Nutrient Use Efficiencies

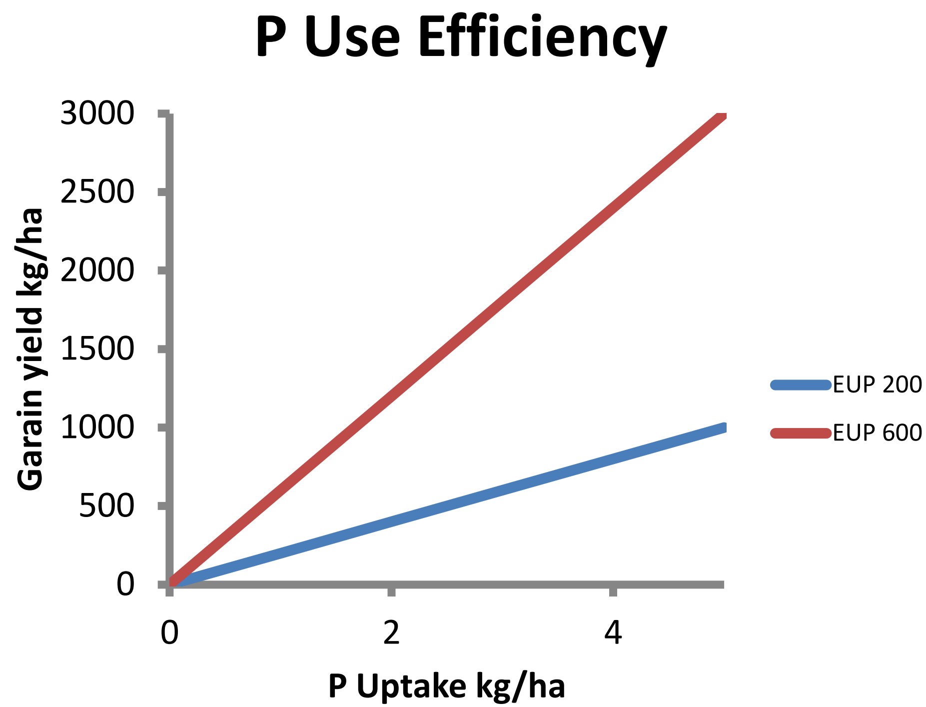
Grain production /Plant uptake

- Nitrogen 30 – 70 kg grain/kg N
- Phosphorus 200 – 600 kg grain/kg P

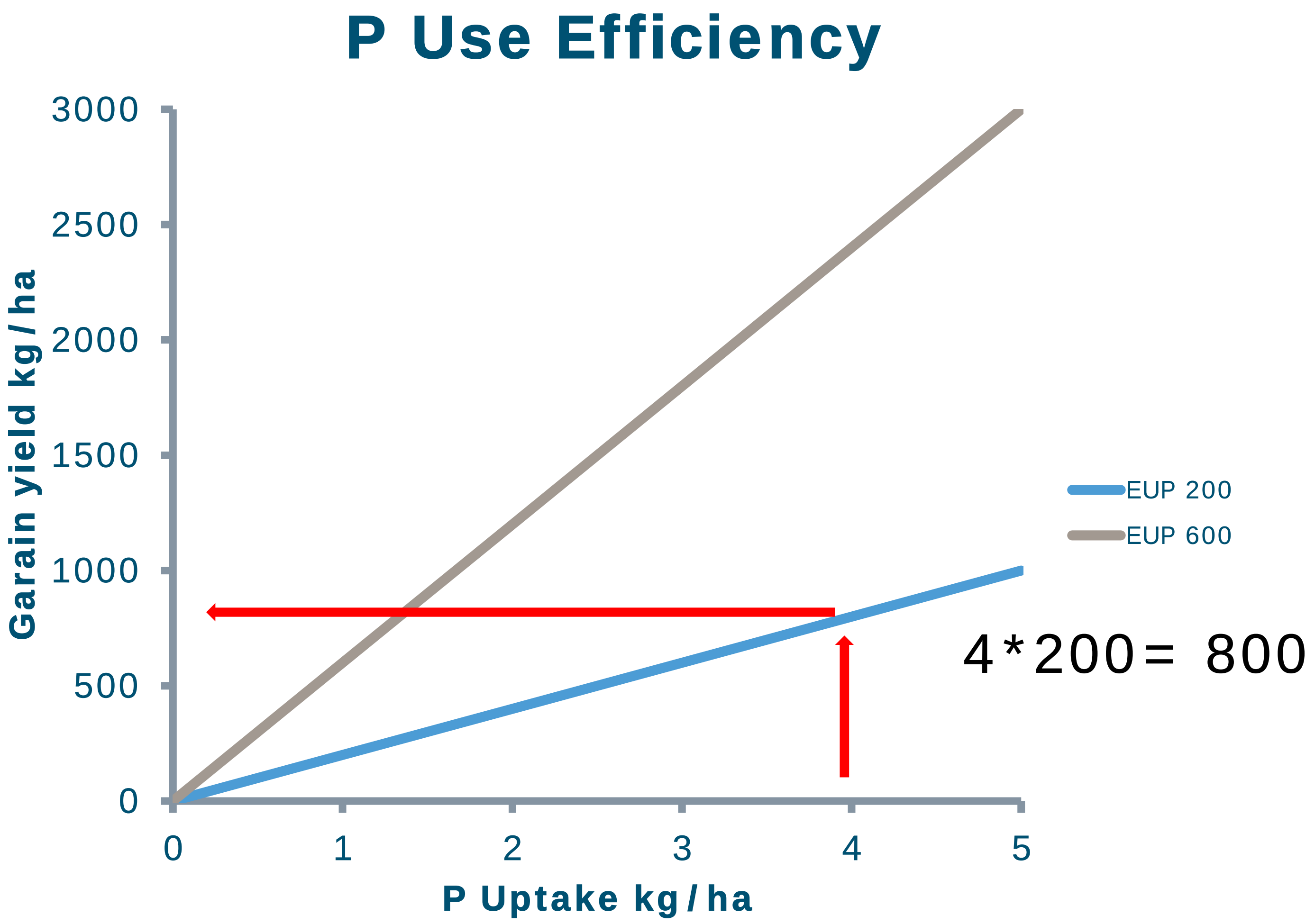
(Van Keulen and Van Heemst, 1982)

Soil and Plant analysis

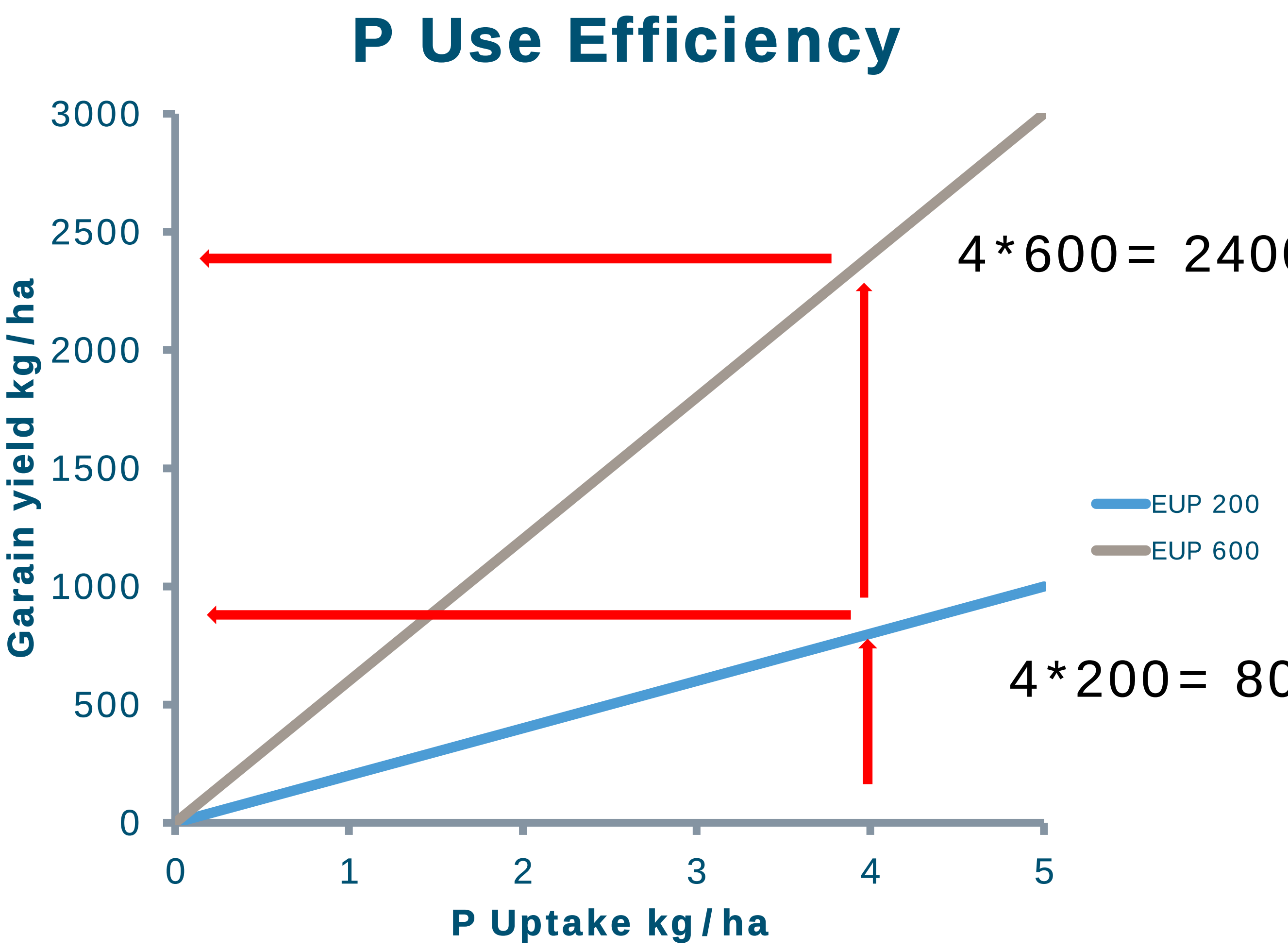




Soil and Plant analysis

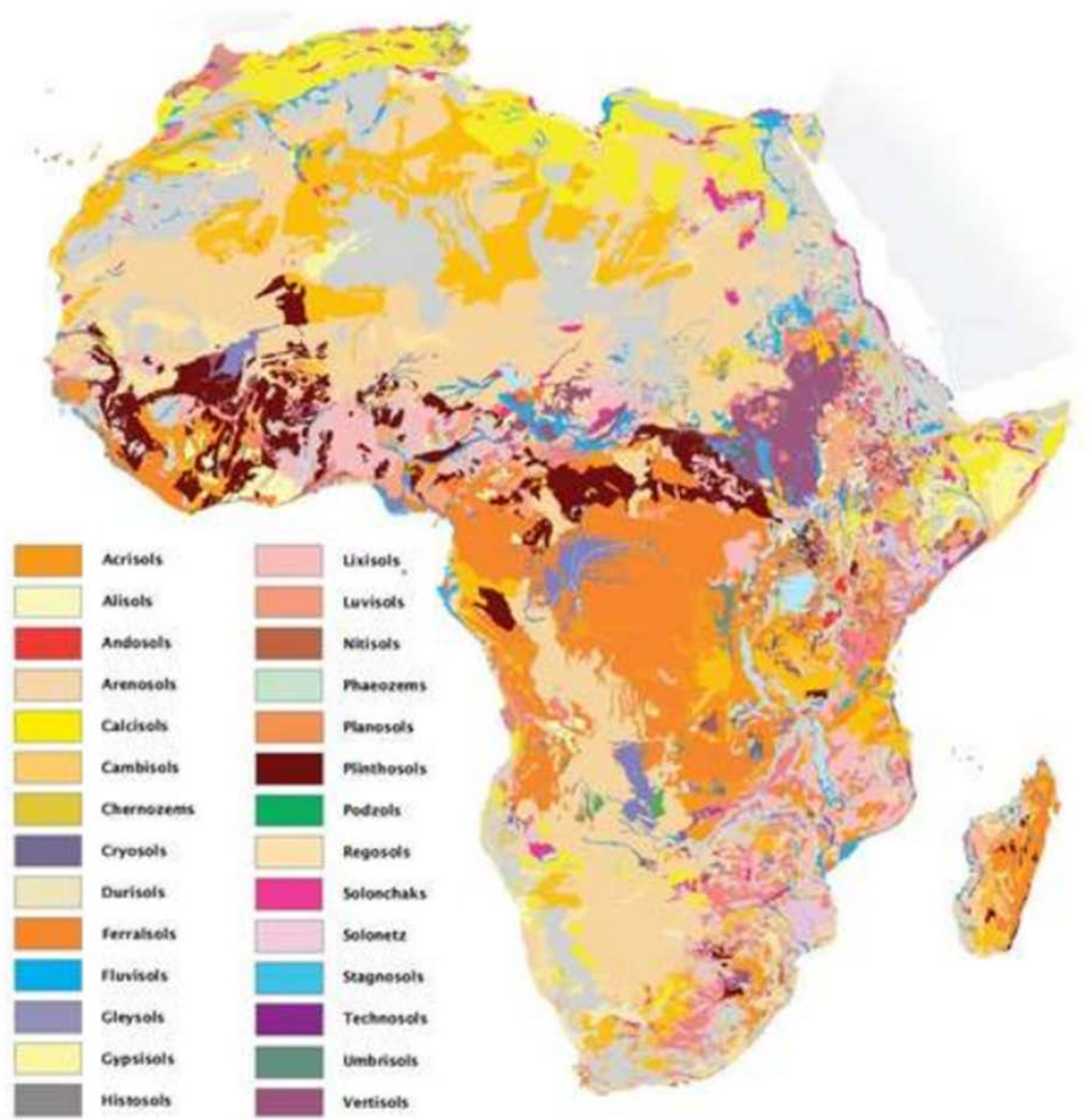


Soil and Plant analysis



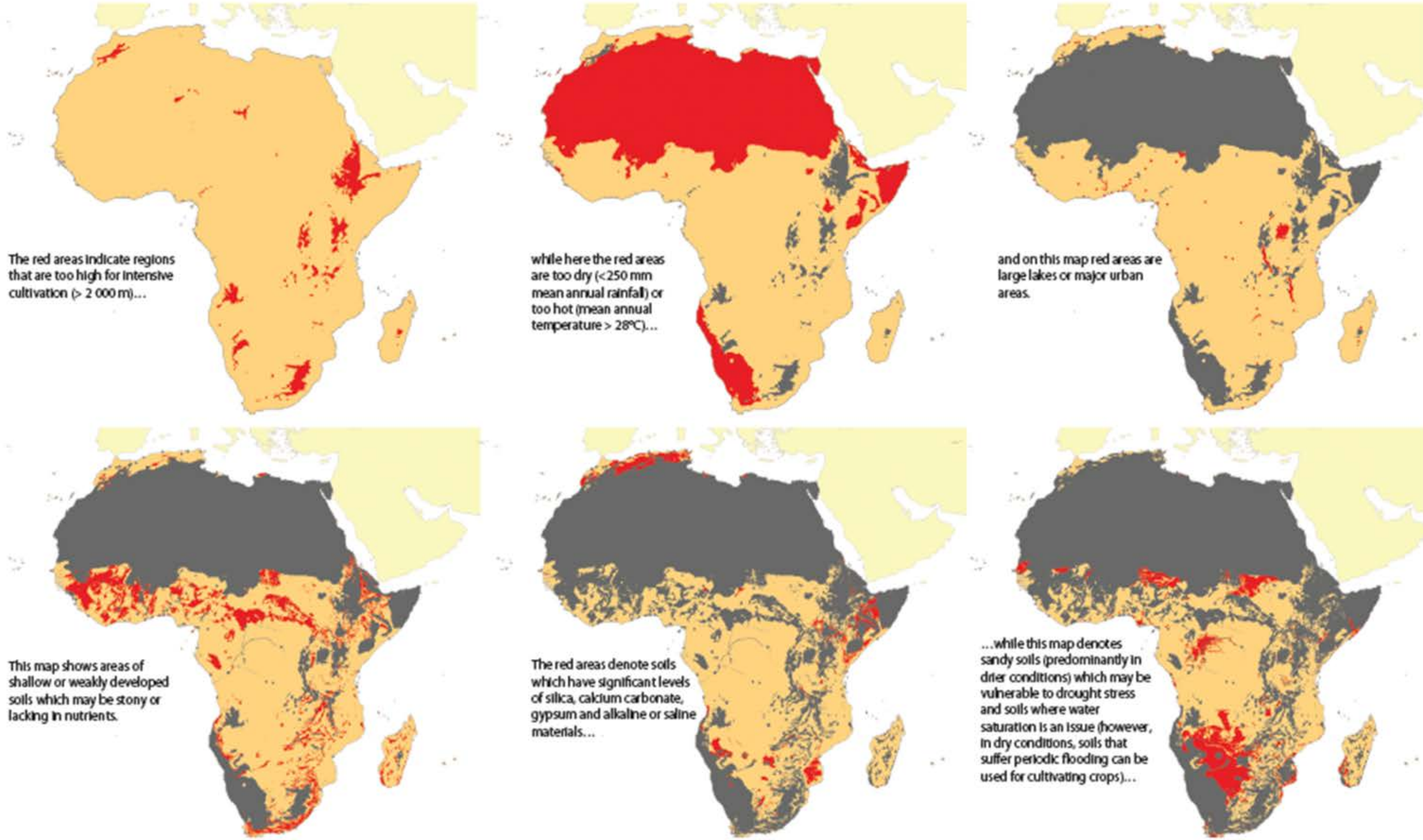
EU Soil atlas
of Africa (2013)

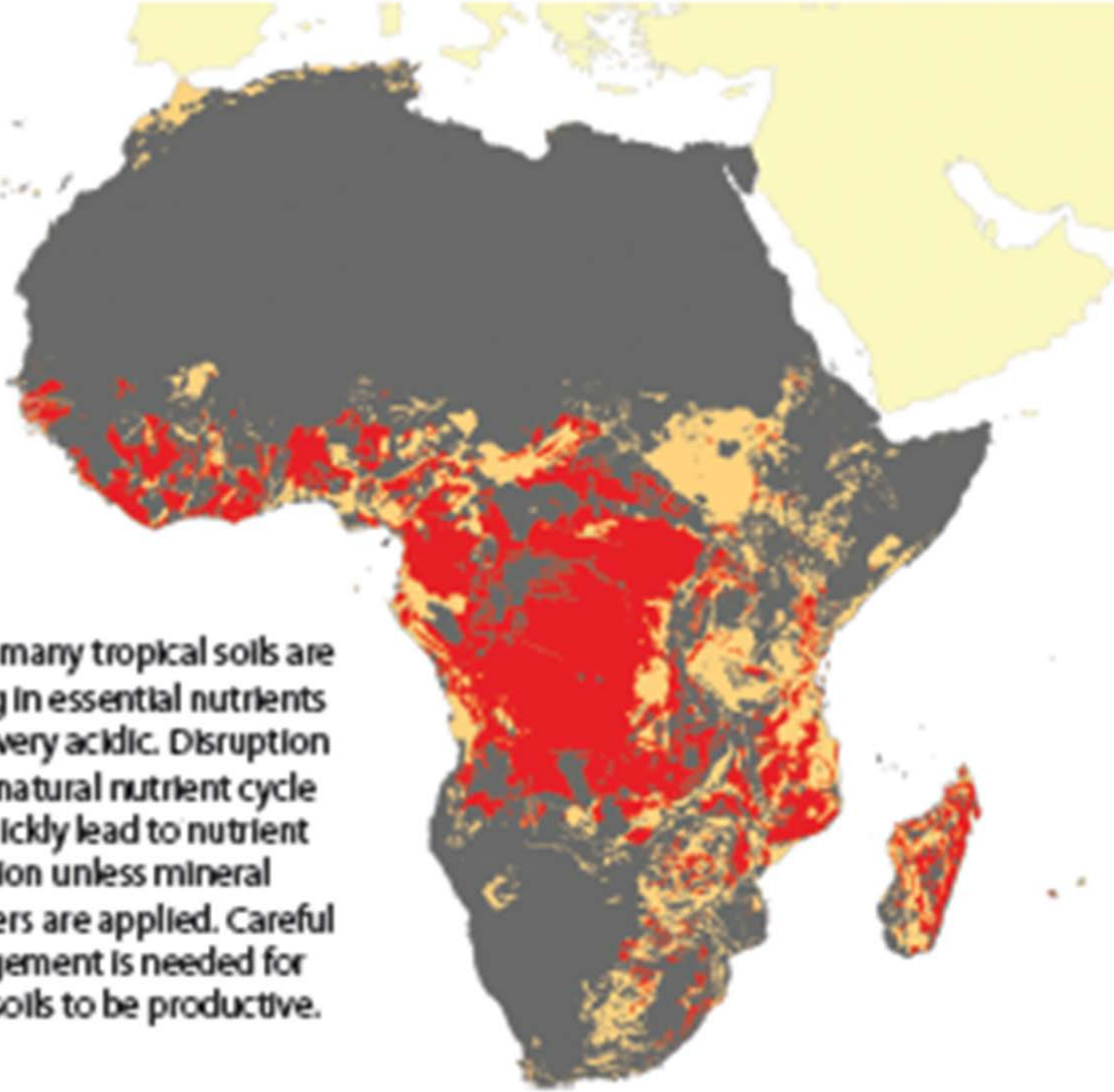
The major soil types in Africa



WAGENINGEN UR
For quality of life

Soil constraints for agriculture in Africa

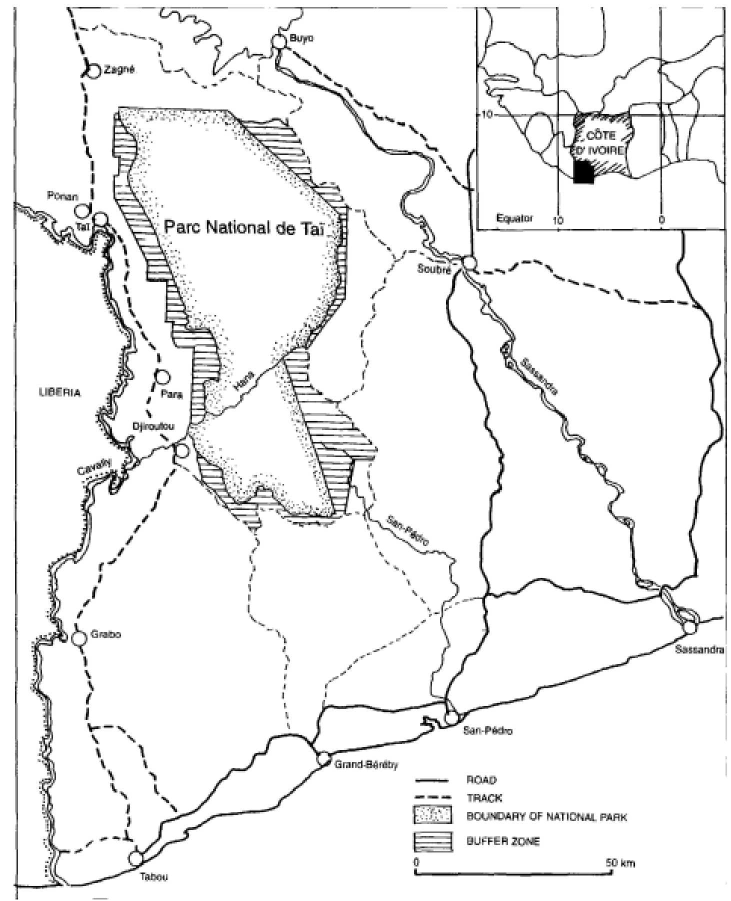




…and many tropical soils are lacking in essential nutrients or are very acidic. Disruption of the natural nutrient cycle can quickly lead to nutrient depletion unless mineral fertilisers are applied. Careful management is needed for these soils to be productive.

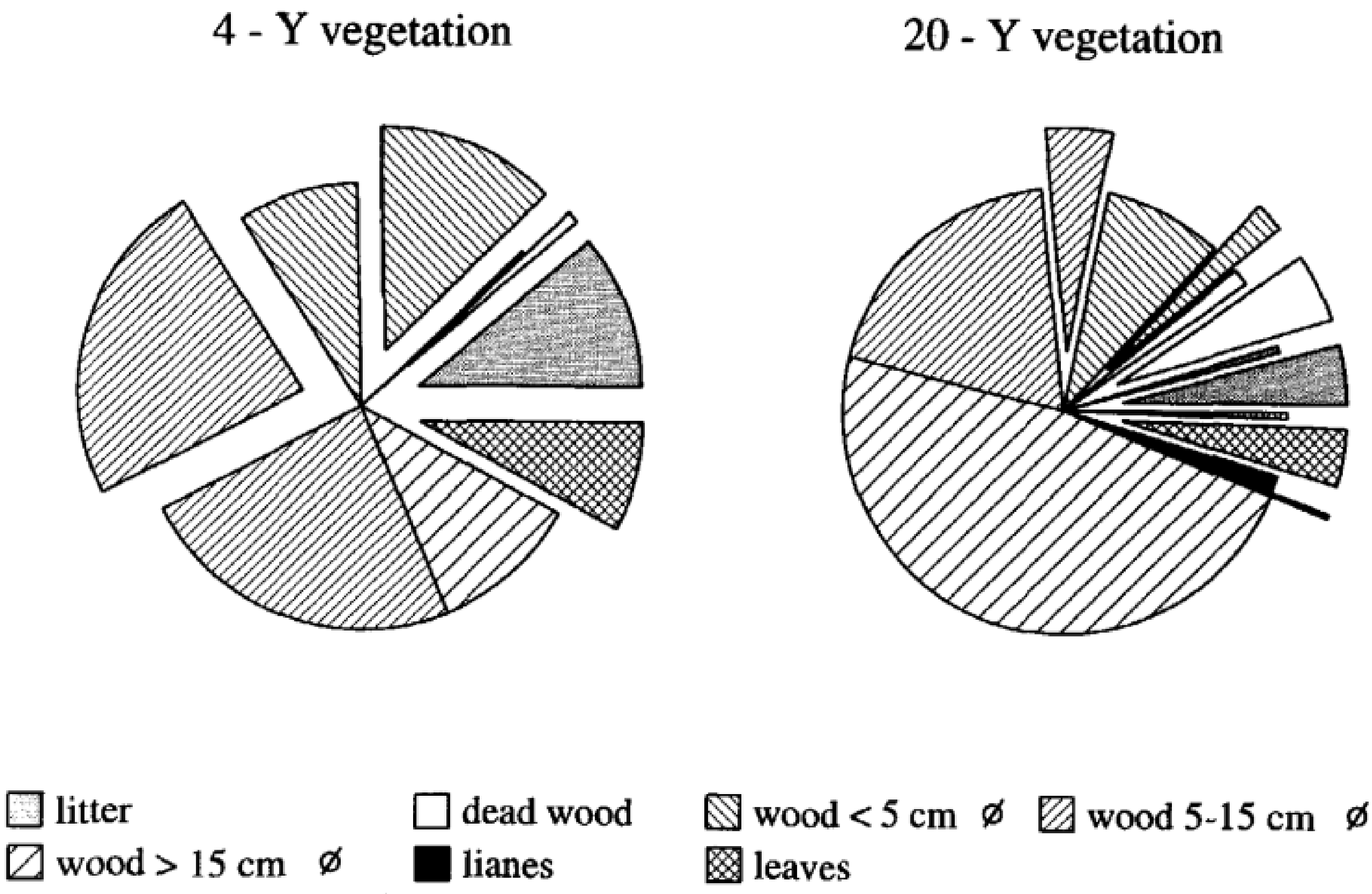
Case study

- S.W. Ivory Coast
- Semi deciduous forest
- Shifting cultivation
    - One season Upland rice
    - Long fallow period or
    - Coffee and cocoa
- National Park



WAGENINGEN UR
For quality of life

Case study



(Van Reuler and Janssen,1993a)

Case study

Table 3.5 Frequencies of the maximum temperatures reached during the burn at soil surface, 0.5 and 1.5 cm depth.

T (°C)	4-Y vegetation Depth (cm) 0	0.5	1.5	20-Y vegetation Depth (cm) 0	0.5	1.5
< 49		2		9	8	6
49 - 99		10	10		5	3
99 - 149		16	3		8	
149 - 199		5	1		5	
199 - 260		3			3	1
260 - 320					2	
320 - 375	1			1		
375 - 500	17			7		
>500	18			14		

(Van Reuler and Janssen,1993a)

WAGENINGEN UR
For quality of life

Case study

Case study

Case study

Case study

Effect of burning the vegetation on grain yields (t/ha)

	4 Y		**20 Y**	
	Not Burnt	Burnt	Not Burnt	Burnt
Year 1 season 1 Rice	0.93	1.64***	0.82	1.72***
season 2 Maize	0.49	1.61***	0.29	1.42***
Year 2 season 1 Rice	1.16	1.54**	1.26	1.24

(Van Reuler and Janssen,1993b)

Burning increased grain yields

Mainly a P effect but also an increase of pH

Intensification through improvement management

Case study

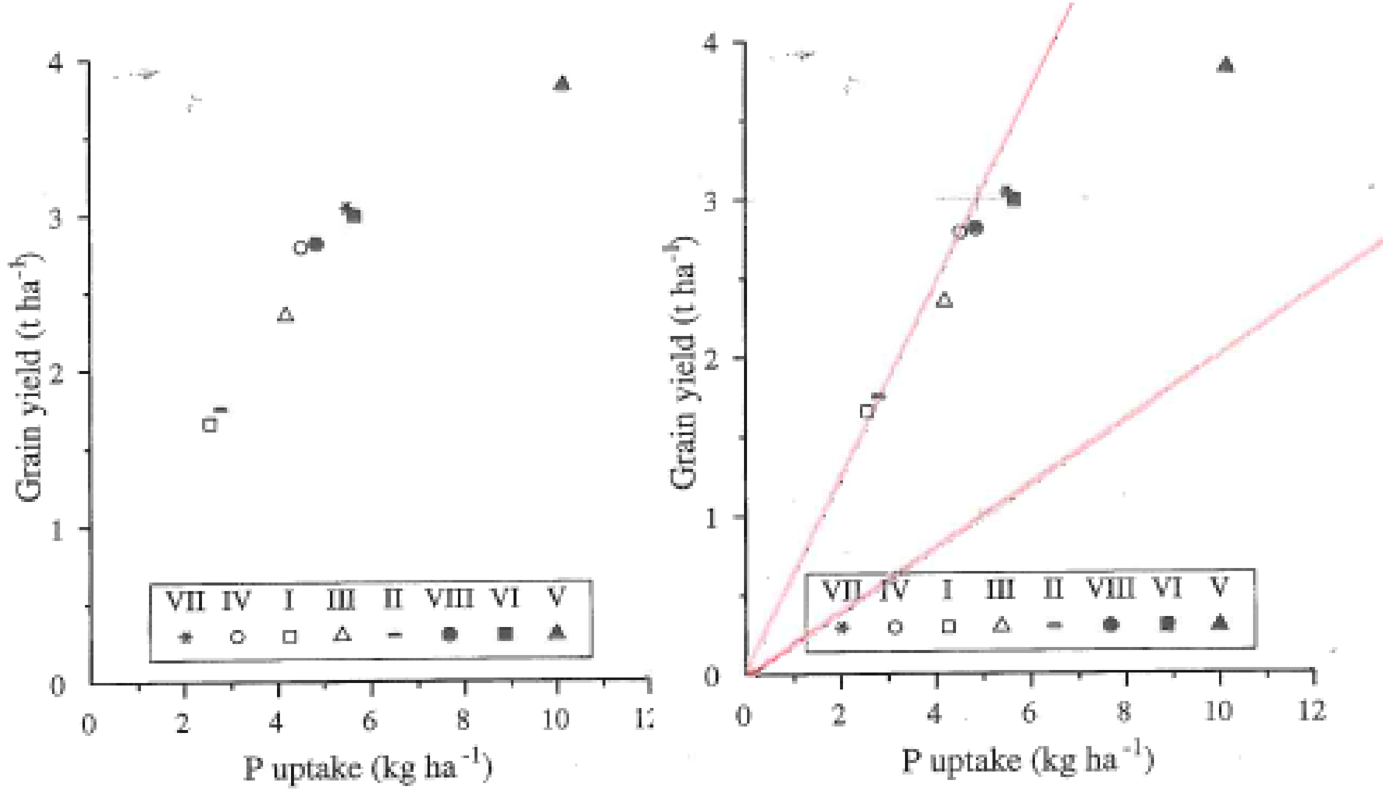
Table 4.4 Average numbers of weed species and weed seedlings on the non-burnt (NB) and and burnt (B) plots of the 4-Y and 20-Y site 28 days after sowing in 1990-1.

	4-Y site		20-Y site	
	NB	B	NB	B
Total species	9.4	3.3***	9.5	4.7***
Total seedlings	81	12.4**(a)	24.9	10.6**

*, **, *** significant difference between NB and B per site at 0.05, 0.01 and 0.001 level, respectively.
(a) without *Triumfetta rhomboidea*

(Van Reuler and Janssen,1993b)

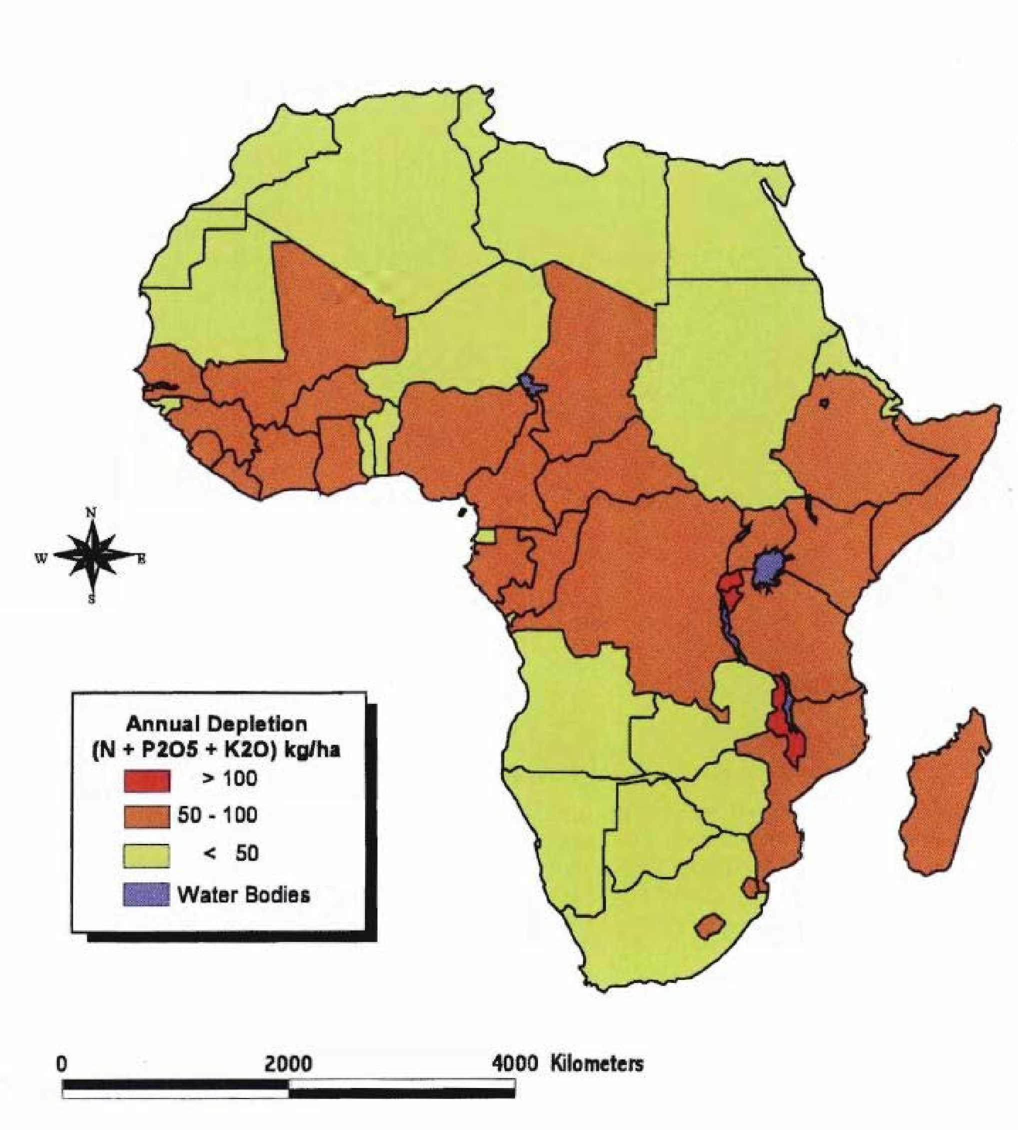
Case study



All locations, except V, only a response to P fertilizer in a 2^4 factorial experiment (N, P, K and Lime at two levels)

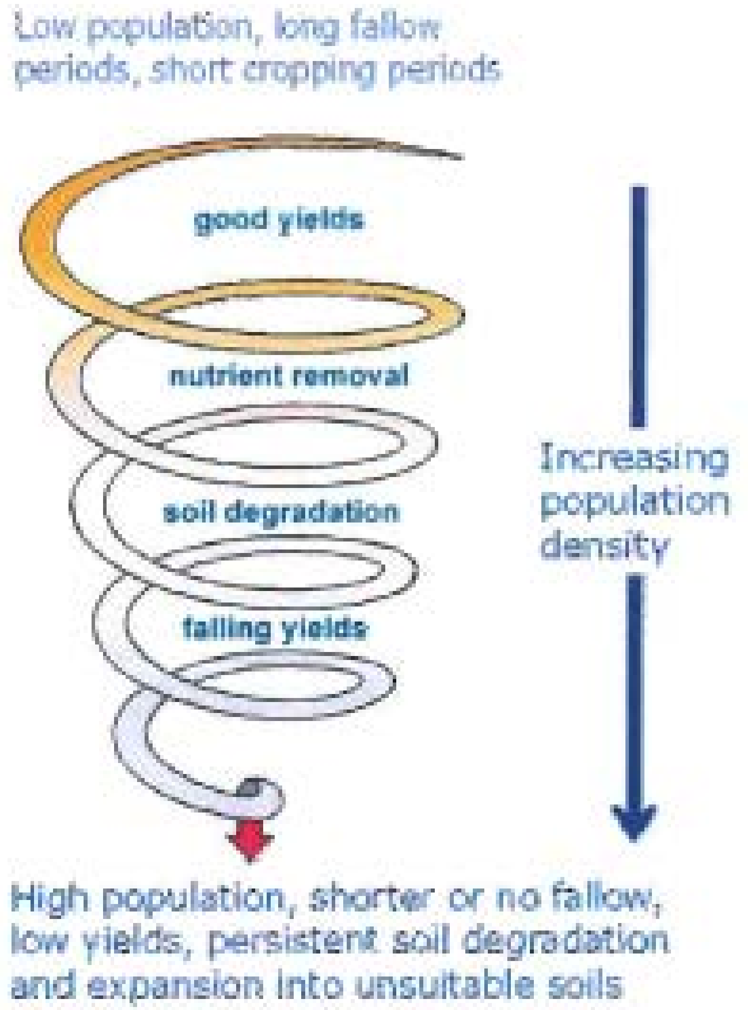
WAGENINGEN UR
For quality of life

Fertilizer application



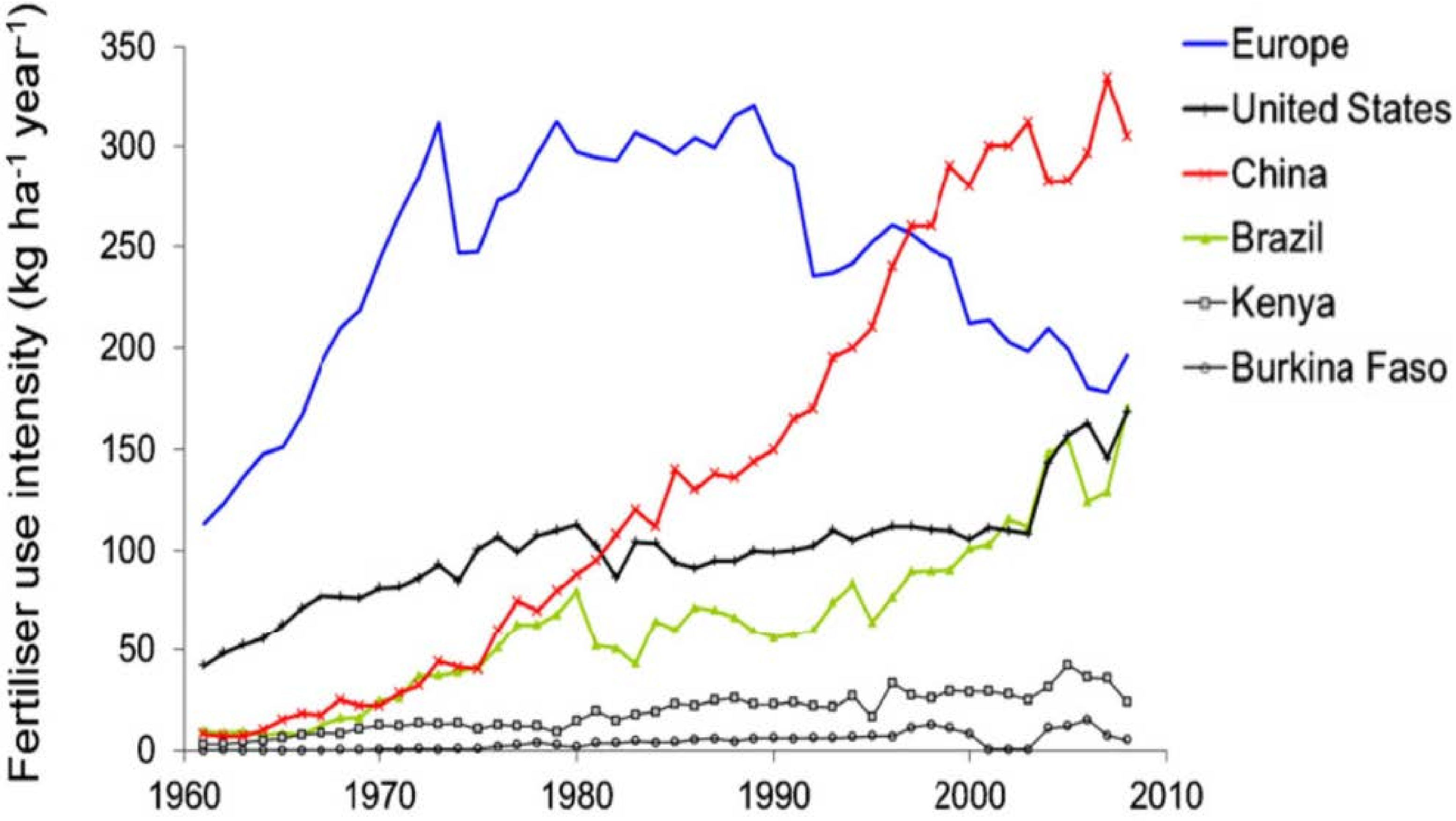
(IFDC)

Fertilizer application



(FAO,2007)

Fertilizer application



Tittonell and Giller, 2013

Fertilizer application

- Mineral fertilizers have bad reputation
  - Availability
  - Pollution
  - Costly
  - ……
- However
  - Organic fertilizers are often not available
  - Biological N fixation needs P
  - Green manure means additional work

Fertilizer application

Integrated Soil Fertility Management

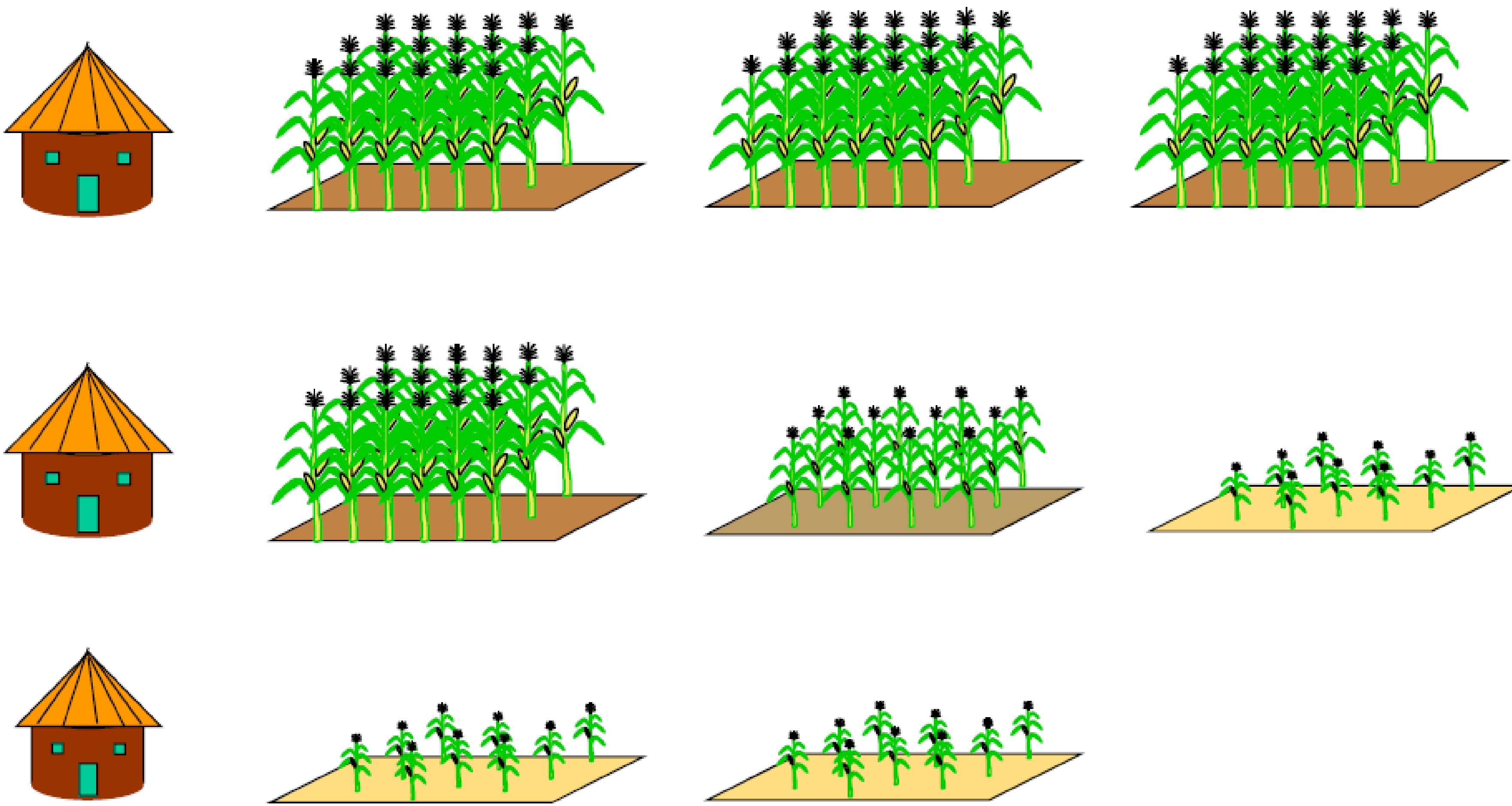
- Maximizing the agronomic efficiency of applied inputs through proper use of improved varieties, fertilizers and organic inputs adapted to local inputs

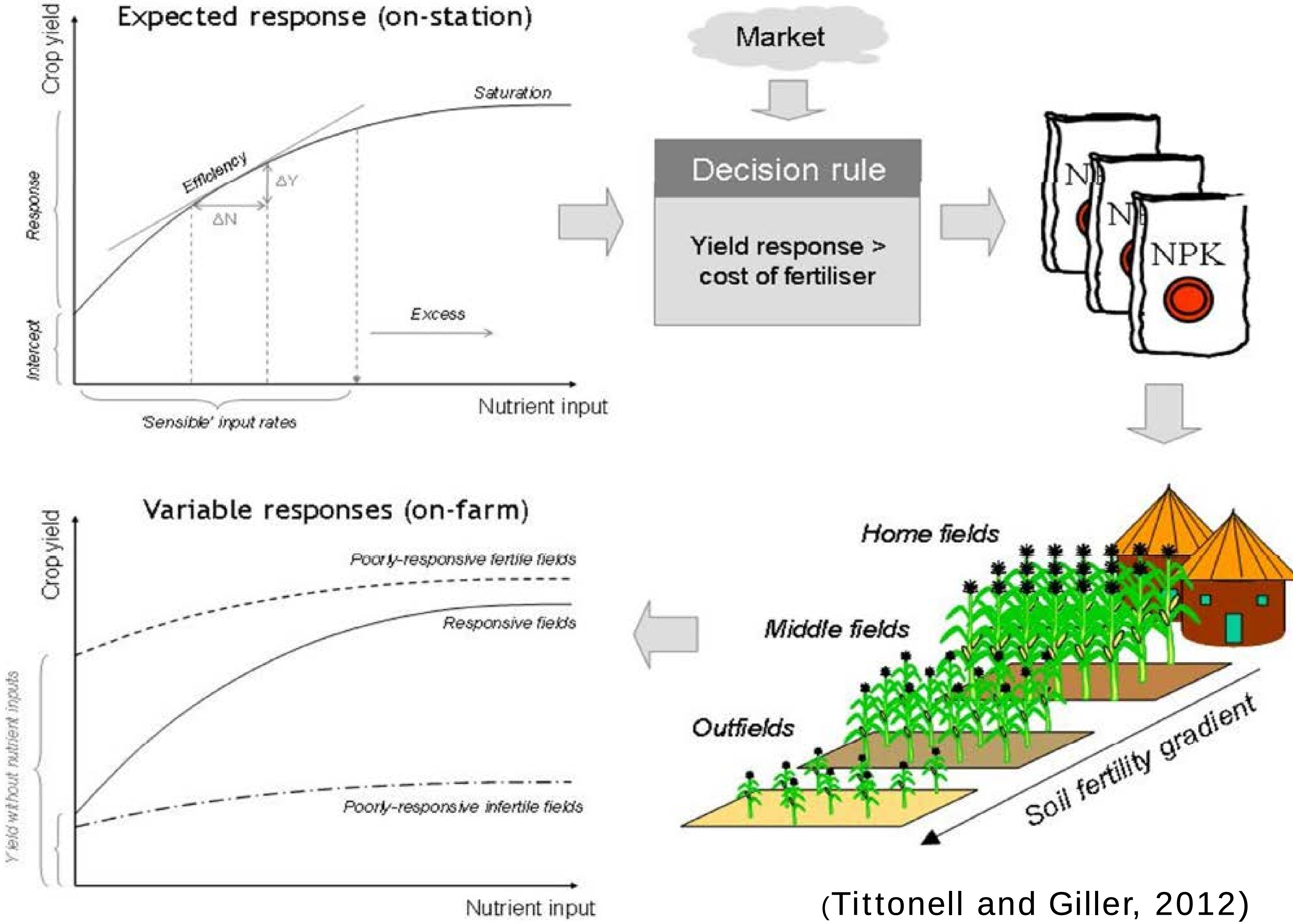
Fertilizer application

- Improvement of fertilizer use
  - Localized application of fertilizer-P
  - Split application fertilizer-N
  - If possible in combination with organic inputs
- Differentiated fertilizer recommendations
- Biological Nitrogen fixation

Fertilizer application

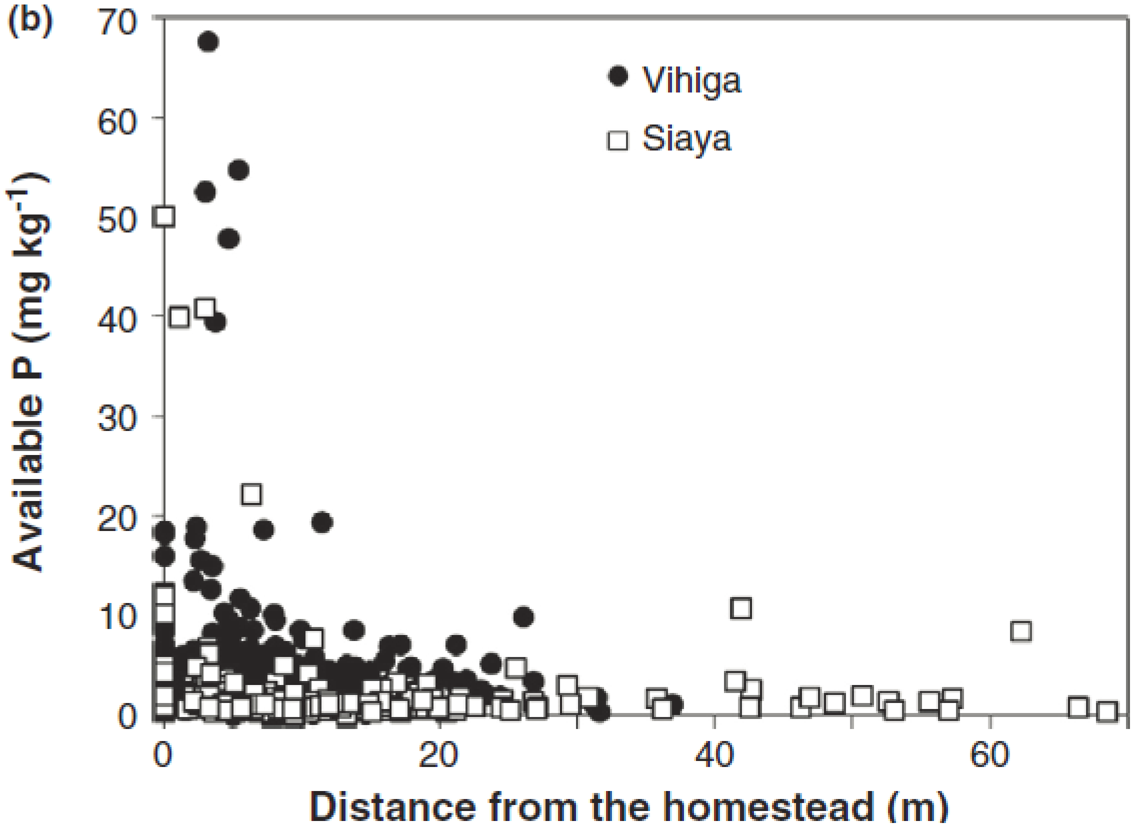
Farm(er)s are not all the same (Giller,2015)





(Tittonell and Giller, 2012)

Soil fertility gradient



(Van Lauwe et al., 2014)

WAGENINGEN UR
For quality of life

Locality/position within the farms	Soil organic C (g kg^{-1})		Total soil N (g kg^{-1})	
Aludeka				
Homefields	10.9	(9.6–12.2)	0.9	(0.6–1.4)
Midfields	6.6	(5.8–7.6)	0.6	(0.5–0.7)
Outfields	6.7	(4.5–7.6)	0.6	(0.4–0.8)
Emuhaya				
Homefields	17.4	(12.2–25.5)	1.3	(0.9–1.6)
Midfields	12.8	(8.9–16.4)	1.2	(0.8–1.5)
Outfields	11.7	(7.5–15.1)	1.1	(0.9–1.4)
Shinyalu				
Homefields	19.6	(16.9–24.0)	1.7	(1.5–1.9)
Midfields	17.2	(13.6–21.0)	1.6	(1.2–1.9)
Outfields	16.2	(13.5–18.4)	1.5	(1.2–1.7)

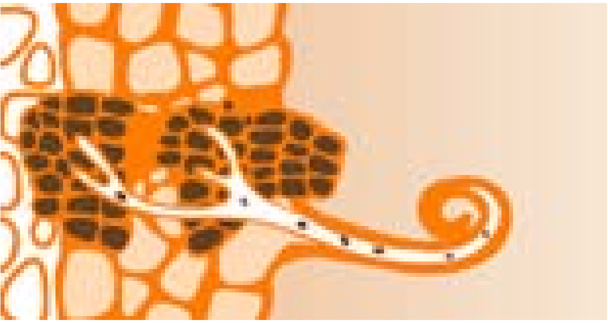
(Tittonell et al., 2008)

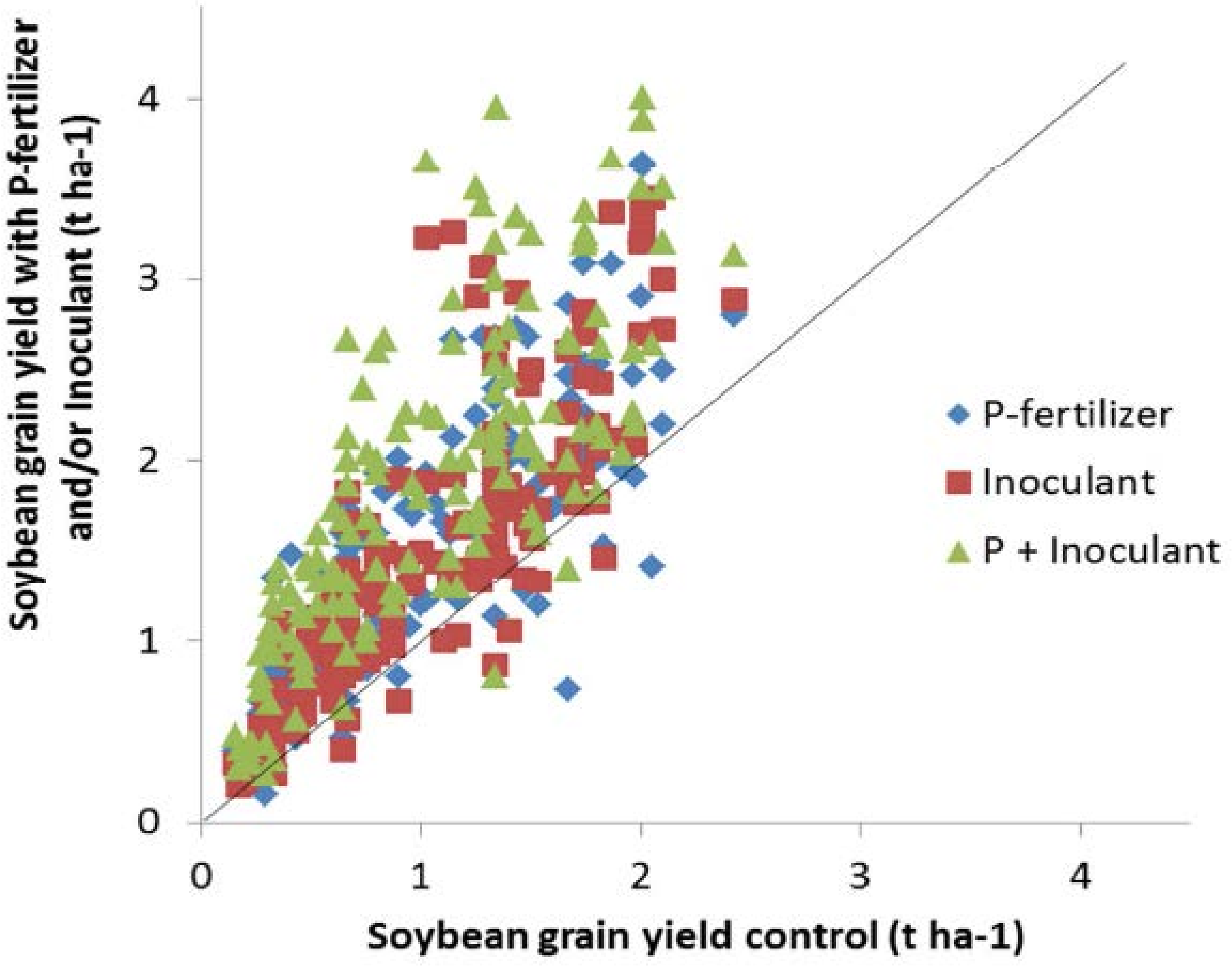
Locality/position within the farms	Soil organic C ($g\ kg^{-1}$)		Total soil N ($g\ kg^{-1}$)	
Aludeka				
Homefields	1.7	(1.2–2.3)	0.9	(0.6–1.4)
Midfields	1.0	(0.8–1.3)	0.6	(0.5–0.7)
Outfields	0.7	(0.3–1.1)	0.6	(0.4–0.8)
Emuhaya				
Homefields	2.4	(1.1–3.8)	1.3	(0.9–1.6)
Midfields	2.2	(0.9–3.6)	1.2	(0.8–1.5)
Outfields	1.4	(0.7–2.9)	1.1	(0.9–1.4)
Shinyalu				
Homefields	2.6	(1.7–4.0)	1.7	(1.5–1.9)
Midfields	1.7	(0.7–2.1)	1.6	(1.2–1.9)
Outfields	1.4	(0.8–2.3)	1.5	(1.2–1.7)

(Tittonell et al., 2008)

Fertilizer application

Effect of fertilizer-P and/or inoculant on soybean yield in Nigeria in 2011/12 (Giller, 2015)





WAGENINGEN UR
For quality of life

Concluding remarks

- Shifting cultivation is sustainable at low population densities
- Small amounts of P increase yields significantly
- Plant analysis are a useful tool
- Integrated Soil Fertility Management
- Right species or variety
- Alternatives for mineral fertilizers, N fixation, closing nutrient cycles, urine as N source?

- **Socio economic conditions** !!

Not discussed
but very important!

- Capacity building at different levels
- Vocational education
- Demonstrating methods with substantial impact
- Participatory approach
- Stakeholder management

WAGENINGEN UR
For quality of life

Thank you for your attention