Determinants of sustainability in urban and peri-urban agriculture

Andreas Buerkert, Eva Schlecht, Martina Predotova, Rodrigue V.C. Diogo , Katja Kehlenbeck and J. Gebauer

Faculty of Organic Agricultural Sciences, University of Kassel, Germany

Email: tropcrops@uni-kassel.de

Ökologische Agrarwissenschaften
UNIKASSEL

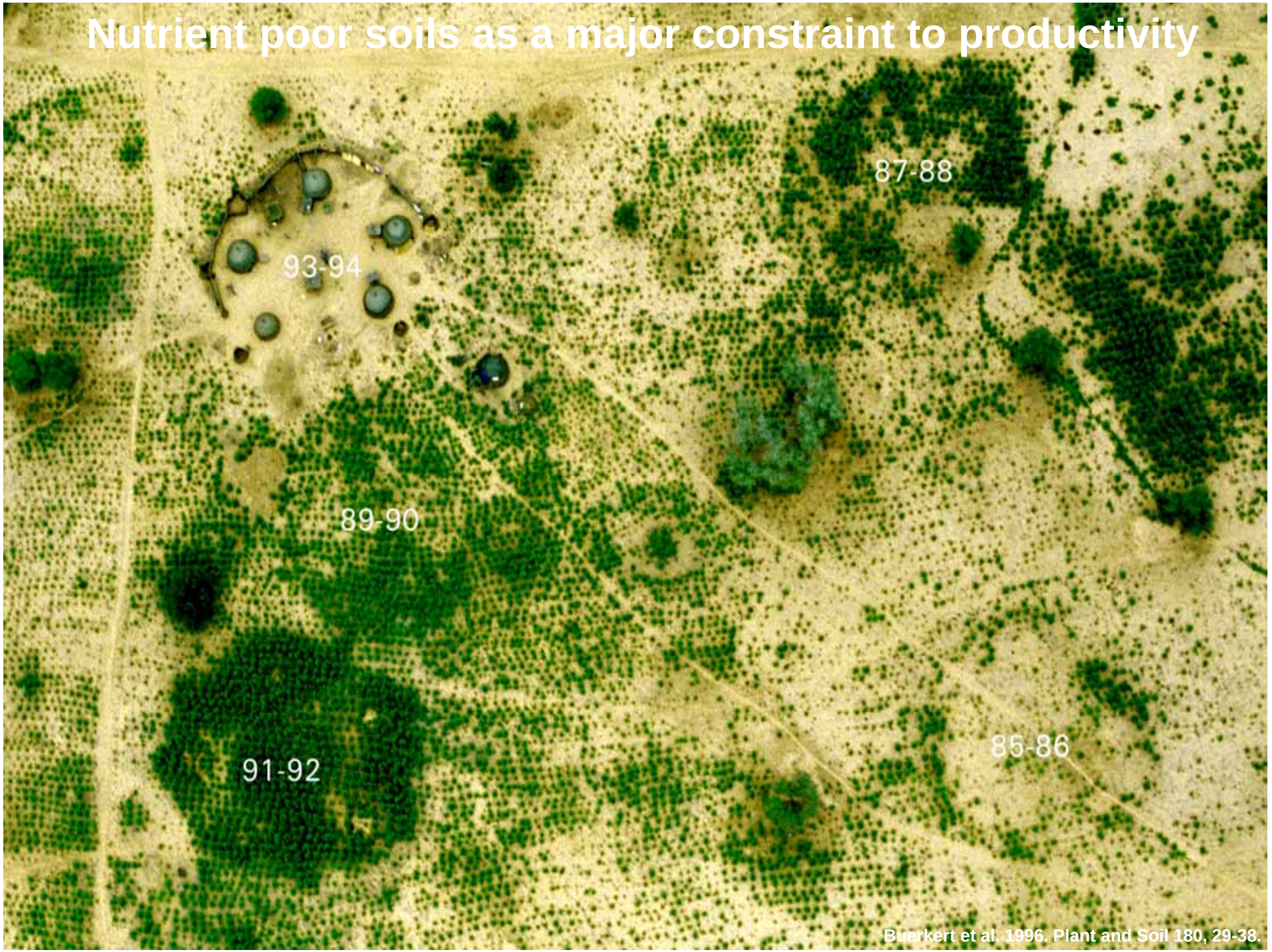
Nutrient depletion and erosion of rainfed land

Effects of placed NPK application at 4 kg P ha^{-1} on millet growth in a farmer's field (Maradi, Niger)

Buerkert et al. 2001. Field Crops Research 72, 1-15.

unfertilized control

Nutrient poor soils as a major constraint to productivity



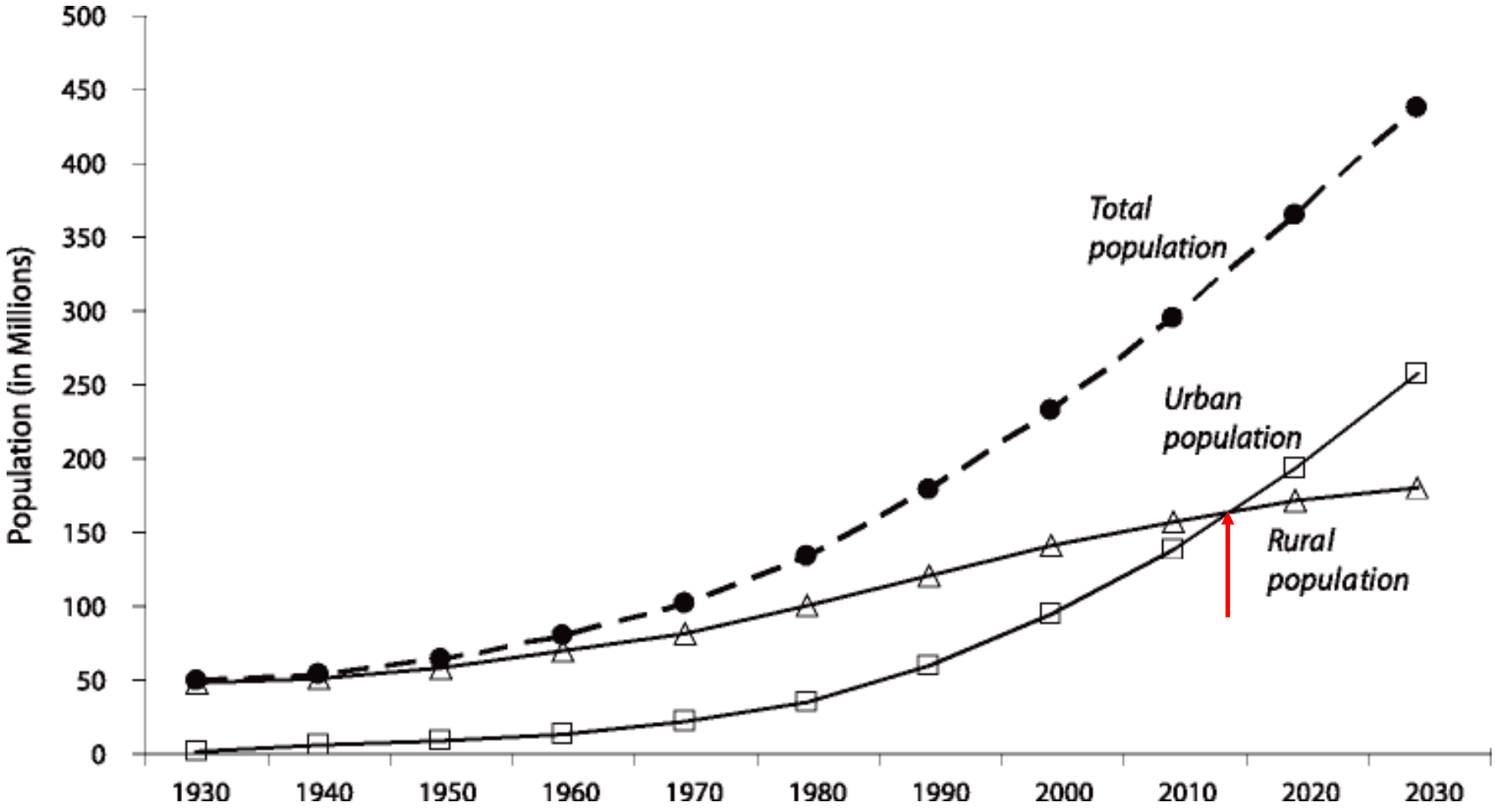
Buerkert et al. 1996. Plant and Soil 180, 29-38.

Rural insecurity, hunger & poor soil productivity cause rapid urbanization

Image source: own, afp. dpa

Population growth and distribution in Africa

- many causes one consequence -



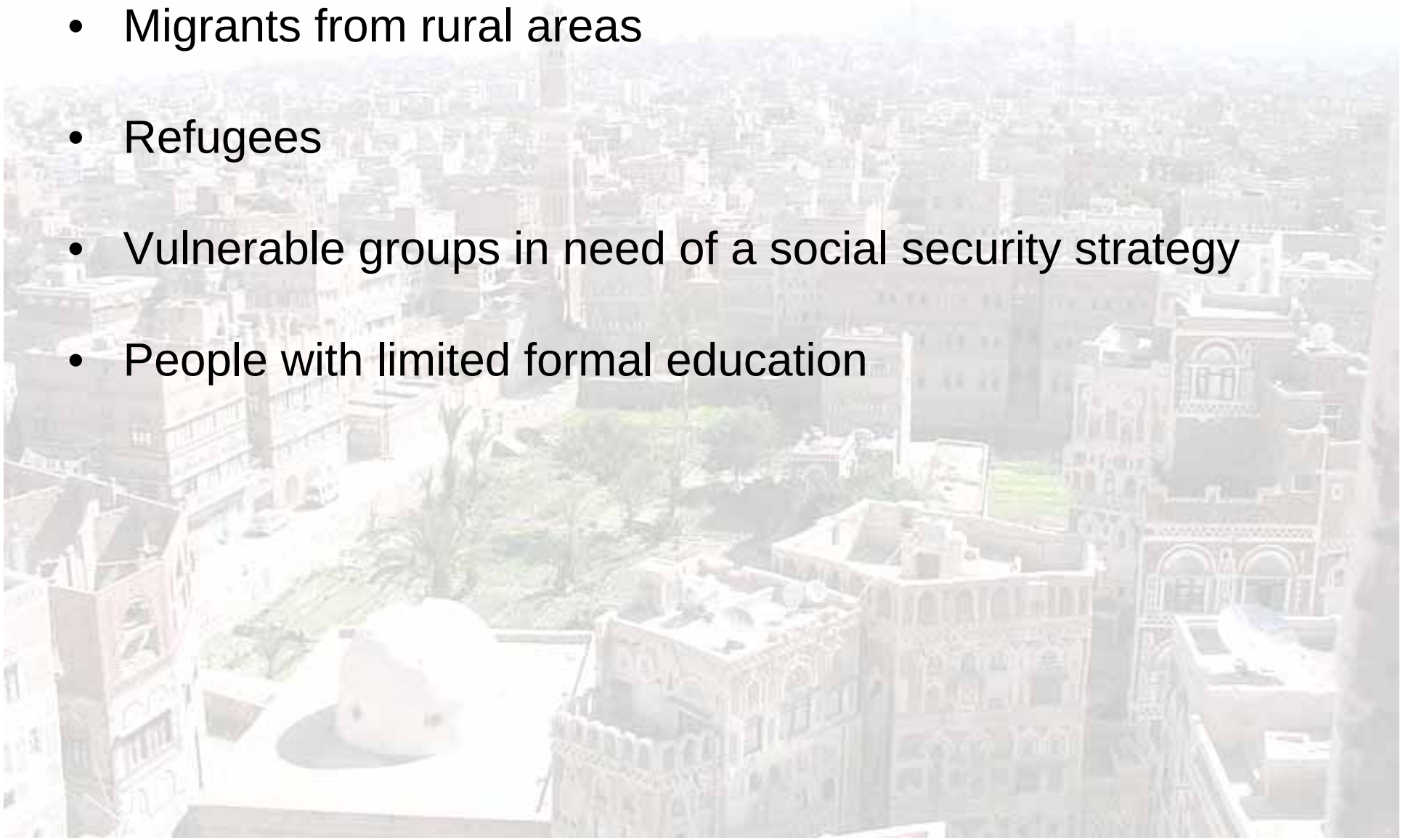
Based on data by UN Population Division, 2004.
Pay Drechsel, Sophie Graefe, Moise Sonou and Olufunke O. Cofie, 2006. IWMI Research Report 102

Consequences of rapid urban growth

- Unplanned and informal, often illegal settlements
- Inefficient infrastructure (water supply, energy supply, waste disposal, sewage)
- Pollution from urban wastes (household, industrial, traffic)
- Increased level of urban food insecurity and malnutrition
- Increasing urban poverty, accompanied by a widening income gap

Who are urban agriculturalists?

- Migrants from rural areas
- Refugees
- Vulnerable groups in need of a social security strategy
- People with limited formal education



Extent of urban food production in Africa

City	Proportion of urban dwellers involved in UPA
Kano (Nigeria)	75
Ouagadougou (Burkina Faso)	36
Harare (Zimbabwe)	80
Nairobi (Kenya)	29
Mombasa (Kenya)	30
Dar-Es-Salaam (Tanzania)	44-70

Smith 2001, IDRC

Income effects of UPA along the marketing chain



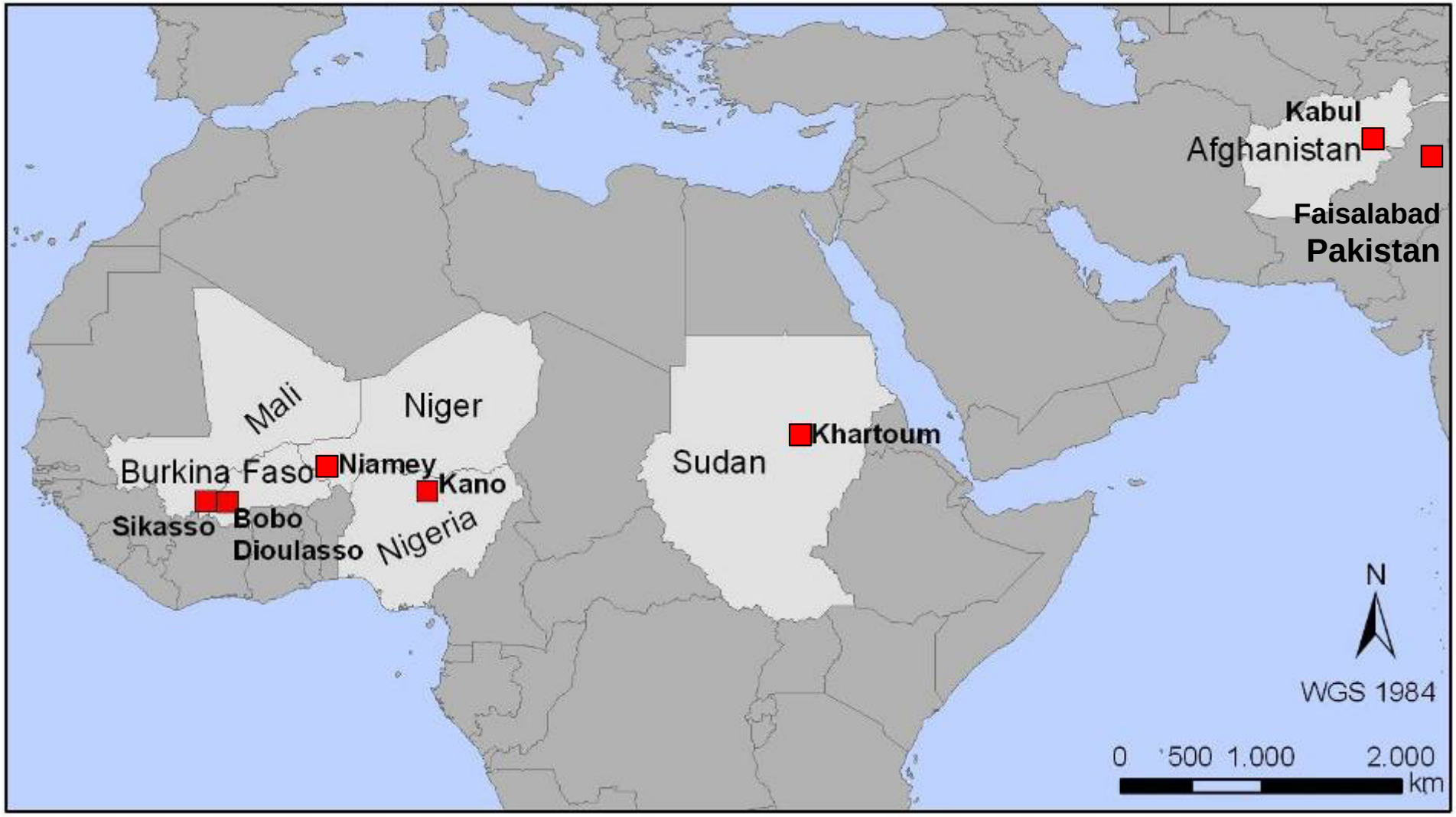
	Average income (US$) per week (range reflects seasonal differences)		
	Farmers	Wholesalers	Sellers
Number of observations	62	54	190
Average household size (adults and children)	4.7	5.2	4.6
Net profit from vegetable sales	17-23	80-108	9-25
Nonagricultural income	0-8	9	8
Contribution by other household members	15-16	35	6-11
Total household income per week	32-39	124-152	23-44

Note: n.a. = not available.

Source: IWMI, unpublished.

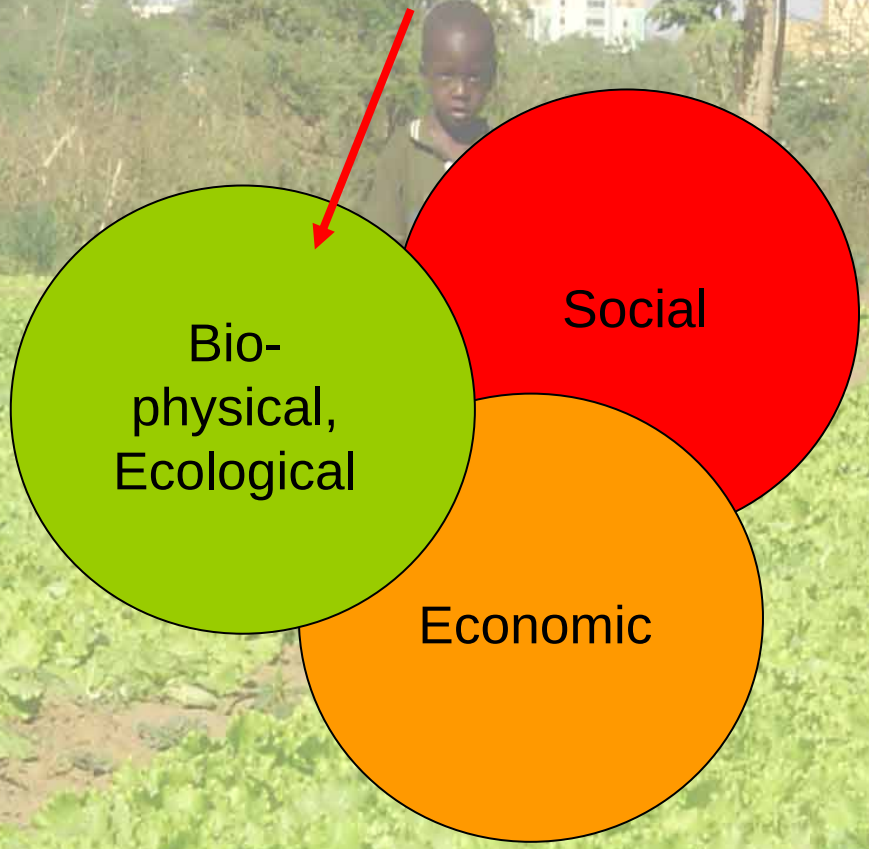
Drechsel et al., 2006

The UrbanFood – Research Network



VolkswagenStiftung DAAD Alexander von Humboldt Stiftung/Foundation Deutsche Forschungsgemeinschaft DFG

How to define sustainability?
→ a need for indicators



Sustainability depends largely on <u>interactions</u> between social, economic and bio-physical components of the system!

Research goals and methodological approach



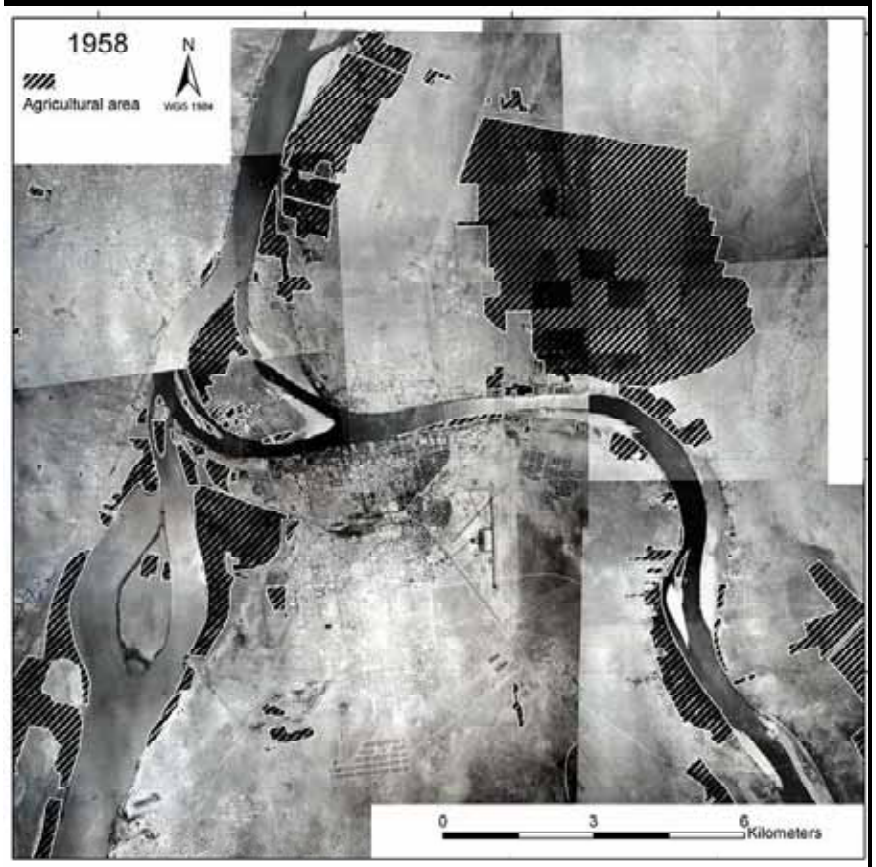
Goals

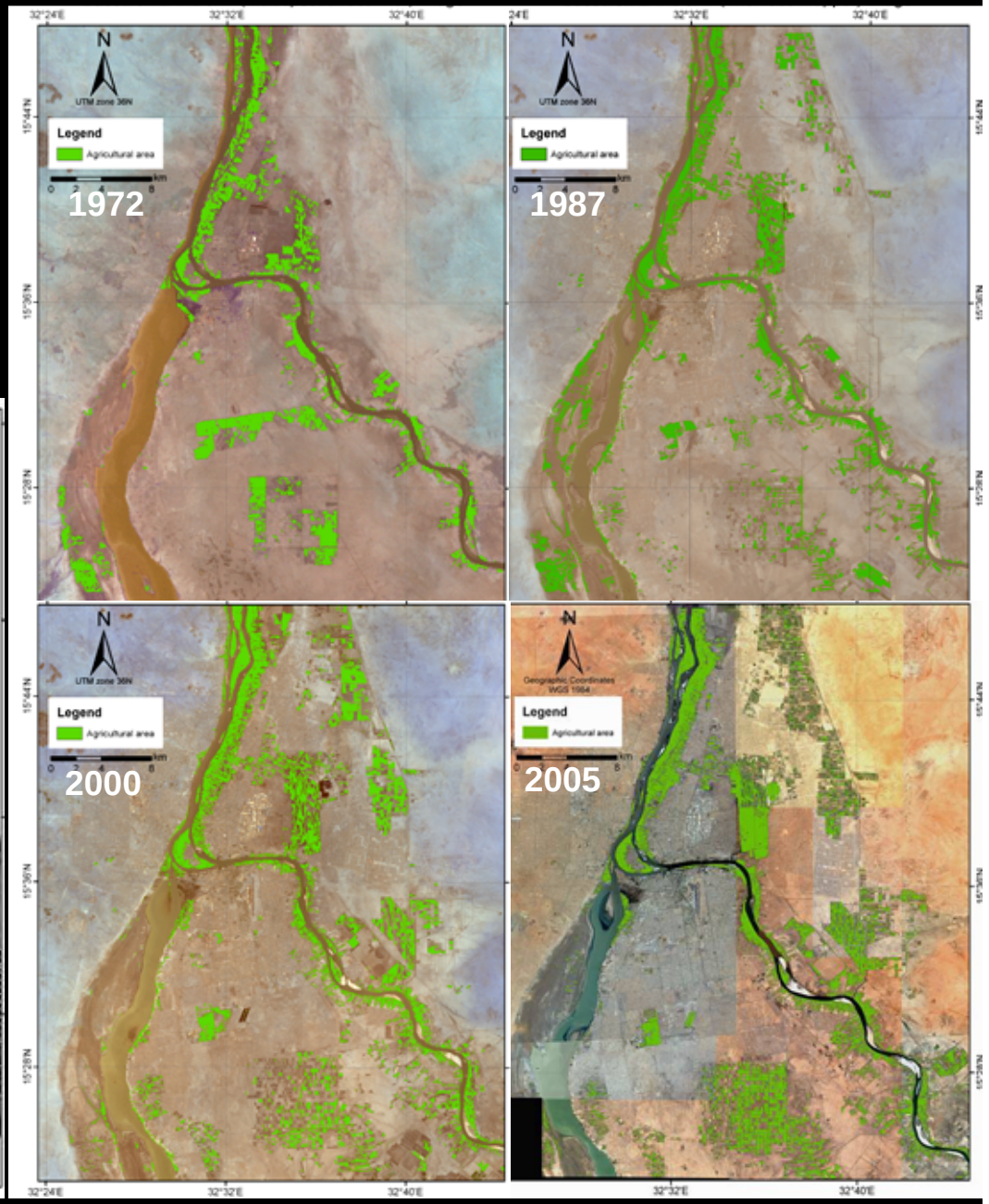
Increase resource use efficiency based on process-oriented research on the functioning of (peri-) urban agriculture, matter fluxes, product contamination and negative externalities

Multi-step approach

- Typology and classification based on satellite images and a (socio-economic) baseline-survey in six cities
- Measurement of matter fluxes (C, N, P, K balances)
- Environmental effects and product quality

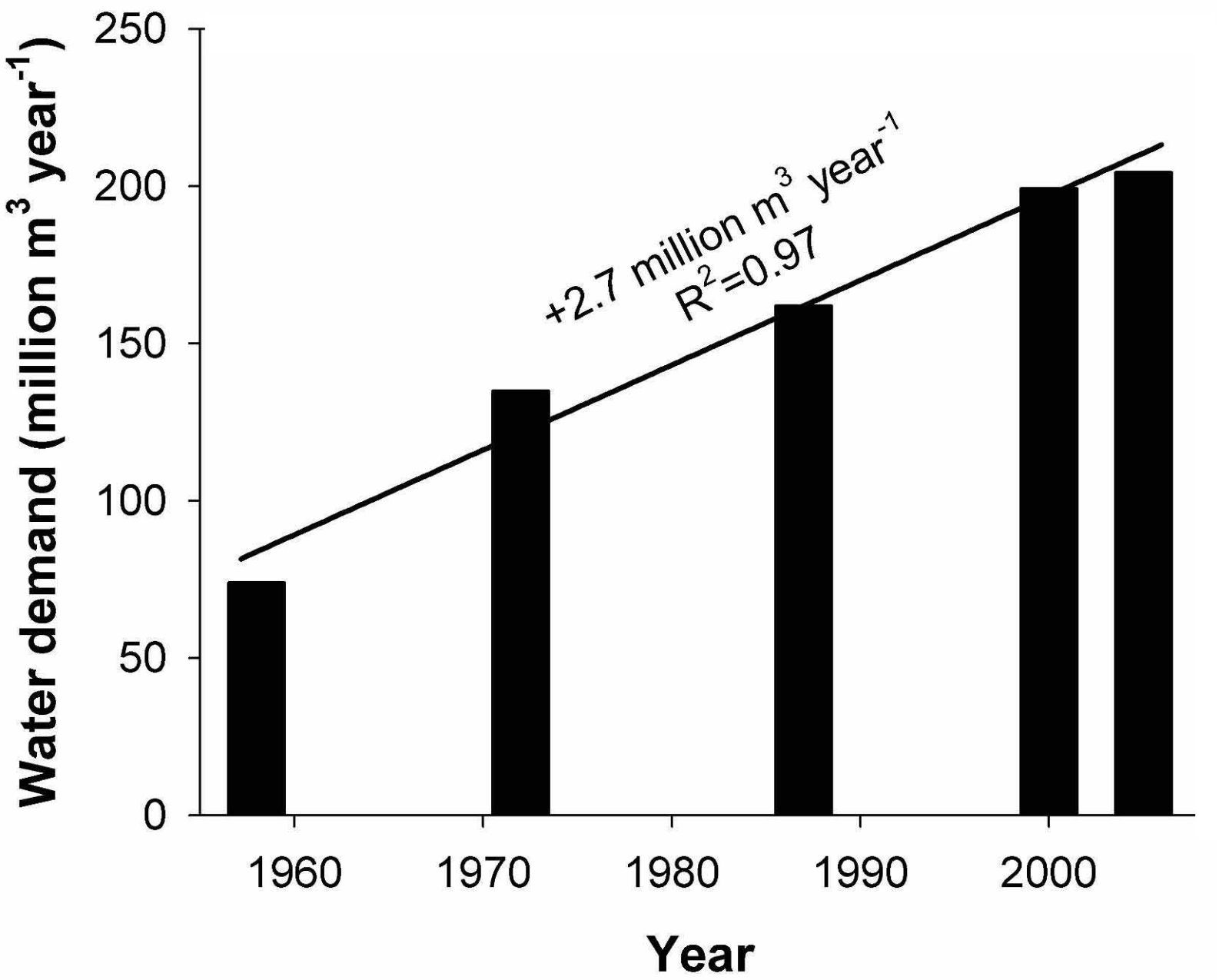
Spatial development of UPA in Khartoum (Sudan)





Schumacher et al. 2009. Journal of Arid Environments (in press).

Modelled irrigation water use in Khartoum, Sudan



Schumacher et al. 2009. Journal of Arid Environments (in press).

Quality of irrigation water in Kano (Nigeria)

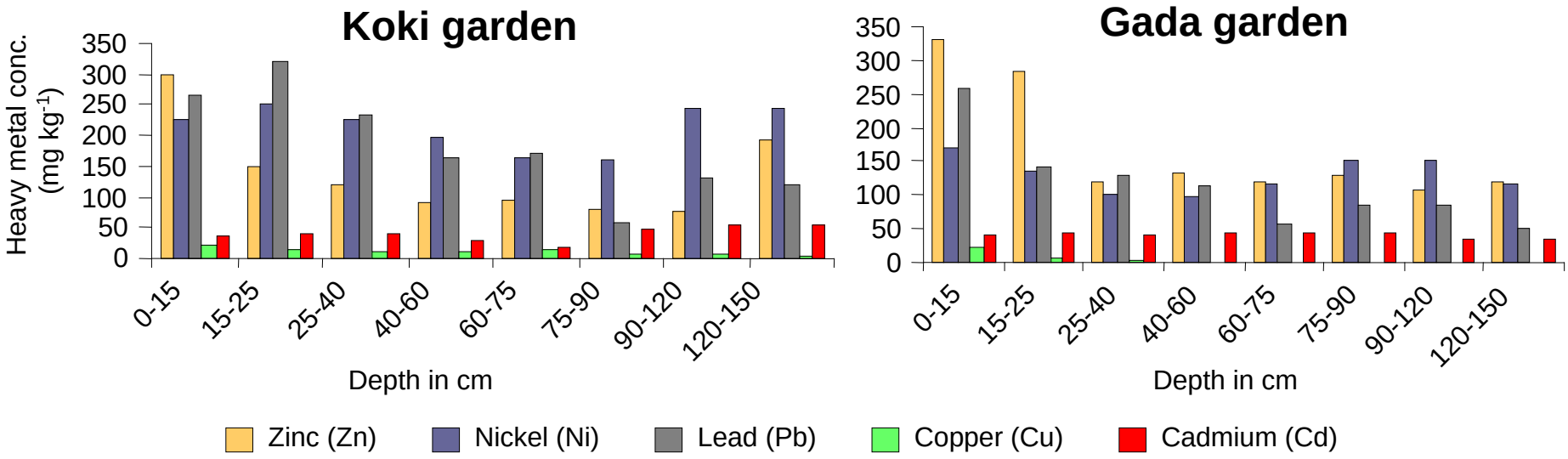
Irrigation water characteristics

Metals	Conc (mg l^{-1})[a]	Limits[b]
Zn	8.3	2.0
Fe	4.8	5.0
Mn	0.6	0.2
Cr	28.4	0.1
Ni	1.2	0.2
Pb	28.5	5.0

[a] Kano State Environmental Planning and Protection Agency

[b] Pescod, M.B. 1992 Wastewater treatment and use in agriculture. Irrigation & Drainage Paper 47, FAO, Rome, Italy

Soil loading with heavy metals in Kano, Nigeria



Nafiu et al. (unpublished data)

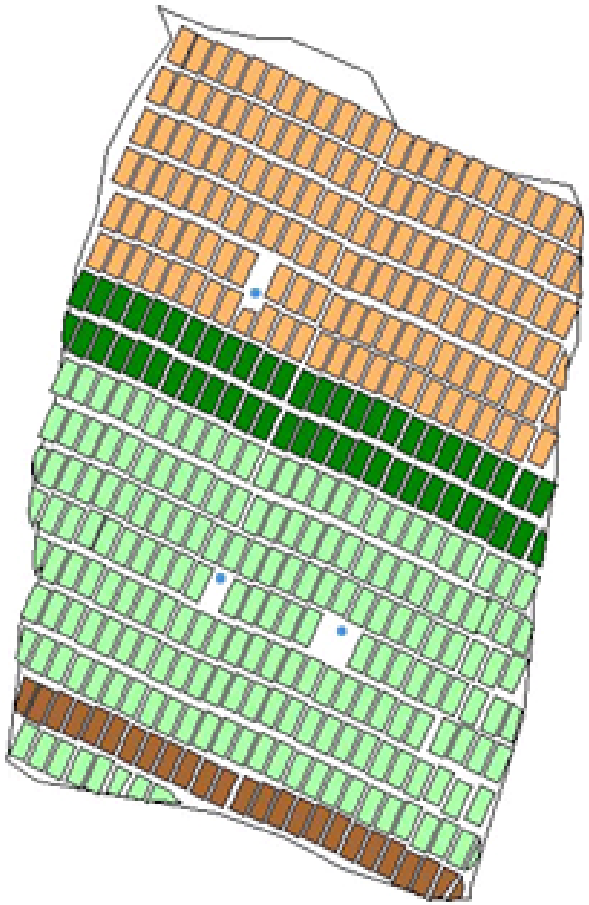
A representative selection of UPA sites is essential for a relevant extrapolation of results

Low cost approach to obtain aerial photographs

Establishing seasonal GIS-based garden maps

- Example: Bobo Dioulasso, Burkina Faso -

SANOU Hamadou



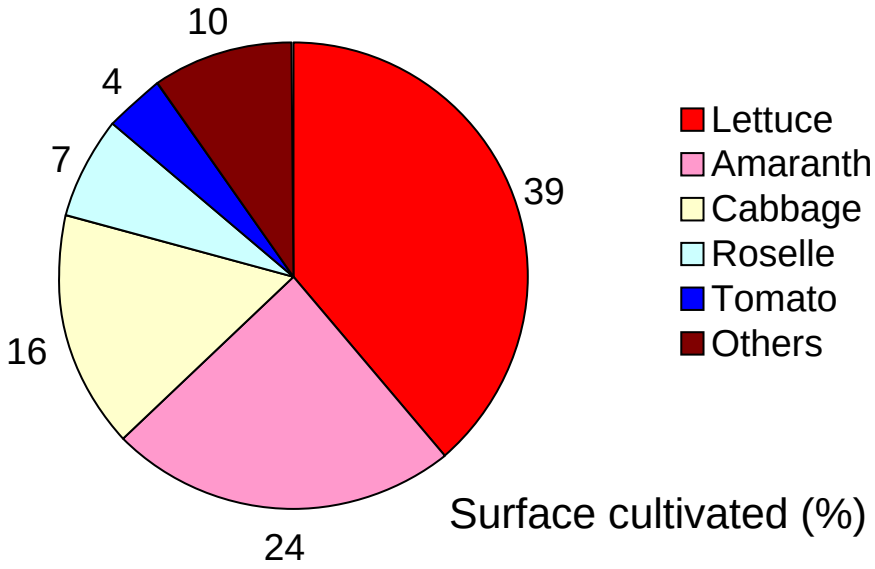
Green beans
Lettuce
Fallow
Tomato
Well
Plot boundary

20 0 20 40 Meters

Household classification after a baseline survey

	HH type	n	Fields (n in K, S; ha in B)	Gardens (m² in B, S; n in K)	Ruminants (TLU)
Bobo	Poor	37	1.1	257	0.2
	Large gardener	14	3.2	1661	1.4
	Mixed farm	17	4.5	471	3.4
	Small crop-livestock	14	2.7	0	3.3
	Medium crop-livestock	13	4.6	0	6.2
	Large crop-livestock	16	3.1	0	48.0
Sikasso	Poor	64	0.6	2507	0.1
	Small poultry	15	1.7	1450	0.6
	Large gardener	5	0.6	12500	0.0
	Medium livestock	5	1.4	2820	12.9
	Mixed farm	11	1.2	6473	4.0
	Rich crop-livestock	3	1.7	11967	33.9
	Large livestock	5	1.2	330	27.4
Kano	Poor	33	0.8	1.3	0.6
	Small gardener	21	2.2	2.7	0.7
	Large gardener	17	2.2	6.6	1.0
	Medium livestock	8	1.6	1.0	4.7
	Mixed farm	10	2.3	3.5	5.3
	Large livestock	11	1.4	0.1	43.3

Yields in UPA gardens
- Example: Niamey, Niger -



Air-dried yields (t ha^{-1} yr^{-1}) of five vegetable types cultivated under different management systems in Niamey, Niger from January 2006 to January 2008

Vegetable	High input (1490 kg N, 290 kg P, 850 kg K ha^{-1})	Low input (480 kg N, 160 kg P, 660 kg K ha^{-1})
Lettuce	2.1	2.7
Cabbage*	9.2	2.3
Amaranth	2.4	6.3
Roselle	1.6	2.4
Tomato	0.4	0.1

* Cabbage yield is expressed in t ha^{-1} 3 month^{-1}

Diogo et al. (unpublished data).

Plant biodiversity in UPA gardens

- Example: Niamey, Niger -

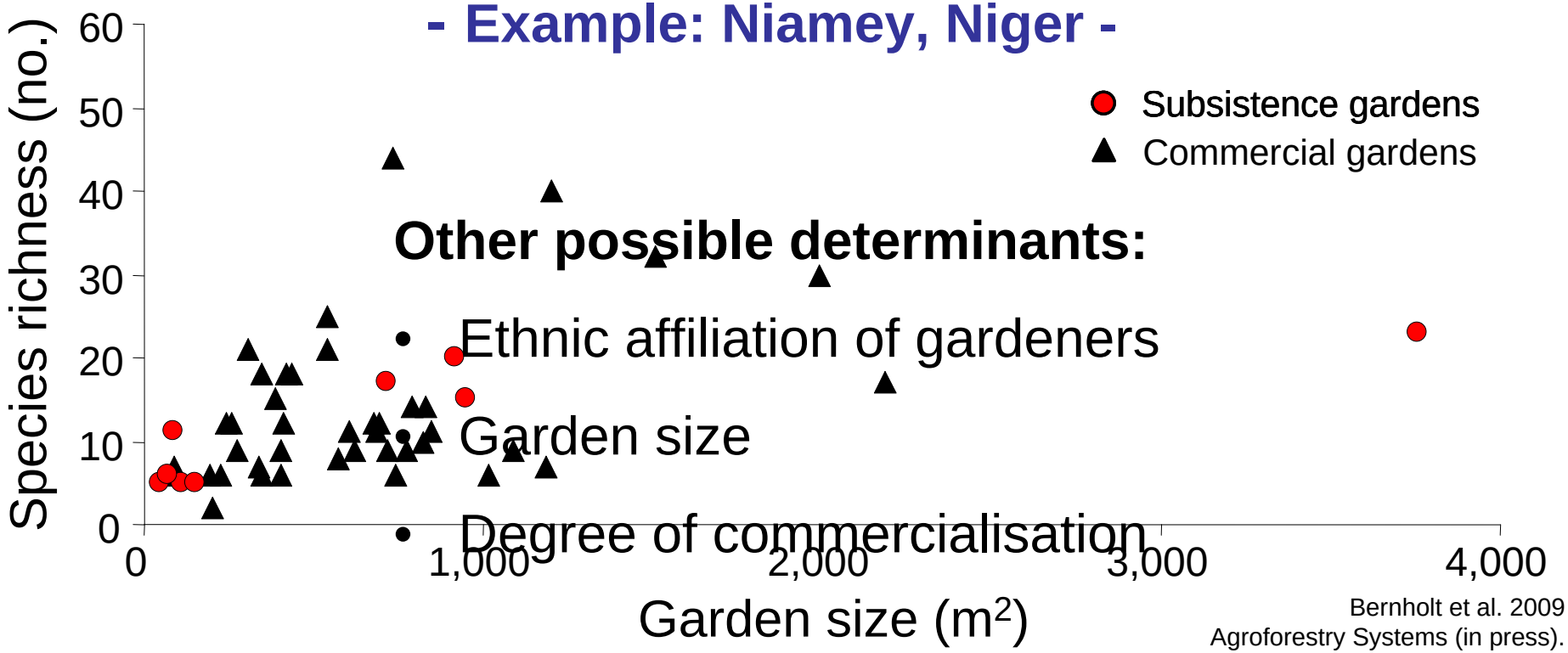
Mean plant species diversity in the cold, hot and rainy season 2007

Parameter	Cold season (n=51)	Hot season (n=51)	Rainy season (n=45)
Species richness	14.1	9.8	6.7
Species density	15.0	10.2	6.8
Shannon index	1.0	0.8	0.5

Bernholt et al. 2009. Agroforestry Systems (in press).

Plant biodiversity in UPA gardens

- Example: Niamey, Niger -

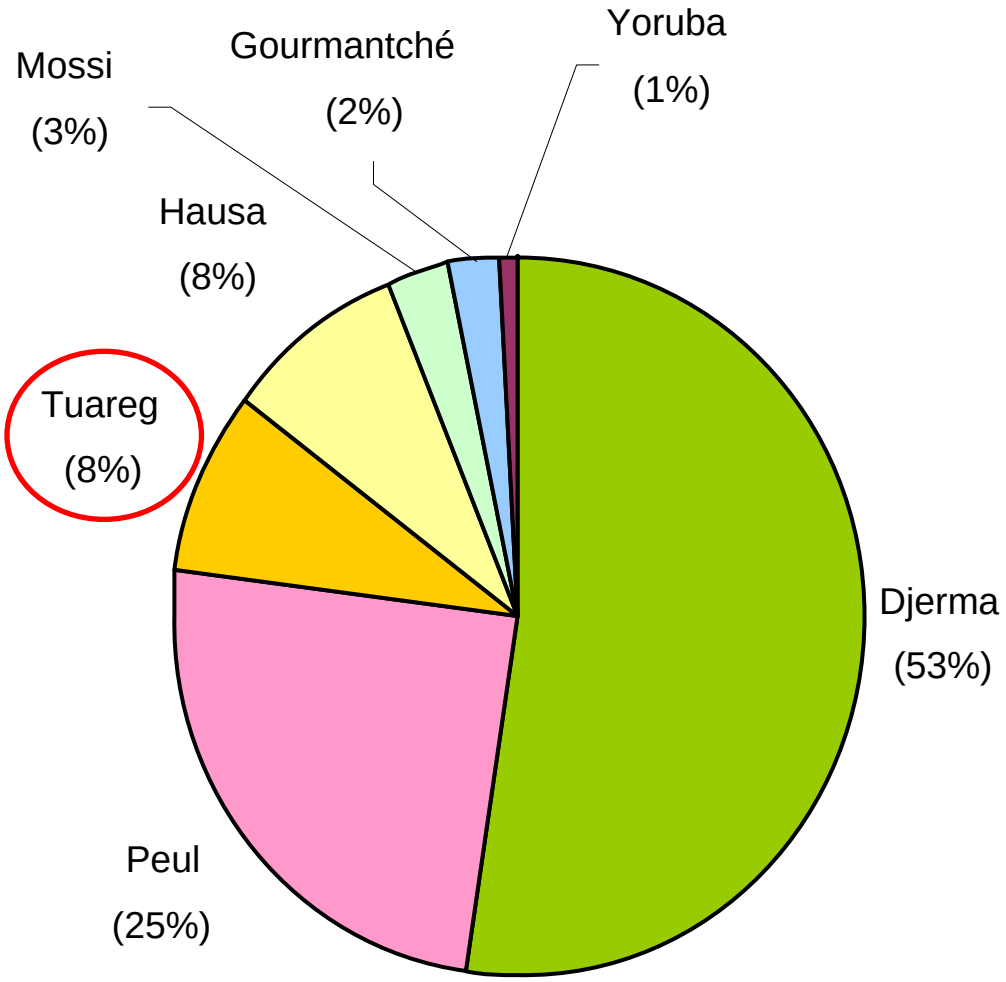


Bernholt et al. 2009
Agroforestry Systems (in press).

Plant biodiversity in UPA gardens

- Example: Niamey, Niger -

Highest species diversity
found in gardens of nomads!



Bernholt et al. 2009. Agroforestry Systems (in press).

Determination of nutrient fluxes at the garden scale

Gaseous losses

CH_4, CO_2, NH_3, N_2O

Inputs

Manure,
mineral fertilizer

Outputs

Exported harvest

Leaching losses

NO_3, P_{org}

Leaching with cation / anion exchange resins

Digging of profile

Preparing
resin:sand mixture

Installing
cartridge

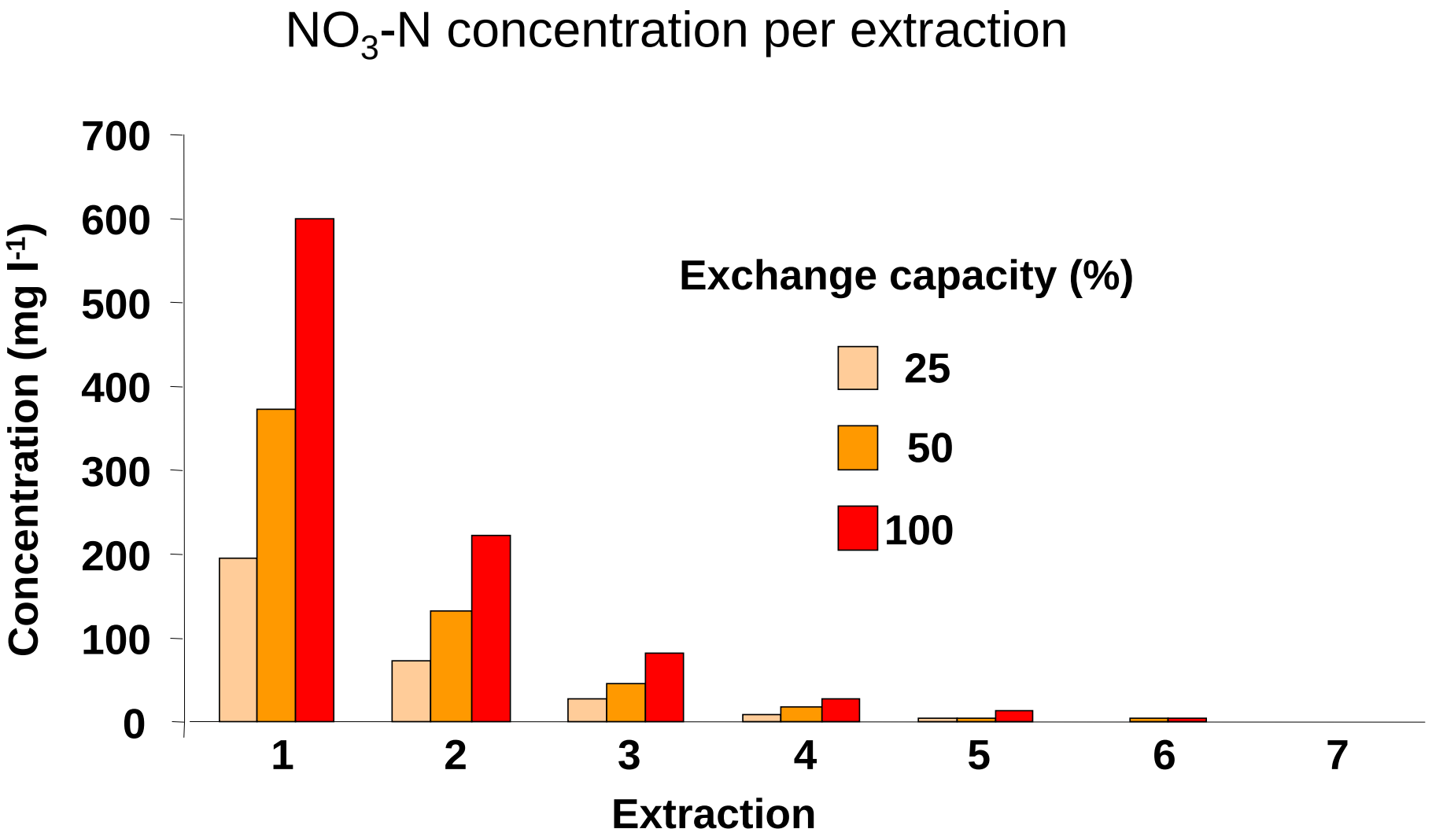
Recovery rates achieved with resin method?

Recovery rates achieved with resin method

Factor	Flow time / Saturation		Recovery rates (%) NO_3^-	NH_4^+	PO_4^{3-}	K^+
Saturation level of ion-exchange resin	20%		100	92	104	219
	80%		98	108	114	169
Flow rate / Resin saturation	3 hours	20%		85	77	180
	9 hours	20%		99	131	257
	3 hours	80%		133	110	192
	9 hours	80%		83	118	146
Mean			**99**	**100**	**109**	**194**

Siegfried et al. (unpublished data).

Recovery rates achieved with resin method



Siegfried et al. (unpublished data).

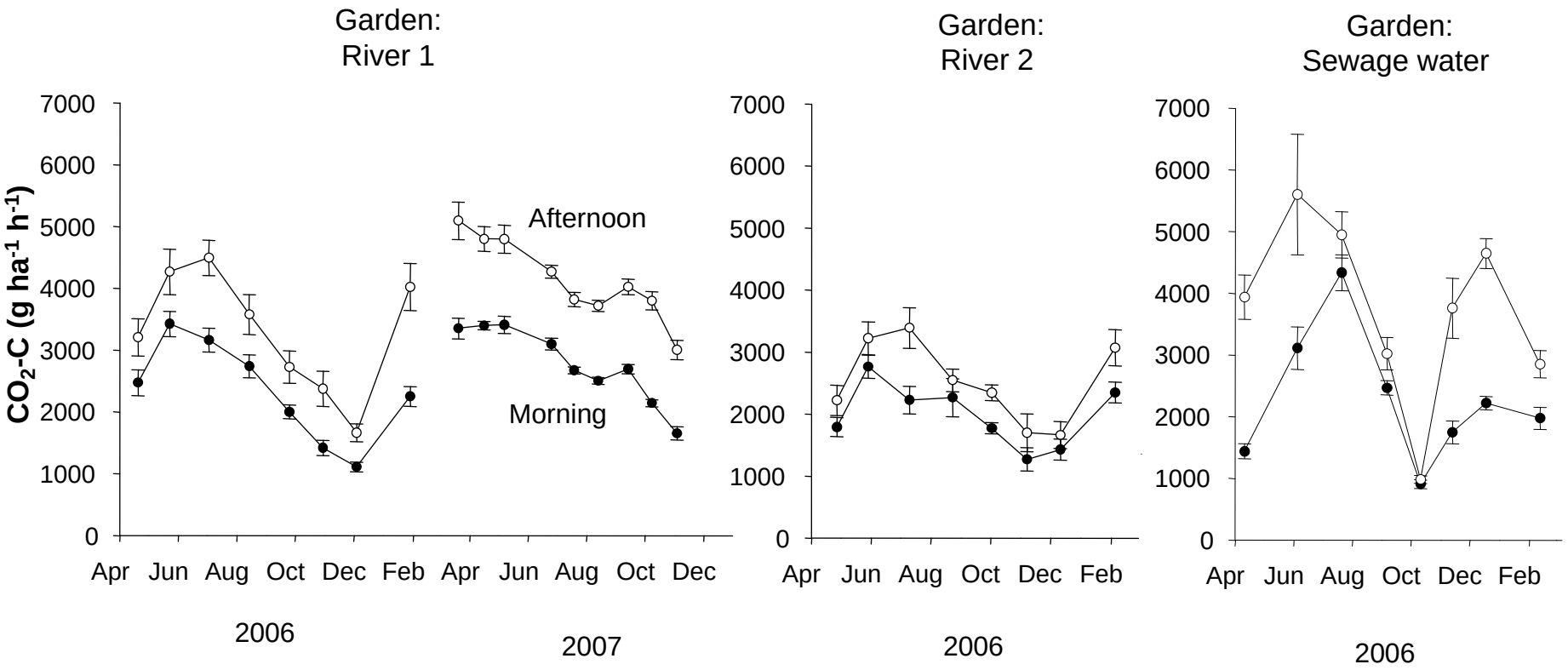
Measuring gaseous C & N losses
- a photo-accoustic multigas monitor approach -

Closed-chamber system

Gaseous C losses from three UPA gardens

- Example: Niamey, Niger -

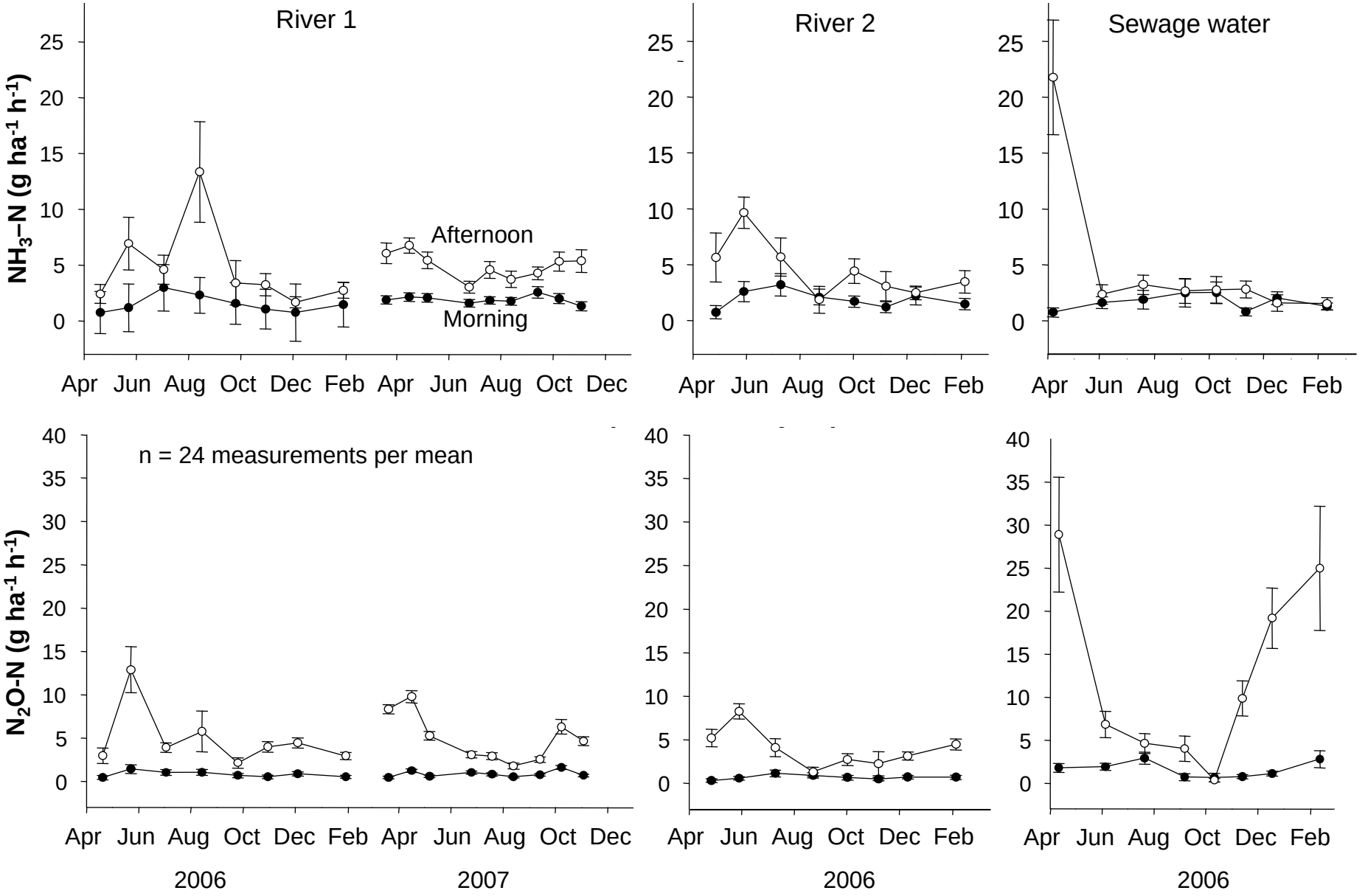
n = 24 measurements per mean



Predotova et al. Field Crops Research (submitted).

Gaseous N losses from three UPA gardens

- Example: Niamey, Niger -



Predotova et al. Field Crops Research (submitted).

Horizontal N and C balances of UPA gardens

- Example: Niamey, Niger -

Garden type	N balances (kg ha^{-1} a^{-1})	N input source	C balances (kg ha^{-1} a^{-1})
High input (n=5)	890 – 2,991	Manure (n=5) 0 – 73 % Sewage water (n=2) 73 – 100 %	785 – 19,588
Low input (n=5)	-142 - 597	Manure (n=5) 49 – 93 %	4,454 – 28,320

Total N balances of UPA gardens
- Example: Niamey, Niger -

	Horizontal N fluxes		Gaseous N losses			N leaching	Total N balance
Garden	Input	Output	Total	NH_3	N_2O	NO_3-N	
	(kg ha^{-1} a^{-1})		(kg ha^{-1} a^{-1})	(%)		(kg ha^{-1} a^{-1})	(kg ha^{-1} a^{-1})
River 1	470	100	53	52	48	6*	310
River 2	780	190	48	59	41	2*	540
Sewage water	3,820	830	92	32	68	7*	2,890

* values of rainy season 2007

Predotova et al. (unpublished data).

Total C balances of UPA gardens

- Example: Niamey, Niger -

Horizontal C fluxes | **Gaseous C losses** | **Total C balance**

Garden	Input		Output	Total	CO_2	CH_4	Total C balance
	Fertilizer	Roots*		(kg ha^{-1} a^{-1})	(%)		(kg ha^{-1} a^{-1})
River 1	30,520	2,200	2,200	25,150	98	2	5,270
River 2	12,280	2,190	2,190	20,190	98	2	- 7,910
Sewage water	7,820	7,030	7,030	26,630	98	2	- 18,810

* Estimated to be equivalent to the harvested shoot C

Diogo et al. (unpublished data).

N and C losses from dung storage in UPA gardens

- Example: Niamey, Niger -

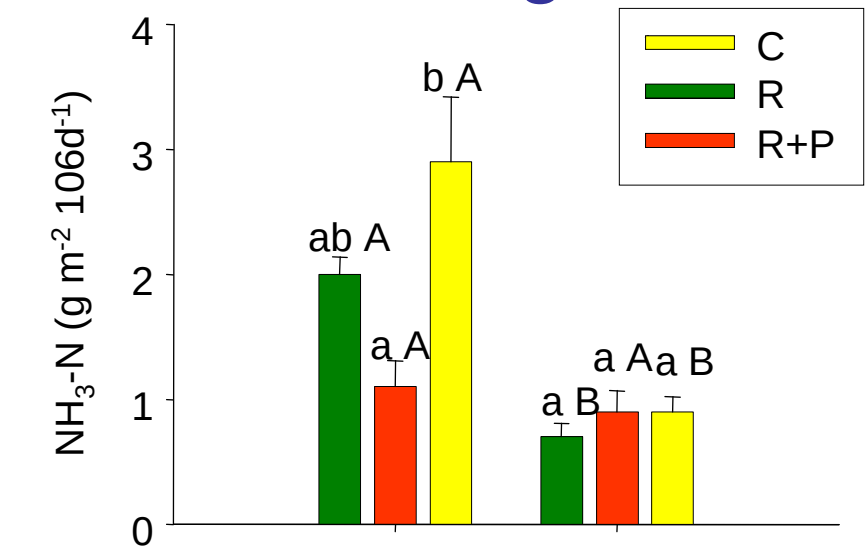
Rainy season + hot dry season in 2007 (each 3,5 month)

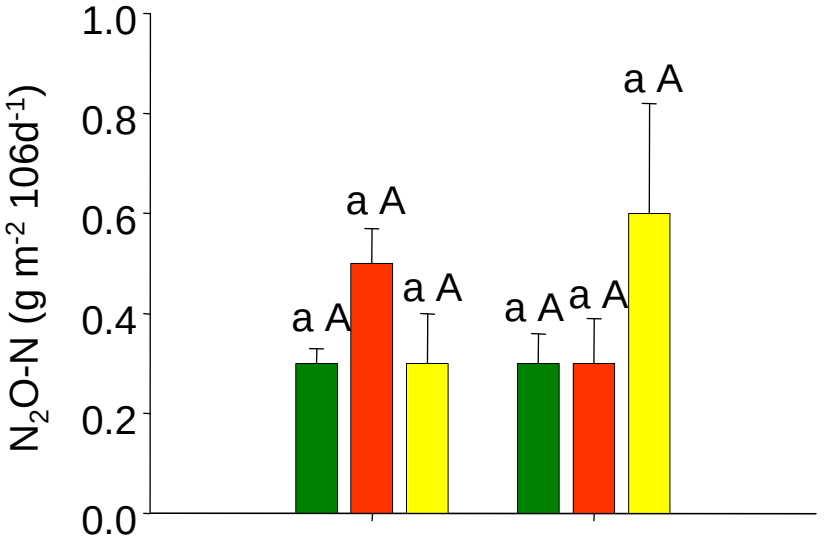
Mixture of fresh dung heaped on 1 m^2 metal tables installed with a slight slope to collect leachates

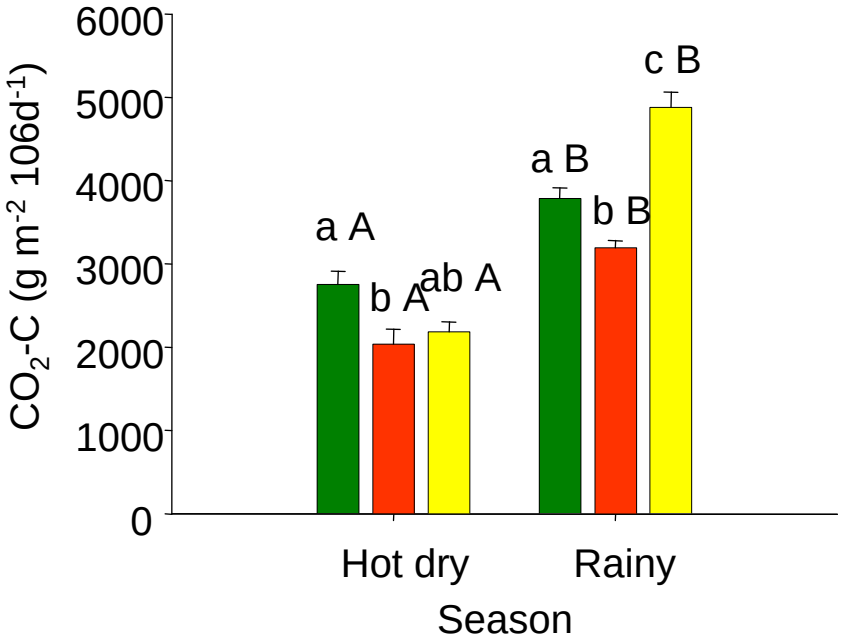
3 treatments / 4 repetitions

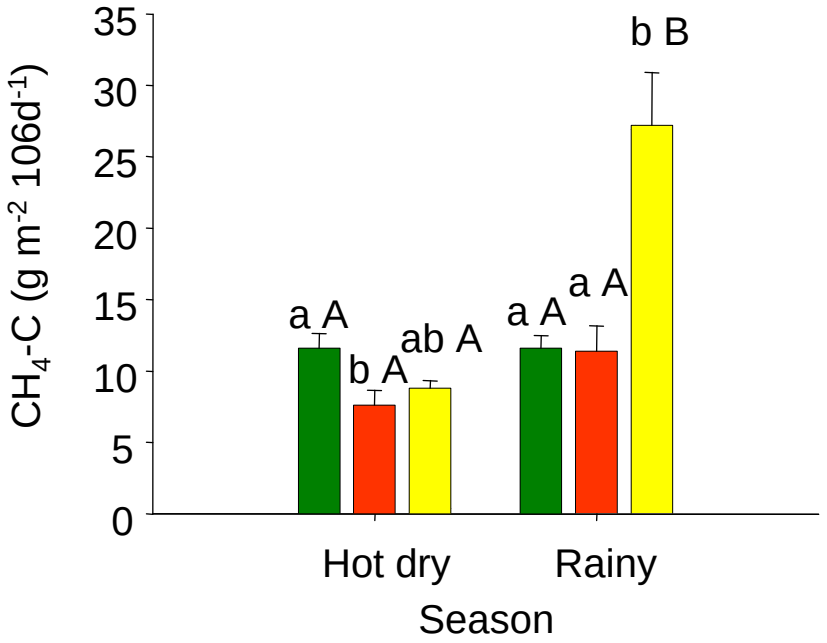
- **Unprotected control (C)**
- **Roofed (R)**
- **Roofed + rock phosphate (RP)**

Gaseous N and C losses from dung storage in UPA gardens of Niamey, Niger

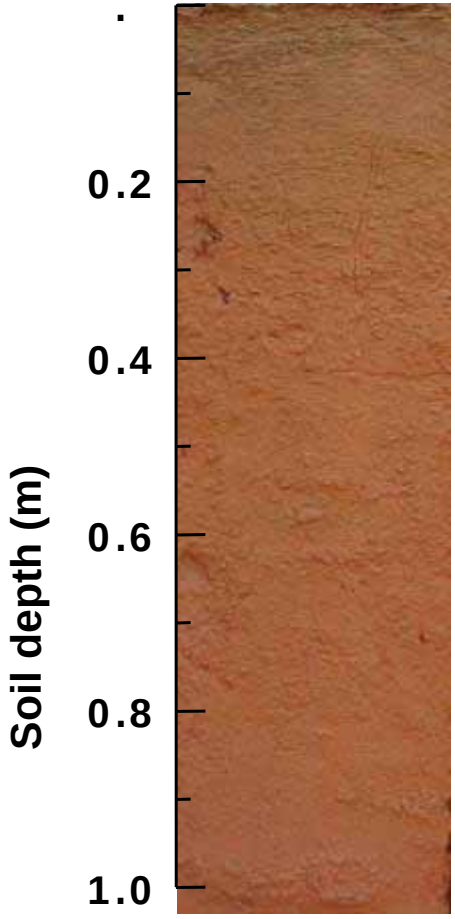








Soil profiles in millet field *versus* UPA garden in Niamey



0-0.2 m	pH_{KCl}	P_{Bray} (mg kg^{-1})	C_{org} (%)	CEC ($cmol_c$ kg^{-1})
	4.4	3	0.23	1.10

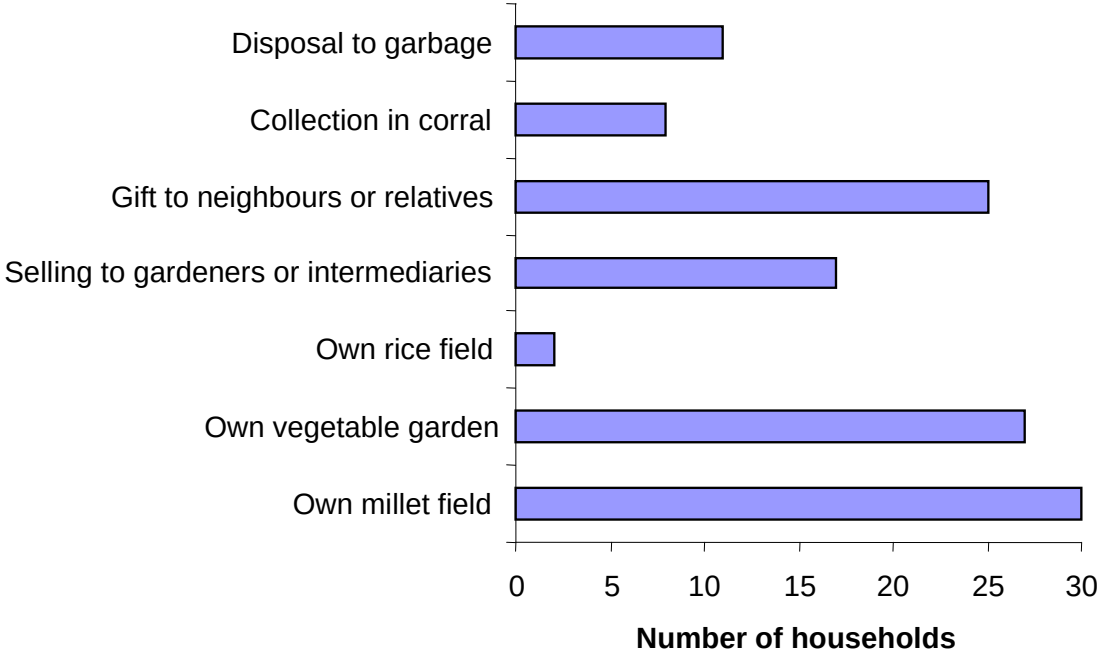
Arenosol
Sadoré (Niger)

	pH_{KCl}	P_{Bray} (mg kg^{-1})	C_{org} (%)	CEC ($cmol_c$ kg^{-1})
	6.1	41	0.27	2.92
	6.7	41	0.96	9.57

Fluvisol on river bench
Niamey (Niger)

Manure use in livestock keeping UPA households

Niamey **Khartoum** **Kabul**



Brick making ***Fuel***

Conclusions

Urban and peri-urban agriculture (UPA) can make an important contribution to supplying food and income opportunities to the raidly growing urban populations of developing countries, but its role strongly varies between locations.

- **Negative externalities of UPA need careful analysis to derive effective recomendations fostering the sustainability of the systems.**

- **Carbon and nutrient balances strongly vary between and within locations. While N balances are often excessively possitive leading to N losses via volatilisation, C-balances heavily depend on the use of manure.**

- **A thorough unterstanding of the biophysical, economic and social sustainability of UPA systems may also allow us to derive important conclusions for the farm-level adoption of improved soil fertility management options in the vast rainfed systems across semi-arid Africa and parts of Asia.**