Output 3
Partnerships and tools developed and capacity enhanced of all stakeholders for improving the health and fertility of soils

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Rationale

Managing soil fertility for improved livelihoods requires an approach that integrates technical, social, economic, and policy issues at multiple scales. To overcome this complexity, research and extension staff needs the capacity to generate and share information that will be relevant to other stakeholders working at different scales (i.e., policy-makers, farmers). Thus the activities of Output 3 are founded on building the human and social capital of all TSBF-CIAT stakeholders for research and management on the sustainable use of tropical soils.

The challenge of building the social capital encompasses both the new and existing networks of scientists and other stakeholders (e.g.: AFNET, MIS, CSM-BGBD project). Within these networks, as within the individual project activities where TSBF-CIAT works in partnership with others (NARES, ARI's, NGO's), building social capital means ensuring that communication and co-learning support effective institutional collaboration and build confidence in the collaborative advantage afforded by partnerships. Networks run best with diligent coordination that responds to internal and external challenges. However, partnerships become truly empowering when stakeholders themselves recognize and exploit research and development opportunities. The activities prescribed here envisage tapping the potential of South-South collaboration and establishing strategic partnerships that can build learning strategies that to institutionalize ISFM approaches.

The second challenge, of building human capacity, is particularly acute in sub-Saharan Africa and Central America, where the lack of strong tertiary education systems and the chronic under-funding of NARES hamper the professional development of many of our partners. Since ISFM approaches are inherently holistic, effective training demands interdisciplinary cooperation to instill both a specialized knowledge and a competent understanding of the context(s) in which to apply it (the so-called "T-shaped" skill set). Again, working through new and existing networks and partnerships, TSBF-CIAT will continue to support training that offers cutting-edge bio-physical science, laboratory techniques, and also embraces holistic understanding of social, cultural, economic, and policy issues related to soil fertility management.

Building human capacity also applies to the relationship land users have with the products of research. At present, many ISFM technologies remain little used by farmers. This is commonly conceived of as a failure to disseminate the results of research, but can also be seen as indicating a fundamental failure of research to recognize, value, and address farmers' conditions and knowledge. Greater involvement of farmers in the technology design process (to adapt solutions to actual conditions) will not only generate more relevant and adoptable ISFM technologies but is also expected to facilitate the potential dissemination and up-scaling of these technologies through the better interaction and integration of indigenous and formal knowledge systems.

Finally, the lack of an enabling policy environment is made manifest by the often-contradictory policies relating to farm, village, or regional-level conditions. The poor functioning of local input and output markets distorts the incentives for resource conservation. Coherent policy options are needed to address the low added value of farmers' products, the general lack of marketing opportunities on the one hand, and the lack of appropriate infrastructure and mechanisms for input delivery on the other.

Key research questions

1. What are the mechanisms and information required for institutionalization of ISFM approaches with partners for scaling-up and increased impact?
2. Who are the key stakeholders and partners for SLM?
3. What are the relevant learning processes and approaches to improve stakeholders' skills to make improved decisions?
4. How can South-South integration facilitate the development of global products?

Output targets 2009

- ***Farmer-to farmer knowledge sharing and extension through organized field trips and research activities result practices in at least two sites***

Completed work

AfNet Research Highlights from West Africa

Since 2001, AfNet has continued to support network experiments in West Africa using commonly developed research protocols. The research activities in West Africa are conducted under a memorandum of understanding between TSBF institute of CIAT and ICRISAT. Collaborative research is being undertaken with researchers from Niger, Burkina Faso, Nigeria, Ghana, Senegal etc. The themes which are investigated are 1) Water harvesting and nutrient management 2) Combining organic and inorganic nutrient sources; 3) use of different cropping systems; 4) On-farm evaluation of soil fertility restoration technologies; 5) Optimum management of organic resources and inorganic nutrient sources, 6) conservation agriculture, and 7) use of phosphate rock in crop production.

In Niger (West Africa), several sites have been established since 2001 and being continued in 2007. **(Table 16)** below shows a list of Network collaborative trials in Niger, 2006 giving the type of trial and sites located.

Table 16: Network collaborative trials in Niger (West Africa), 2006

Type of Trials	**Site**
Long-term operational scale research	Sadore
Long-term cropping system	Sadore
Long-term crop residue management	Sadore
On-farm evaluation of cropping systems technologies	Sadore Karabedji Gaya
On-farm evaluation of soil fertility restoration technologies	Karabedji Gaya
Comparative effect of mineral fertilizers on degraded and non degraded soils	Karabedji
Fertilizer equivalency and optimum combination of low quality organic and inorganic plant nutrients	Banizoumbou Karabedji Gaya
Optimum combination of phosphate rock and inorganic plant nutrients	Banizoumbou, Gaya Karabedji, Sadore
Corral experiment (demonstration)	Sadore

Long-term soil fertility management trials

Long-term management of phosphorus, nitrogen, crop residue, soil tillage and crop rotation in the Sahel

This experiment started in 1986 by ICRISAT Sahelian Center is a long-term soil fertility management trial that studies the sustainability of pearl millet based cropping systems in relation to management of N, P, and crop residue, rotation of cereal with cowpea and soil tillage. The data in (**Table 17)** gives the main treatments in this trial. It's a split-split-plot design where split-split plot consists of crop residue application or no crop residue (CR) application and the sub-sub plot are with or without nitrogen application. The amount of CR applied is half of the total production of the previous year.

Table 17: Main treatments used in the operational scale research trials at Sadore. Niger

1= Traditional practices
2= Animal traction (AT) +no rotation +Intercropping + P
3= Animal traction (AT) + rotation +Intercropping + P
4= Hand Cultivation (HC) +no rotation +Intercropping + P
5= Hand Cultivation (HC) + rotation +Intercropping + P
6= Animal traction (AT) +no rotation +Pure millet + P
7= Animal traction (AT) + rotation + Pure millet + P
8= Hand Cultivation (HC) +no rotation + Pure millet + P
9= Hand Cu ltivation (HC) + rotation + Pure millet + P

In the 2007 cropping season, traditional farmers' practices yielded 23kg/ha of pearl millet grain whereas with application of 13kg P/ha, 30kg N/ha and crop residue in pearl millet following cowpea yielded 640kg/ha of pearl millet grain and 689kg/ha when ridging is associated (**Table 18**). These results clearly indicate the high potential to increase pearl millet yields in the very poor Sahelian soils with improved soil water and nutrient management practices.

Table 18: Effect of fertilizers, soil tillage, crop residue, cropping system on pearl millet grain yield; Sadore 2006-2007 cropping seasons

Treatments	**Pure millet grain yield (kg/ha)**							
	- Rotation				+ Rotation			
	- Crop residue		+ Crop residue		- Crop residue		+ Crop residue	
	-N	+N	-N	+N	-N	+N	-N	+N
3a: 2006								
Traditional	156	146	225	234				
Phosphorus + HC	448	651	566	853	741	902	652	925
Phosphorus + AT	329	404	481	638	654	882	1043	977
3b: 2007								
Traditional	23	30	43	49				
Phosphorus + HC	228	391	331	500	296	486	534	640
Phosphorus + AT	217	315	332	626	442	400	709	689

HC- Hand Cultivation, planting on flat; AT- Animal Traction, planting on ridges

Long-term management of manure, crop residues and fertilizers in different cropping systems
This factorial experiment started in 1993 was initiated at the research station of ICRISAT Sahelian Center at Sadore, Niger. The first factor was three levels of fertilizers (0, 4.4kg P + 15kg N/ha, 13kg P + 45kg N/ha), the second factor was crop residue applied at (300, 900 and 2700 kg/ha) and the third factor was manure applied at (300, 900 and 2700 kg/ha). The cropping systems are continuous pearl millet, pearl millet in rotation with cowpea and pearl millet in association with cowpea. The analysis of variance of the data indicated that fertilizer; crop residue and manure application resulted in a highly significant effect of both pearl millet grain and total dry matter yields. IN 2007 cropping season, fertilizer alone account for 13% (18% in 2006) in the total variation of the grain, cropping system accounted for 9% (19% in 2006) whereas manure account for only 4% (5% in 2006). The results of 2007 were lower compared to 2006's results confirming the negative effect of late planting combined with early stopping of rain water. The duration of the rainy season at Sadore was about 2 months only (July 14th to September 14th).

For pearl millet dry matter, the application fertilizer, manure, crop residue and cropping systems together account for 35% (56% in 2006) of the total variation. The data in **(Figure 27)** illustrates the response of pearl millet grain to the crop rotation and to the different input of organic and inorganic fertilizers. The farmer's practices yielded 133 kg/ha of millet grain; the application of 13 kg P and 45 kg N/ha yielded 482 (670kg/ha in 2006) but when these mineral fertilizers are combined with 2.7 t/ha of manure or crop residue in rotation with cowpea, millet grain yield of 708 (900 kg/ha in 2006) was achieved.

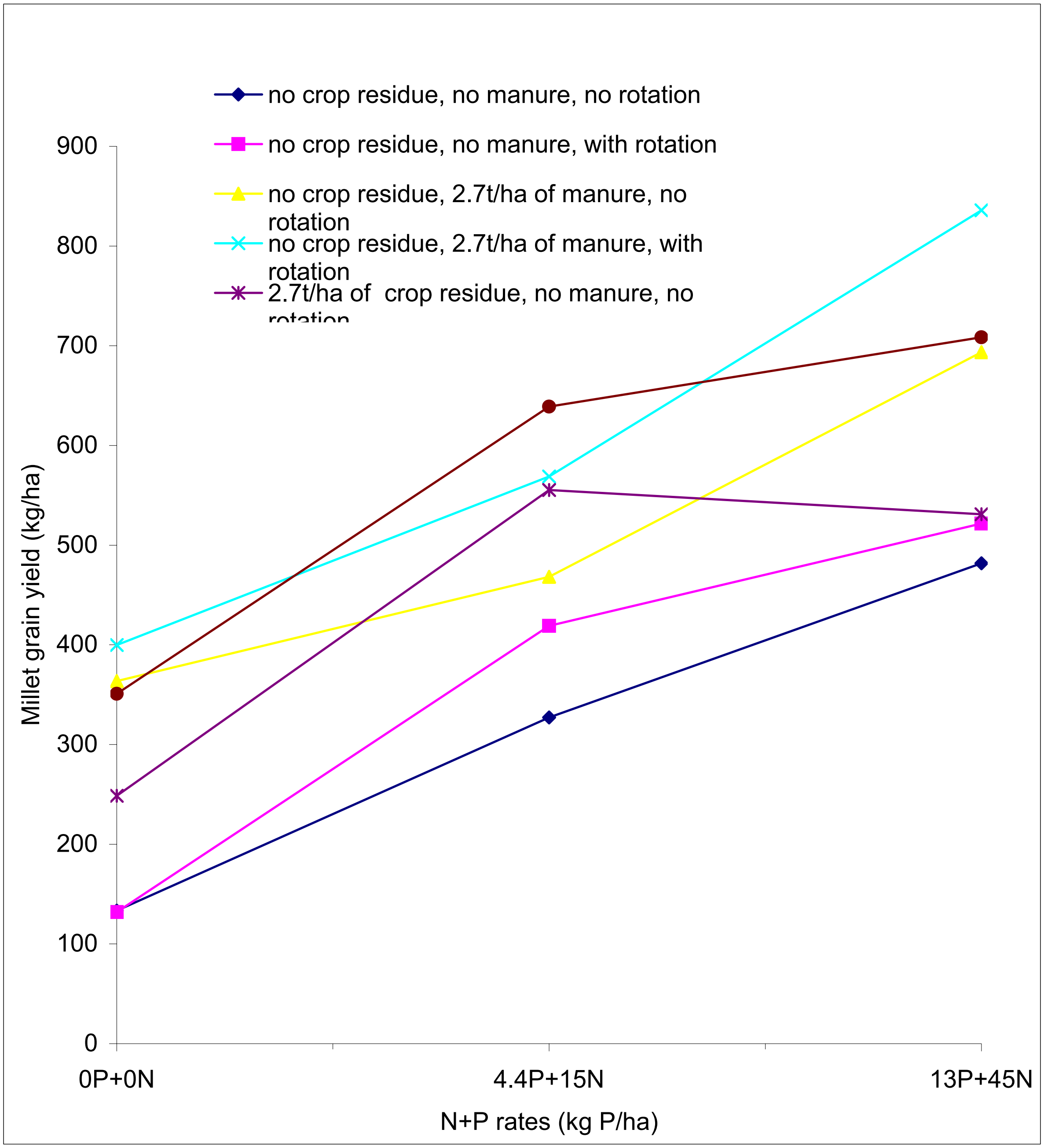


Figure 27: Effect of different N and P rates on pearl millet grain yield, Sadore, Niger, 2007 rainy season

Another crop residue (CR) trial established since 1982 sole application of CR resulted in millet grain yield of 251 kg/ha. This yield increased to 675 kg/ha with fertilizer (F) application and to 1005 kg/ha when both are applied (CR+F).

The millet total dry matter yield increased from 1173 to 4290 kg/ha with CR application **(Table 19)**. These high yields compared to 2006 results were attributed to timely planting of the crop as well as improved soil properties (organic carbon, protection against erosion) as a result of long term application of nutrient resources.

Table 19: Effect of fertilizer and crop residue on pearl millet and cowpea at Sadore, 2007 rainy season

Treatment	Grain yield (kg/ha)	TDM (kg/ha)	
	Millet	Millet	Cowpea
1=Control	251	1173	75
2=Crop residue (CR)	433	2225	50
3=Fertilizer (F)	675	3204	35
4=CR+F	1005	4290	210
SE	73	250	43
CV	25%	18%	93%

CR- Crop Residue; F- Fertilizer; TDM-Total dry matter

Optimum combination of Phosphate rock (PR) and inorganic sources of nutrients

In the past tree years we have experimented the combined application of organic resources and mineral inputs that forms the technical backbone of the Integrated Soil Fertility Management (ISFM) approach. Procuring a sufficient amount of organic matter of a desired quality and quantity is often a major problem faced by farmers in the region. Since 2005, experimentation was done on the combination of minerals fertilizers with phosphate rock (PR) which is readily available and affordable for poor farmers.

In 2007, farmers conducted network experiments at 4 benchmark locations across Niger country to investigate the best combination of mineral fertilizer and PR that are available for direct use.

The data in (**Table 20)** give the rainfall and chemical characteristics at study sites in the Sahel. These soils are acidic and inherently low in nutrients with ECEC of less than 1 c mol/kg for all the sites except Gaya where the organic carbon is slightly higher and an ECEC of 1.3 c mol/kg.

Table 20: Annual precipitation (2006-2007) and soil characteristics for selected villages

Sites	Rainfall Mm		pH KCl	C.org (%)	P-Bray1 (mg/kg)	Ca^{2+} Cmol/kg	ECEC Cmol/kg	N_{min} (mg/kg)
	2006	2007						
Sadore	558.6	506.6	4.3	.12	2.0	0.3	1	3
Banizoumbou	-	-	4.4	.12	1.5	0.4	0.8	5
Karabedji	493.7	486.1	4.2	.16	1.9	0.2	0.8	4
Gaya	998.7	849.6	4.2	.33	2.5	0.4	1.3	9

The data in **(Tables 21, 22 & 23)** indicate the comparative advantage of combining PR and inorganic plant nutrients for the low buffering soils in the Sahel. The use of only PR as the source of P in Sadore yielded 561kg/ha of millet grain whereas the same rate in the mineral P farm gave 1211kg/ha. IN general, the combination of both PR and soluble P sources at different rates resulted in higher millet grain and dry matter compared to sole application of either resource. The results from this tria point o the feasibility of farmers saving on cost of purchasing soluble P fertilizer by combining the cheap PR source with a small quantity of soluble P.

Table 21: Optimum combination of plant nutrients for millet grain and TDM (kg/ha) at Karabedji and Gaya, Niger, 2007 cropping season

Treatments	**Karabedji**		**Gaya**	
	Grain	**TDM**	**Grain**	**TDM**
Absolute Control	828	3578	293	2805
30 kg N/ha	1193	4622	298	2805
12 kg P/ha	1469	5464	573	4180
12 kg P/ha PR+ 30kg N/ha	1724	6143	428	3505
9kg P/ha PR+ 3kg P + 30kg N/ha	1958	6672	440	3685
6kg P/ha PR + 6kg P + 30kg N/ha	2182	7382	508	3915
3kg P/ha PR + 8 kg P + 30kg N/ha	2417	8005	353	4365
12 kg P + 30 kg N/ha	1953	6566	478	5450
SE	40	143	51	192
CV	5%	5%	24%	10%

Table 22: Optimum combination of plant nutrients for millet grain and TDM yields (kg/ha) at Banizoumbou and Sadore, Niger, 2007 cropping season

Treatments	**Banizoumbou**		**Sadore**	
	Grain	**TDM**	**Grain**	**TDM**
Absolute Control	323	1333	348	1819
30 kg N/ha	479	1994	775	2292
12 kg P/ha	1031	3913	1211	4125
12 kg P/ha PR+ 30kg N/ha	646	2448	561	2177
9kg P/ha PR+ 3kg P + 30kg N/ha	865	3483	1185	3385
6kg P/ha PR + 6kg P + 30kg N/ha	1271	4681	1213	5558
3kg P/ha PR + 8 kg P + 30kg N/ha	1208	4938	1113	4552
12 kg P + 30 kg N/ha	1167	4313	1200	4604
SE	141	448	122	520
CV	32%	26%	26%	

A similar but onfarm trial using the same treatments as above was also tested with farmers in the above locations. The cowpea fodder yielded 1910kg/ha with inorganic P application at Gaya give and 1395kg/ha with the PR **(Table 23)**. Synergies were also observed when the two resources were used together.

Table 23: Optimum combination of plant nutrients for cowpea fodder (kg/ha) at Karabedji, Banizoumbou, Sadore and Gaya, Niger, 2007 cropping season

Treatments	Karabedji	Banizoumbou	Sadore	Gaya
Absolute Control	772	230	260	815
30 kg N/ha	1003	345	395	890
12 kg P/ha	1121	335	250	1250
12 kg P/ha PR+ 30kg N/ha	1265	435	390	1395
9kg P/ha PR+ 3kg P + 30kg N/ha	2053	565	345	1540
6kg P/ha PR + 6kg P + 30kg N/ha	2877	560	265	1860
3kg P/ha PR + 8 kg P + 30kg N/ha	4490	620	365	1850
12 kg P + 30 kg N/ha	1750	375	245	1910
SE	176	58	82	62
CV	18%	27%	52%	9%

Interaction of N, P and manure (Karabedji, Banizoumbou and Gaya)

A factorial experiment of manure (0, 2 and 4t/ha), nitrogen (0, 30 and 60 kg N/ha) and phosphorus (0, 6.5 and 13kg P/ha) was established in Karabedji, Banizoumbou and Gaya to assess the fertilizer equivalency of manure for N and P. The data in (**Table 24)** show a very significant effect of N, P and manure on pearl millet yield. Whereas P alone accounted for 14% (16% in 2006) of the total variation, nitrogen accounted for 4% (14% in 2006) in the total variation indicating that P is the most limiting factor at this site. Manure account for 7% (13% in 2006) in the total variation.

Table 24: Interaction of N, P and manure on millet grain yield (kg/ha) at Karabedji, Banizoumbou, and Gaya, Niger, 2007 cropping season

Treatments	Karabedji		Banizoumbou		Gaya	
	Grain	TDM	Grain	TDM	Grain	TDM
P0	625	2876	281	1119	340	2385
P13	1047	4149	854	3079	510	3170
P26	1094	4383	979	3210	398	3565
M0	625	2876	281	1119	340	2385
M2	1443	5470	708	2471	410	2895
M4	1583	6170	1042	3819	475	3085
N0	625	2876	281	1119	340	2385
N30	839	3517	583	1973	330	2350
N60	1063	4053	625	2348	490	2770
SE	81	194	156	485	60	254
CV	10%	6%	27%	23%	22%	14%

Placement of phosphorus and PUE (Karabedji)

Kodjari Phosphate Rock (PRK) was broadcast (BC) and/or hill placed (HP). For pearl millet grain P use efficiency for broadcasting SSP at 13kg P/ha was 12 (42kg/kg P in 2006) but hill placement of SSP at 4kg P/ha gave a PUE of 46 (147kg/kg P in 2006) and 58 (169kg/kg P in 2006) with NPK hill placement. Whereas the PUE of TPR broadcast was only 3 (14kg grain/kg P in 2006), the value increased to 11 (47kg/kg P in 2006) when additional NPK was applied as hill placed at 4kg P/ha. Those data clearly indicate that P placement can drastically increase P use efficiency and the placement of small quantities of water-soluble P fertilizers can also improve the effectiveness of phosphate rock **(Table 25)**. The comparison to 2006 results shows that P was not efficiently used this year due probably to rain distribution and early stopping.

For cowpea fodder PUE for P broadcast seemed to be better than HP opposite to the common results obtained the previous years. These results can be the effect of residual fertilizer in the broadcasted plots.

Table 25: Effect of P sources and placement on pearl millet and cowpea yield and P use efficiency (PUE) at Karabedji, Niger, 2006-2007 cropping seasons

Treatments	**Millet**				**Cowpea**			
P sources and methods of placement	Grain yield (kg/kg P)		PUE (kg/kg P)		Fodder (kg/ha)		PUE (kg/kg P)	
	2006	2007	2006	2007	2006	2007	2006	2007
Control	411	59			1842	402		
SSP (BC)	962	217	42	12	2378	1429	13	85
SSP (BC) + SSP (HP)	1464	713	62	38	5685	3288	62	75
SSP (HP)	997	243	147	46	3965	1669	14	28
15-15-15 (BC)	1048	254	49	15	4713	1729	59	88
15-15-15 (BC) + 15-15-15 (HP)	1821	1127	83	63	8184	4320	76	62
15-15-15 (HP)	1087	292	169	58	5560	2076	22	29
TPR (BC)	587	99	14	3	2709	895	64	160
TPR (BC) + SSP (HP)	1133	234	42	10	3502	1368	39	94
TPR (BC) + 15-15-15 (HP)	1202	248	47	11	4297	1958	53	140
PRK (BC)	571	149	12	7	2612	919	62	75

PRK (BC) + SSP (HP)	1048	305	38	14	3214	1570	37	81
PRK (BC) + 15-15-15 (HP)	1156	353	44	17	4078	2084	51	97
SE	36	60			288	153		
CV	7%	36%			14%	17%		

SSP: Single Superphosphate, 15-15-15: N_2 P_2O_5 K_2O compound fertilizer; TPR: Tilemsi Phosphate Rock, PRK: Kodjari phosphate rock; BC: Broadcast at 13 kg P/ha, HP: hill placed at 4 kg P/ha; PUE: P use efficiency kg yield/kg P applied

Farmer's evaluation of soil fertility restoration technologies (Karabedji and Gaya)

Past research results indicated a very attractive technology consisting of hill placement of small quantities of P fertilizers. With DAP containing 46% P_2O_5 and a compound NPK fertilizer (15-15-15) containing only 15% P_2O_5, fields trials were carried out by farmers on 54 plot per treatment at Karabedji to compare the economic advantage of the two sources of P for millet production. As hill placement can result in soil P mining another treatment was added consisting of application of phosphate rock at 13kg P/ha plus hill placement of 4kg P/ha as NPK compound fertilizers.

The data in **(Tables 26 & 27)** clearly shows that at Karabedji, there was no significant difference between hill placement of DAP and 15-15-15 (675 and 690 kg/ha) indicating that with the low cost per unit of P associated with DAP, this source of fertilizer should be recommended to farmers. The basal application of Tahoua Phosphate rock gave about 200 kg/ha additional pearl millet grain. The combination of hill placement of water-soluble P fertilizer with phosphate rock seemed a very attractive option for the resource poor farmers in this region.

Table 26: Farmers managed trials at Karabedji, 2006-2007 rainy seasons

Treatments	**Millet grain yield (kg/ha)**		**Millet TDM yield (kg/ha)**	
	2006	2007	2006	2007
1=farmers' practices	244	188	1180	1651
2=NPK HP	832	690	2260	3130
3=DAP HP	835	675	2209	3095
4=PRT+NPK HP	1111	900	2925	3852
SE	9	14	15	30
CV	8%	15%	5%	7%

NPK: 15-15-15 compound fertilizers; DAP: Diammonium phosphate; HP: hill placement at 4 kg P/ha; PRT: Tahona Phosphate rock broadcast at 13 kg P/ha

Table 27: Farmers managed trials at Gaya, 2006-2007 rainy seasons

Treatment	**Millet grain yield (kg/ha)**		**Millet TDM (kg/ha)**	
	2006	2007	2006	2007
1=farmers' practices	982	605	3752	4186
2=NPK HP	1683	825	5404	5196
3=DAP HP	2075	934	6447	5743
4=PRT+NPK HP	2547	1131	7404	6628
SE	37	17	68	68
CV	14%	15%	8%	9%

NPK: 15-15-15 compound fertilizers; DAP: Diammonium phosphate; HP: hill placement at 4 kg P/ha; PRT: Tahoua Phosphate rock broadcast at 13 kg P/ha

The data in **Figure 28 & 29** is show the variation of yield of each plot in farmers fields as compared to the farmer's practices and clearly show that the application of Tahoua PR with hill placement of water soluble P outperformed the other treatments in most instances. At Gaya, with 46 plots per treatment the same effect can be observed and DAP seem better than NPK (934 VS 825 kg/ha) and confirm the choice on this source **(Table 27).**

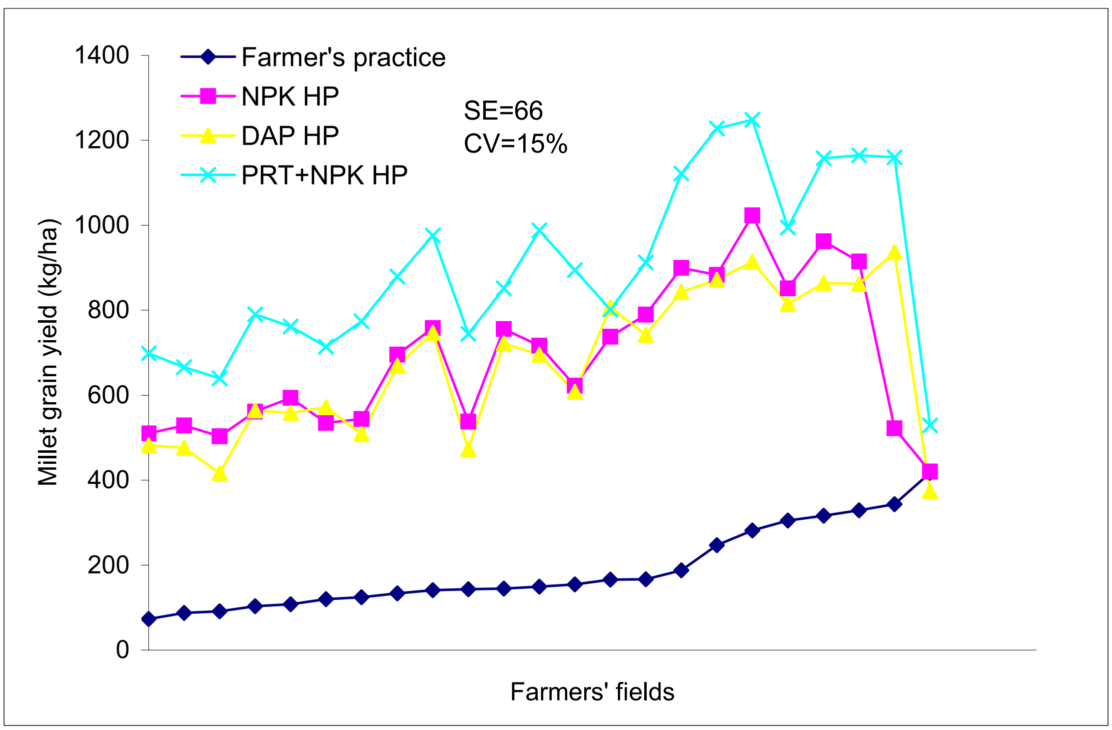


Figure 28: Millet grain yield response to different management practices, Karabedji, Niger, 2007 rainy season

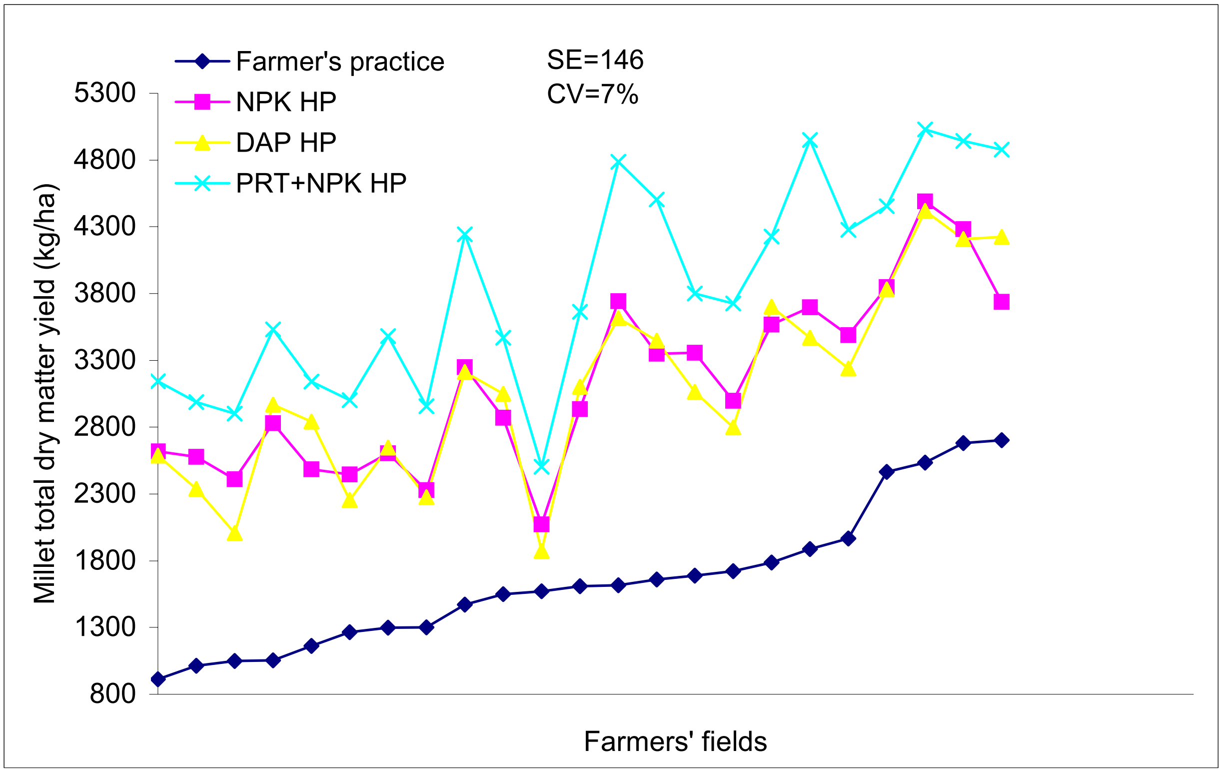


Figure 29: Millet total dry matter yield response to different management practices, Karabedji, Niger, 2007 rainy season.

Cropping systems and mineral fertilizers evaluation (Sadore, Karabedji and Gaya)
Farmers' practices were compared to a three cropping systems consistency on pure millet crop with planting density at recommended level to be rotated next year with a pure cowpea, a fourth plot with millet and cowpea intercropped but not as farmer's practice. Here four lines of cowpea were be rotated with two lines of millet. Tahoua Phosphate rock at 13 kg P/ha and NPK hill placed at 4 kg P/ha were applied for each plot except farmer's practice.

The data in **(Table 28)** indicates that millet grain yield at Sadore can be significantly increased (366 to 804 kg/ha) with this system and higher biomass can be yielded especially by integrating cowpea into the system. With increased biomass production, crop-livestock integration can be supported. The same trial was implemented at Karabedji and gave a similar effect (227 to 984 kg/ha) as Sadore **(Table 29)**. At Gaya, cowpea was replaced by groundnut due to cowpea crop failures in previous years **(Table 30)**. The data in these tables shows how the yield of the technologies evaluated fluctuated as compared to the farmers' practices with the high density and rotation systems dominating the other systems in most instances.

Table 28: Farmers managed trials at Sadore, 2006- 2007 rainy seasons

Treatment	Millet grain yield (kg/ha)		Millet TDM (kg/ha)	
	2006	2007	2006	2007
Control	204	366	1164	2119
NPK HP + PRT intercrop	449	564	2188	2568
NPK HP + PRT pure crop	645	804	2742	3151
SE	120	21	140	259
CV	39%	5%	10%	14%

NPK: 15-15-15 compound fertilizers; HP: hill placement at 4 kg P/ha; PRT: Tahona Phosphate rock broadcast at 13 kg P/ha

Table 29: Farmers managed trials at Karabedji, 2006-2007 rainy seasons

Treatment	Millet grain yield (kg/ha)		Millet TDM (kg/ha)	
	2006	2007	2006	2007
Control	172	227	3606	2162
NPK HP + PRT intercrop	361	492	4606	2915
NPK HP + PRT pure crop	680	984	5111	4254
SE	61	46	101	160
CV	26%	14%	4%	9%

NPK: 15-15-15 compound fertilizers; HP: hill placement at 4 kg P/ha; PRT: Tahona Phosphate rock broadcast at 13 kg P/ha

Table 30: Farmers managed trials at Gaya, 2006-2007 rainy seasons

Treatment	Millet grain yield (kg/ha)		Millet TDM (kg/ha)	
	2006	2007	2006	2007
Control	221 (162)	59 (29)	2905 (435)	1754 (228)
NPK HP + PRT intercrop	430 (322)	252 (113)	3988 (966)	2541 (701)
NPK HP + PRT pure crop	1263 (1073)	541 (455)	6197 (3064)	3641 (3100)
SE	91 (17)	12 (60)	145 (55)	94 (192)
CV	20% (5%)	6% (42%)	5% (5%)	5% (20%)

NPK: 15-15-15 compound fertilizers; HP: hill placement at 4 kg P/ha; PRT: Tahona Phosphate rock broadcast at 13 kg P/ha; NB: Number in bracket are yields for groundnut.

Comparative effect of mineral fertilizer on degraded and non-degraded soils (Karabedji)

This trial started in 1999 and is ongoing and can also be considered as long-term soil fertility experiment. Mineral fertilizers were applied on two locations of the farm: Farm close to the village/household where household waste, human excreta and farm yard manure are commonly thrown, and, farms far from the village without any organic material added and often considered as degraded.

The data in **(Figures 30 & 31)** show that the application of P significantly increased both millet grain and total dry matter yields and this effect was more pronounced in fertile soils (home gardens) than in the off fields. This responses support the observation that greater nutrient responses are more likely to occur in fertile soils with high organic matter than in the degraded low organic matter soils. Higher P responses when P is combined with organic fertilizer. Nitrogen alone gives no significance but when combined with P the result is clear.

The results also showed a greater response of pearl millet grain and total dry matter yields to P than N application. P alone account for 18% (43% in 2006) in the total variation of millet grain yield whereas system (degraded and non-degraded) account for 37% (25% in 2006). Nitrogen is also significant but account for only 6% (20% in 2006) also. Its significance is linked to the availability of P or organic fertilizer in the soil.

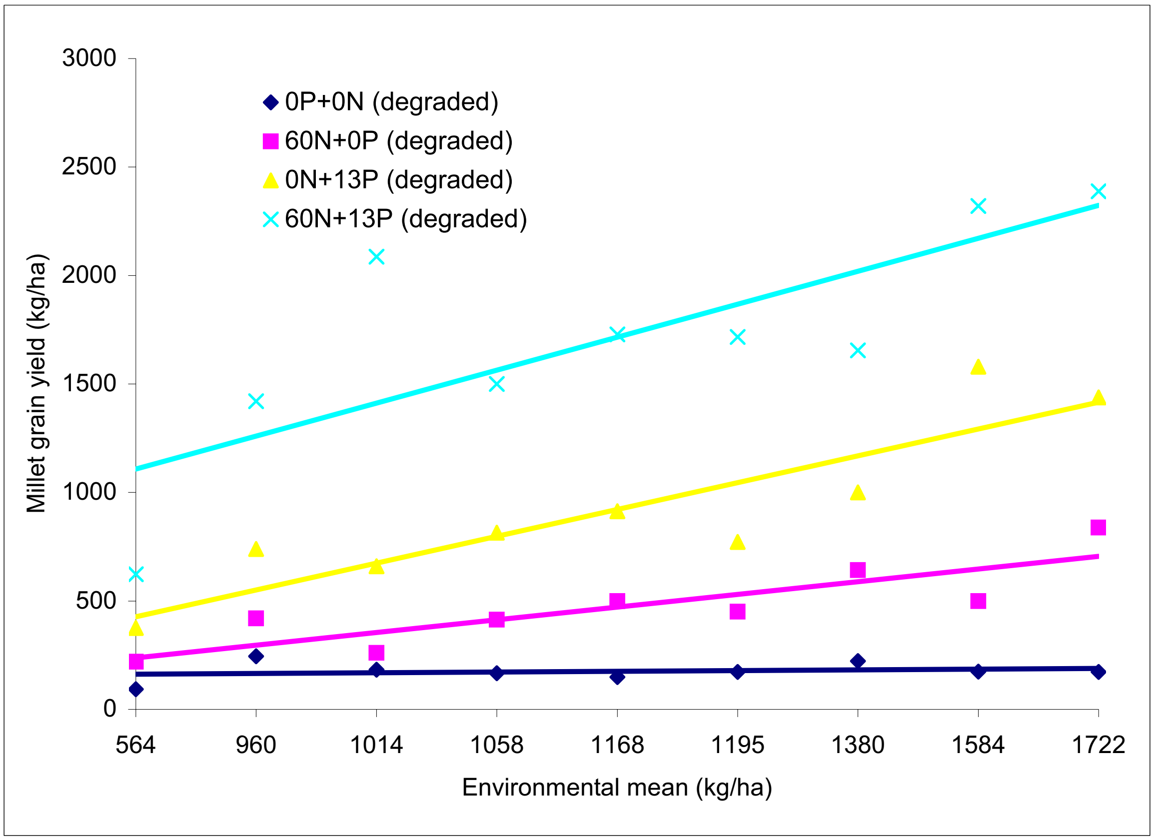


Figure 30: Effect of environmental mean on pearl millet grain yield, Karabedji, Niger, degraded lands, 1999-2007.

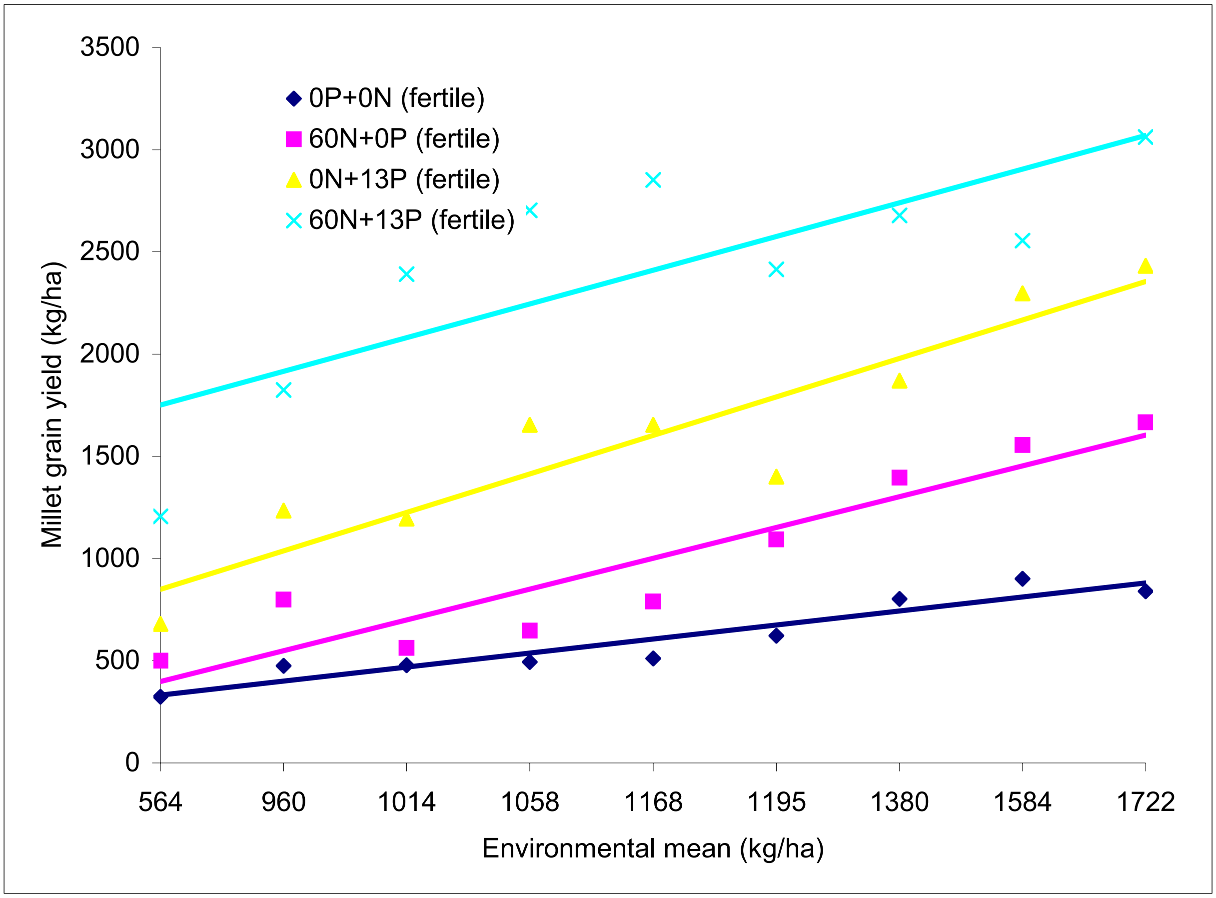


Figure 31: Effect of environmental mean on pearl millet grain yield, Karabedji, Niger, non degraded (fertile) lands, 1999-2007

Conclusion

The above research activities continue to generate valuable information essential in technology testing and development. The TSBF's interventions in Niger (West Africa) are highly appreciated by farmers, and researchers in the region. As shown in many tables comparing 2006 and 2007 results, it appear that date of planting can highly affect crops yields and early planting gives better yield since rainfall duration is now becoming short. The use of DSSAT simulation can help predict the most appropriate date of planting, which can be used in the future to avoid such losses in crop production.

AfNet Research Highlights from Eastern Africa

AfNet research activities continued to be implemented in several sites in Kenya and Uganda during the year 2007. AfNet continued to support 14 experiments in this region as indicated in the table below.

Table 31: AfNet Trials in Western, Central and Eastern Regions of Kenya

Experiment	Location
Integrated Nutrient Management Trials (IN2 and INM3	Maseno, Western Kenya
Conservation Agriculture research trials (CT Trials)- 4 sites	Nyabeda, Mathayos and Teso, Western Kenya
Rock phosphate trial in Maseno	Nyabeda, Western Kenya
Fertilizer Equivalency Trial (N1- Kabete)	NARL, Kabete, Central Kenya
Long-term experiment, Kabete	NARL, Kabete, Central Kenya
Hedge-row Intercropping Trial- Embu	Embu, Eastern Kenya
ISFM Trials in Eastern Kenya	Kirege, Eastern Kenya
IFS Machanga trial	Machanga, Eastern Kenya
Water and nutrient management research in the dryland of Eastern Kenya	Emali, Eastern Kenya
AfNet-ERI-IDRC Project Sites	Eastern Uganda and Eastern Kenya

Improved land, nutrient and water management research in the drylands of Eastern Kenya

The current high population pressure on land necessitates exploitation of arid and semi-arid lands (ASALs) for crop production. However, agricultural production in ASALs is limited by low and erratic rainfall, high transpiration rates and generally fragile ecosystems which are not suitable for rainfed agriculture.

On station and on-farm up-scaling trials were conducted on farmers' fields in the DMP sites in Makueni district during the short rains of 2007 under the collaboration among the DMP research scientists from collaborating institutions that included the TSBF Institute of CIAT, KEFRI, KARI, extension staff from the line ministries, NGOs and community based organizations from the DMP sites.

Rainwater harvesting using tied ridges and open ridges are some of the cheap methods of mitigating dry spells in areas where farmers have inadequate resources to invest in irrigation. The on-going DMP field trials in Makueni District and other studies have indicated that tied ridges increase maize yields by more than 50% above the conventional flat tillage practiced by farmers. There were significant increases in maize yield when tied ridges are combined with integrated nutrient management. The research hypothesis was that combining water harvesting techniques with improved soil fertility will result in higher efficiency of resources and increase in crop yields in the ASALs.

Water harvesting methods consisted of tied-ridging and open furrows while the INM treatments were: (1) manure (10t/ha), (2) manure (5 t ha), (3) manure (10t/ha) + 20kg N/ha+ 20 kg P_2O_5, (4) manure (5t/ha) + 20kg N/ha+ 20 kg P_2O_5, (5) control (farmers practice with no fertilizers).

On-farm studies have shown that tied ridges, when combined with fertility management, have the advantage of increasing crop yields by more than 50% when compared to yields from flat planting. The conclusion was that water harvesting and INM strategies will increase crop production in ASALs while conserving the environment. This will lead to improved food security and increased household incomes.

In extension of sustainable natural resource management, two types of scaling-up strategies were used: (i) strategies for the promotion of readily available technologies and (ii) approaches for participatory learning and innovation on knowledge-based issues including NRM. Open field days continue to be the most prefereed methods of disseminating information especially on the water harvesting and INM technologies being demonstrated in the different sites in Eastern rangelands of Kenya.

AfNet Research Highlights from Southern Africa

Field research activities in the Southern Africa region continued in Zimbabwe and Malawi under the AfNet-ERI-IDRC Project. Other collaborative research activities were implemented between AfNet and the University of Zimbabwe especially on water harvesting technologies and adaptation to climate change by small holder farmers in Africa**.**

The 10th International Symposium on Innovations for a Green Revolution in Africa: Exploring the Scientific Facts, Arusha, Tanzania, 17-21 September 2007

Background

Africa remains the only continent that has not been able to fully benefit from the effects of the Green Revolution. The first Green Revolution failed in Africa because it did not take into account social and ecological variability, culture, policy and institutional bottlenecks, and a host of other issues that prevail in the continent. The Revolution failed to recognize that although agricultural technology is an important factor, it is only one aspect of a complex socio-economic-ecological system. Various local, regional and international forums have been held to discuss how Africa's Green Revolution can be achieved. The African Heads of State Fertilizer Summit held in Abuja Nigeria in June 2006 led to the Abuja Declaration on Fertilizer for African Green Revolution. The Summit identified the three most critical issues that need to be addressed if millions of African farmers are to increase utilization of fertilizer. These are access, affordability and the use of incentives. Similar sentiments were echoed at the African Green Revolution (AGR) Conference held in Oslo where the conference resolved to take concrete and concerted action towards the development of self-sustaining changes in African agriculture.

It is on the above backdrop that the AfNet in collaboration with the Soil Fertility Consortium for Southern Africa (SOFECSA) organized an International Symposium entitled 'Innovations as Key to the Green Revolution in Africa: Exploring the Scientific Facts, (Arusha Tanzania, 17th – 21st September 2007)' to build on the resolutions of the above initiatives. The overall goal of this symposium was to bring together scientists, agricultural extension staff, NGOs and policy makers from all over Africa to explore the scientific facts and share knowledge and experiences on the role of innovation in soil fertility replenishment as a key to the Green Revolution in Africa.

Objectives of the symposium

(i) To assess the potential and feasibility of use of external input and improved soil and crop management to achieve the African Green Revolution
(ii) To identify and learn about innovative approaches needed to build rural input market infrastructure
(iii) To review the main policy, institutional, financial, infrastructural, and market constraints that limit access to innovations by poor farmers;
(iv) To evaluate strategies for scaling out innovations to millions of poor farmers in the continent

Symposium Themes

Theme 1: Constraints and opportunities towards the African Green Revolution
Theme 2: Potential and feasibility of use of external input and improved soil and crop management to achieve the African Green Revolution
Theme 3: Factors that limit access to and adoption of innovations by poor farmers
Theme 4: Innovation approaches and their scaling up/out in Africa

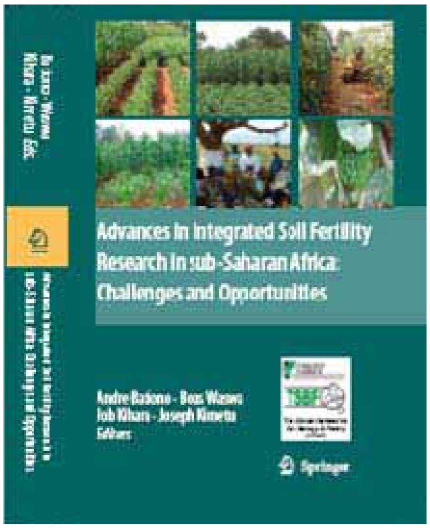
Symposium Attendance

The symposium was attended by 230 participants (*See group photo*) drawn from 20 African countries, Europe, North and South America, Asia and Australia. The symposium was also attended by representatives from the Bill and Melinda Gates Foundation; several CG centres (ICRAF, ICRISAT, IITA, WARDA, CIMMYT, ILRI and CIAT; advanced research organizations (Norwegian Institute of Agriculture, JIRCAS); international NGOs (Catholic Relief Services, IFDC, UNDP, AFRICARE, AVRDC, UNECA); universities from the north (KTH University, Cornell University, Wageningen Universtiy, Columbia University, University of Aberdeen and La Trobe University) and the private sector (YARA, IFA, Chemplex Corporation Ltd). The symposium was also attended by representatives from the donor institutions among them the Rockefeller Foundation/AGRA), the Gates and Melinda Foundation, IDRC), IFS and CIDA.

Photo 1: Photo taken during opening ceremony of the symposium

Yaoundé Symposium Book Launch

During the Symposium, AfNet officially launched the book entitled: *Advances in Integrated Soil Fertility Management: Challenges and Opportunities (See photos and flyer)*. This book was published by Springer, the Netherlands. The book contains 105 papers presented at the Yaoundé Symposium in 2004. The Network has ordered 800 copies of the book which will be distributed free to all network members, university and regional libraries, national agricultural research systems (NARS) and donor community.



AfNet Book: Bationo A, Waswa B, Kihara J, Kimetu J 2007. Advances in Integrated Soil Fertility Management in Sub-Saharan Africa: Challenges and Opportunities. Springer NL

Symposium Recommendations

Recognizing that AfNet is a pan-African network with members from the 4 regions of the continent (Eastern, Western, Central and Southern)
Recognizing the enormity of the problems facing the smallholder farmers in Sub-Saharan Africa;
Acknowledging and endorsing the Abuja Declaration on Fertilizer for the African Green Revolution by the African Union Heads of State, that amongst other steps, seeks to ensure increase in level of fertilizer use in the continent from the current average of 8kg/ha to at least 50kg/ha by 2015;
Applauding the establishment of the Alliance for a Green Revolution in Africa (AGRA) and recently the Soil Health Initiative (SHI) by both the Rockefeller and the Bill and Melinda Gates Foundations as some of the steps towards attaining an AGR; *and*
Acknowledging the role and multiplicity of stakeholders and the fact that an alliance of the various stakeholders (farmers, scientists, extension, policy makers, private sector) is necessary to accelerate the African Green Revolution;

The participants of the AfNet organized International Symposium on Innovations as Key to the Green Revolution in Africa: Exploring the Scientific Facts *recommended:*

1. Rather than just advocate for the general use of fertilizers, researchers, together with other partners, should also focus on site-specific fertilizer use efficiency and the combinations of organic and inorganic nutrient sources as a valid entry point for promoting Integrated Soil Fertility Management in SSA
2. Holistic approach to research and policy development towards an AGR: Although soil fertility management is at the heart of the African Green Revolution, there is need to embrace and address opportunities and challenges put forward by all other livelihood realms (health, markets, access to credit and support services, working institutions, enabling policy framework and socio-cultural aspects), in consonance with the Millennium Development Goals (MDG).
3. Research, Extension and policy development should target the heterogeneity in Soil Fertility and Farmer Resource Endowment.
4. Enhance farmers' access to input and output markets:
5. Conference participants call for unreserved commitment and support of Member States of the AU in strengthening the dwindling capacity prevailing in SSA NARES for making AGR a reality and to sustain it in the long run.
6. The strengthening of a pan African Network such as AfNet to ensure that benefits of networking are achieved in all member regions/countries for a true African Green Revolution.
7. Participants of the symposium appeal to the donor community to further accelerate their current support and investment for and in R&D and do this more and more based on a specific country's/region's research agenda and priorities.

Output targets 2008

- ***Web content in the BGBD website enhanced to contain data and information on BGBD taxonomy and species identification***

Work in progress

The BGBD global website had new additions including project progress reports from 2003 to 2007. In 2007, the Kenya and Uganda BGBD websites were completed and linked to the global website. The Brazilian website had earlier been developed and linked to the global website in 2004. The *urls* of the websites are here below. We did not place the species data on the global website since data from the countries were still unpublished by end of 2007. The species data though available will be on-line in 2008 after the global synthesis planned for March 2008.
http://www.bgbd.net
http://www.uonbi.ac.ke/research_projects/BGBD/index.html
http://www.bgbd.or.ug
http://www.biosbrasil.ufla.br/

Output targets 2009

- ***Profitable land use innovations scaled out beyond pilot learning sites through strategic alliances and partnerships, and application of alternative dissemination approaches***

Output targets 2009

- ***Strategies for institutionalization of participatory NRM approaches and methodologies established***

Output target 2010

- ***Research on practical strategies and decision support tools for integrated water and nutrient management, including organic and mineral nutrient sources is further strengthened and added to the existing organic resources DSS/database***

Published work

Rufino [1,2], M.C., Tittonell [1,3], P., van Wijk [1], M.T., Castellanos-Navarrete [1], A., Delve [4], R.J., De Ridder [1], N. and Giller [1], K.E. (2007) Manure as a key resource within smallholder farming systems: Analysing farm-scale nutrient cycling efficiencies with the NUANCES framework. Livestock Science. 112: 273–287

[1] Plant Production Systems, Department of Plant Sciences, Wageningen, The Netherlands;
[2] Plant Research International, Wageningen University and Research Centre, Wageningen, The Netherlands; [3]CIAT-TSBF, Kenya; [4]CIAT-TSBF, Zimbabwe

Abstract: Smallholder farmers in Africa recognize the important role of manure in maintaining soil fertility. For smallholder farmers who use little fertilizer, efficient management of nutrients in manure is key for crop production. We describe a simple model to analyze the effect of manure management on the efficiency of mass and nutrient retention. We used on-farm data on manure excreted and manure management, experimental results, literature and fuzzy logic to model losses during manure storage. The model was used to analyze N cycling efficiency (NCE) within smallholder farms in western Kenya. Simulations showed that manure management during collection and storage had a large effect on the efficiency of C and nutrient retention. Differences in NCE between farmers of different wealth classes arose due to differences in resource endowment. For poorer farmers, large N losses occur at all stages of manure recycling. Urinary-N losses occurred on all farms but their impact on NCE for poor and medium-class farmers was larger due to the smaller amount of N recycled. With current management the poor farmer recovered <1 kg N y^{-1} in composted manure from 15 kg N y^{-1} excreted. Improved manure storage had little effect on increasing overall NCE for the poor farmer due to large losses before storage. For the wealthier farmer improvement of manure storage increased NCE and allowed recycling of 30% of N excreted (ca. 30 kg N y^{-1}) with small investment in infrastructure. Covering manure heaps with a polythene film reduced mass and N losses considerably. For the poor to increase overall NCE, investment in cattle housing and recycling of urinary-N is required.

Increasing cattle numbers or improved feeding would have a larger effect on manure availability but this is constrained by feed scarcity and investment capacity. The absolute amounts of N recycled (1–6, 4–17 and 7–18 kg N y^{-1} for poor, medium and wealthier farmers) were small compared with maize N demand (N50 kg N ha^{-1}), but significant given the small farm sizes (0.1–1.1 ha). Although absolute amounts of N recycled with improved manure management may have little immediate impact on crop productivity, manure is often the only input available. Manure provides other nutrients for crops and maintains soil organic matter - both vital to guarantee efficient use of fertilizer N - which justifies the search for interventions to assist farmers make better use of manure.

- ***Social science aspects are included in the decision making process and tools to better understand actionable management strategies, their knowledge requirements, and economics.***

Published work

Delve[1], R. J., Huising[2], J.E. and Bagenze[3], P. (2007) Target area identification using a GIS approach for the introduction of legume cover crops for soil productivity improvement: a case study eastern Uganda. African Journal of Agricultural Research 2: 512-520
[1]CIAT-TSBF,Zimbqbwe; [2]CIAT-TSBF, Kenya;[3]Makerere University, Uganda
Abstract: Amidst the economic backdrop of resource-poor farmers, combined research and extension efforts in developing countries have focused on developing and promoting potentially adaptable and economically acceptable agronomic technologies that suit farmers' situations. Practices like improved fallows with woody and herbaceous legumes (e.g. *Canavalia* sp., *Crotalaria* sp., *Mucuna* sp., *Lablab* sp., and *Tephrosia* sp.) are considered an appropriate approach to improving soil fertility management and an alternative to expensive, and often not available, inorganic fertilizers. However the challenge remains of how to target such technologies to different socio-economic and biophysical niches at the farm level. Targeting of legume cover crops (LCC) to areas with actual and potential soil fertility management problems using a GIS approach was investigated. Using available datasets it was possible to define, identify, and map potential areas for targeting of LCC soil fertility improvement technologies by overlaying maps of soil fertility status, cropping systems, population density and climate for the eastern region of Uganda. We showed that a geographic information systems based decision support system could provide targeted dissemination output to aid decision making. Shortcomings in the use of available data are discussed, as are the practical applications of this approach in choosing appropriate legume species.

Progress towards achieving output level outcome

- *Strengthened and expanded partnerships for ISFM facilitate south-south exchange of knowledge and technologies*

Strengthening partnerships is at the core of TSBF-CIAT strategy to promote ISFM and SLM in the tropics. This year we have restructured AFNET to include regional multidisciplinary teams in Eastern, Southern, and West and Central Africa to better coordinate and interact with the growing membership. The BGBD project completed its first phase with a successful conference in Manaus where 71 southern scientists were able, for the first time, to share results of pioneering inventory work on belowground biodiversity. We have also consolidated the MIS and CONDESAN Consortia in Latin America and have started a new partnership initially in Colombia aimed at restoring degraded pastureland.

AFNET remains the most dynamic and widespread network for linking scientists working on ISFM in Africa. The more than 350 members now benefit from participation in networked long-term experimental trials, degree-related training and capacity building activities (such as the two short courses and land degradation conference organized in 2005), as well as more general information dissemination (such as on training opportunities and scholarships for young scientists, as well as scientific findings and progress in ISFM). South-south exchange of expertise and findings within the network has been visible in the prominent involvement of many AFNET members in the preparation of successful proposals for the sub-Saharan African Challenge Program.

The 3rd annual symposium of the BGBD project, held in Manaus Brazil, provided a forum for the exchange of preliminary data on (i) Benchmark area description and socio-economic characterization, (ii) Results of the inventory of macro-fauna, (iii) Inventory of nematodes and mesofauna, (iv) Inventory of legume nodulating bacteria and arbuscular mycorrhizal fungi (AMF) (v) Inventory of pathogenic and antagonistic fungi and insect pests and (vi) Standard methods for the inventory of BGBD. The innovative pan-tropical research activities of this project were evaluated by a team of external reviewers in 2005, which has translated into a successful restructuring of the project for the launch of a second phase in 2006.

The MIS consortium is very active in advancing the research agenda for the agriculture in Honduras and Nicaragua. The most important achievement has been the strong commitment from partners in Nicaragua to disseminate the Quesungual System into the Country. This is generating very positive synergies between the NARS, the academia, regional and national authorities and of course farmers. Partners of MIS were involved in 4 regional workshops during 2005 and many students have benefited from training that is associated with MIS activities.

The CONDESAN Consortia continues to be a strong partner in the Andes and will be a major vehicle to transfer research outputs, particularly related to implementation of schemes for payment of environmental services. In 2005, a new partnership was initiated with the regional environmental agency in the Caribbean savannas of Colombia, (CVS), the National Research Institution (CORPOICA) and regional Universities (U. Cordoba and U. Sucre) as well as organizations of indigenous communities, to concentrate efforts in the rehabilitation of degraded pastureland in the region. Pasture degradation is perceived as a major problem in the region. This partnership will greatly strengthen the capacity of partners to focus on land rehabilitation and will also include a large number of students from the region at different project phases.

Progress towards achieving output level impact

- *Improved institutional capacity in aspects related to ISFM and SLM in the tropics contribute to agricultural and environmental sustainability*