

11. Optimizing Fertilizer Use within the Context of Integrated Soil Fertility Management in Niger

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11.1 Agricultural systems of Niger

The crop and livestock sectors are the basis of Niger's economy. These sectors employ more than 80% of the population, generate 43% of GDP and contribute on average to 30% of export earnings of the country.

Most crop production is of staple crops such as pearl millet, sorghum, cowpea, groundnut and rice. Rainfed cash crops produced in favourable areas are groundnut, sesame, cotton and tiger nut, the latter gaining in importance with more fertilizer use than for other crops, particularly in Maradi region.

Land cultivated annually is increasing and competes with grazing. Livestock densities have declined in the Sahel but much livestock is brought from further north for dry-season grazing.

Crop production in Niger is challenged by climate-related risks, soil degradation and demographic pressure which contributes to an improper use of the natural resources and exacerbates food insecurity.

11.1.1 Agro-ecological zones (AEZ)

The AEZ of Niger include the Sahara desert zone in the north of the country; the sub-Saharan pastoral zone in the centre of the country; the Sahelian zone with agro-pastoral prevalence in the southern centre and the Sahelo-Sudan or North Sudan Savanna zone with better agriculture production conditions in the South-West (Figure 11.1). The latter two AEZ are the sedentary areas in contrast to the northern zones where primarily nomadic activities with livestock predominate.

The Sahara AEZ covers more than 65% of the country and has fewer than five inhabitants per km² (Figure 11.1). Agadez, which is in this zone, has a mean annual rainfall of 111 mm, 45% of which falls in August (Table 11.1). Monthly mean maximum and minimum temperatures range

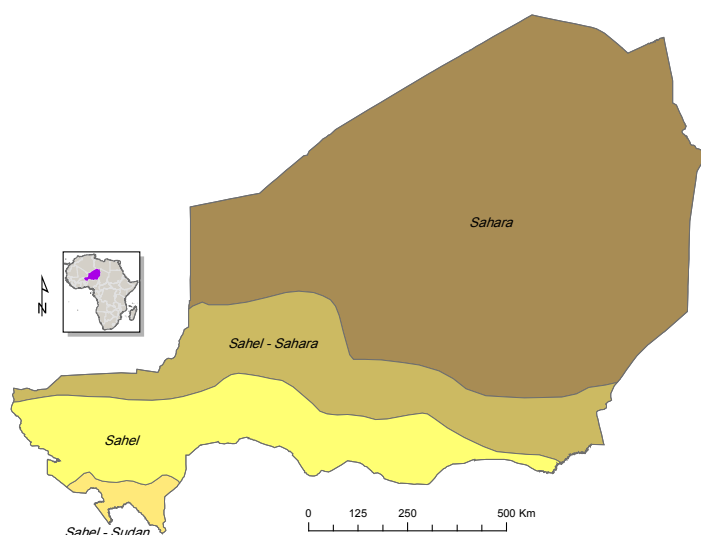


Figure 11.1: Agro-ecological zones (AEZ).

from 26 to 41°C and from 12 to 26°C, respectively. Agriculture activities are conducted in some depressions called oases with microclimates that permit production of high quality vegetables such as onion, garlic and potato.

The Sahelo-Sahara AEZ covers about 20% of Niger's area (Figure 11.1). It is mostly a pastoral and transhumance AEZ receiving about 350 mm of rainfall annually and is marginal for pearl millet and cowpea production. The mean annual rainfall for Tanout, which is in this zone, is 244 mm with 45% falling in August (Table 11.1). Monthly mean maximum and minimum temperatures range from 30 to 40°C and from 14 to 25°C, respectively.

The Sahel AEZ in Niger is semi-arid (Figure 11.1). Annual mean rainfall in Zinder, which is in this zone, is 411 mm with 85% falling from July to September (Table 11.1). Monthly mean maximum and minimum temperatures range from 28 to 42°C and from 12 to 29°C, respectively. The generally high sand content of upland soils combined with low rainfall makes frequent occurrence of drought a major constraint to crop production. The best adapted crops are pearl millet, groundnut,

Table 11.1: Mean monthly rainfall (mm) and maximum and minimum temperature (°C; Tmax; Tmin) for representative locations of AEZ of Niger (2000-2014)

	J	F	M	A	M	J	J	A	S	O	N	D
Sahara AEZ: Agadez												
Rain	0.0	0.0	0.1	2.0	5.5	10.4	35.2	49.7	8.2	0.3	0.0	0.0
Tmax	27.9	31.1	35.0	39.2	41.3	41.3	39.1	37.9	38.9	37.1	32.4	29.0
Tmin	11.7	13.9	18.3	23.1	26.0	26.4	25.1	24.2	24.5	21.7	16.2	12.8
Sahelo-Sahara AEZ : Tanout												
Rain	0.0	0.0	0.0	0.0	3.0	22.0	83.0	99.0	35.2	2.0	0.0	0.0
Tmax	29.5	32.6	36.2	39.0	39.5	37.6	34.0	32.3	34.3	36.2	33.6	29.9
Tmin	13.7	15.7	19.9	23.1	24.6	24.0	22.0	20.9	21.2	20.8	25.5	21.9
Sahel AEZ : Zinder												
Rain	0.0	0.1	0.5	1.0	14.8	39.2	128.6	168.1	53.5	5.0	0.2	0.0
Tmax	29.3	32.5	36.3	39.7	40.6	38.1	34.9	32.7	35.5	37.1	33.7	33.5
Tmin	14.7	17.1	21.4	25.0	26.6	25.6	23.7	23.2	23.7	22.9	18.6	15.4
Sahel AEZ : Maradi												
Rain	30.2	33.6	37.0	40.0	39.7	37.0	33.2	31.7	33.8	36.8	33.9	31.1
Tmax	13.0	15.6	19.8	24.0	25.7	25.0	23.2	22.2	22.5	20.5	16.5	13.5
Tmin	0.0	0.0	0.3	4.1	18.9	63.5	149.0	175.1	74.9	6.6	0.0	0.0
Northern Sudan Savannah: Gaya												
Rain	0.0	1.4	2.6	16.2	70.7	125.0	177.6	225.6	160.1	17.1	0.1	0.1
Tmax	33.1	36.3	39.1	40.3	38.0	34.9	31.9	31.9	32.3	35.7	36.0	33.4
Tmin	18.6	21.6	25.1	27.1	26.3	24.3	22.8	22.4	22.4	22.8	20.5	18.7

sesame and cowpea. The valley soils have relatively more clay content and are suitable for sorghum, vegetables and even maize in low lying areas. Crop and livestock production are both important and transhumance is practised whereby much of the livestock is moved to drier areas during the crop production period and brought back to the arable lands following crop harvest. Manure from livestock is important for soil fertility management, but grazing and harvest of crop residues leave the land bare and exposed to erosion.

The Northern Sudan Savanna is a relatively small area in southwest Niger (Figure 11.1). Gaya, which is in this zone, has a mean annual rainfall of 800 mm (Table 11.1). Rainfall distribution is similar to the Sahel AEZ but with a longer season beginning in June. Monthly mean maximum and minimum temperatures range from 31 to 40°C and from 19 to 27°C, respectively. The soils have more clay and water holding capacity compared with the Sahel. The crops produced are pearl

millet, sorghum, groundnut, cotton, maize, cassava and some rice in the Niger River valley and close to some seasonal streams.

11.1.2 Current soil fertility management

Agricultural soils of Niger, particularly upland soils, have a pH 4.5 to 6.0, just 0.1 to 0.7% soil organic matter, typically have Bray-1 P of 0.4 to 3.4 mg/kg of soil and have low N availability. Mean inorganic nutrient application is only about 1 kg/ha of cropland due to costs, low or untimely availability, lack of access to credit for inputs at a reasonable cost and marketing conditions (Kadi et al., 1990). Nutrient mining has been estimated to average 15, 2, and 11 kg/ha/yr of N, P and K, respectively.

The main traditional practice to restore or improve soil fertility was to fallow for 5 to 10 years following 3 to 5 years of cultivation, but due to high demand for cropland this is now rarely practised. Other traditional soil fertility management practices include application of

organic resources such as manure, household waste and crop residues, and contracting herdsmen to keep livestock overnight in fields during the dry season to benefit from their excretion of urine and faeces. However, these practices are insufficient to meet crop-nutrient requirements as the organic materials are limited in quantity and generally of low nutrient content.

Most crop residue is removed from the field for other uses, such as animal feed, fuel and construction, with negative consequences including high soil temperature and increased evaporation, less trapping of relatively high fertility dust, seedling damage by blowing sand, reduced in-field nutrient cycling and less soil organic matter replenishment (Mason et al., 2015). Crop residue left in the field is subject to livestock grazing and removal by termites. Therefore, leaving residue in the field may be less valuable than anticipated.

Maintaining trees in crop fields, such as *Faidherbia albida*, is important to soil fertility management: crop performance under trees is often better than performance far from trees. Tillage can be advantageous to nutrient availability in that plant growth tends to be more vigorous with tillage compared with no tillage (Mason et al., 2015). Combining crop residue management, manure and/or compost application, and fertilizer application affords the greatest opportunity to increase yields, e.g. to apply 2 t/ha of poultry manure pre-planting followed by point application of 6 kg each of N, P₂O₅ and K₂O at tillering for pearl millet (Maman and Mason, 2013). Cereal yield is greater following a pulse compared with a cereal crop in rotation (Mason et al., 2015).

An important component of nutrient management is to control other constraints. This is true for the parasitic weed *Striga*, which can be reduced by late planting, reduced tillage, fertilizer application and intercropping cereals with legumes (Mason et al., 2015).

Alternating four-row strips of cereal and legume, followed by rotating crops on the strips the following year, is an improved intercrop system that takes better advantage of crop rotation effects compared with continuous intercropping. Other beneficial practices include application of alternative P sources such as rock phosphate

(RP) and phospho-compost; fertilizer micro-dosing; and soil and water harvesting techniques such as zai and half-moon and stones bunds.

Current fertilizer use is about 3.7 kg/ha/yr for cultivated land but most fertilizer is applied to rice and high value rainfed crops like tiger nut. Fertilizer NPK blends (15-15-15 and 20-10-10) are more often used than urea and phosphate fertilizers. In Niger, fertilizer subsidies are an interim measure to enhance capacity for fertilizer use. Most of the fertilizers come from the agro-dealers of the Centrale d'Approvisionnement en Intrants et Matériels Agricoles (CAIMA), the national input supply organization, with less from the private sector. A uniform fertilizer price is applied throughout the country through adjustment and subsidy systems. More private sector supply of fertilizer is being encouraged.

Fertilizer recommendations are issued by the national research institute INRAN. The recommendations issued in 1981 and updated in 1992 were for sole crop pearl millet or sorghum with blanket application rates of 46 kg/ha N, 15 kg/ha P₂O₅ and 20 to 25 kg/ha K₂O when crop residues are returned, or 90 kg/ha N, 20 kg/ha P₂O₅, and 20 to 25 kg/ha K₂O with crop residue removal.

For groundnut and cowpea sole crop, the recommended rates were 22.5 kg/ha P₂O₅. Fertilizer recommended for rice is 30-45 kg/ha of N, P₂O₅ and K₂O applied as NPK 15-15-15, plus 46 to 60 kg/ha N top-dressing applied as urea.

A modification of the recommendations for pearl millet and cowpea varies from 8 to 12 kg/ha of P applied as SSP and 46 kg/ha of N with early planting, but only 4 kg/ha of P for planting after July 15th.

Salou and Sido (2006) found 132-90-30 kg/ha to be economic for irrigated rice. Buerkert et al. (2001) suggested 30 kg/ha each of N, P₂O₅ and K₂O for pearl millet and 20 kg/ha P for cowpea. A starter N application of 15 kg/ha N is recommended for cowpea applied at 5-10 days after emergence.

Fertilizer micro-dosing is an approach to increase efficiency of fertilizer use through point application at 9 kg/ha each of N, P₂O₅ and K₂O at planting or after emergence. Alternative micro-dosing rates are about 4 and 9 kg/ha of N and

P_2O_5 , respectively, for pearl millet and sorghum (Tabo et al., 2007; Saidou et al., 2014; Maman et al., 2015) and maize (MDA 2012).

The policy of fertilizer use in Niger is defined in the document ‘Stratégie décentralisée et partenariale d’approvisionnement en intrants pour une agriculture durable (SIAD), Août 2006’ with an objective to increase fertilizer use to an annual average application of 8 kg/ha/yr of nutrient elements.

CAIMA has regional and district input stores to facilitate farmers’ access to fertilizer at low costs compared with open market prices. However, CAIMA often does not supply the most appropriate fertilizer types.

Extension workers and agro-input dealers are not well informed of good agronomic practices for fertilizer use and fail to advise farmers well. Good fertilizer use practices are summarized as the 4R Nutrient Stewardship approach, consisting of applying the right source of nutrients, at the right rate, at the right time for efficient uptake by the crop and in the right place to be accessible by plant roots. The 4Rs can result in increased crop yields and incomes, and prevent soil nutrient depletion.

11.2 Diagnosis of nutrient deficiencies in Niger

In Niger, P, followed by N, is generally considered to be the most limiting nutrient for crop production. In 30 recently conducted trials as part of the Optimizing Fertilizer Recommendations in Africa (OFRA) project, the average yield increases across all crops were 50, 29 and 16% with P, N and K application, respectively (Figure 11.2). These trials included a diagnostic treatment of N+P+K+Mg+S+Zn+B that was compared with a treatment of the same N+P+K rates for non-legumes. A similar comparison was made for legumes with N omitted. The results determined if one or more of Mg, S, Zn and B are limiting yield once N, P and K are applied. There were mean increases in yield of 12 and 7% due to the diagnostic package for trials conducted on farmers’ fields and on research stations, respectively (Figure 11.2a).

The average yield increases due to the secondary and micro nutrients were similar

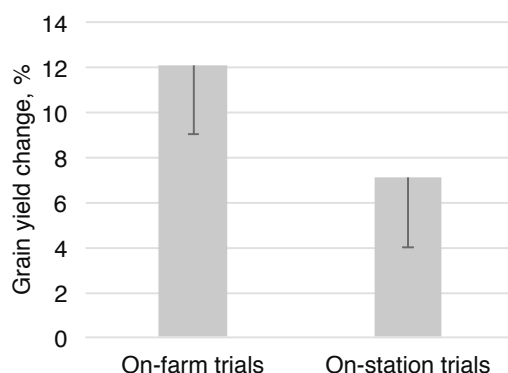


Figure 11.2a: Yield increase due to diagnostic treatment.

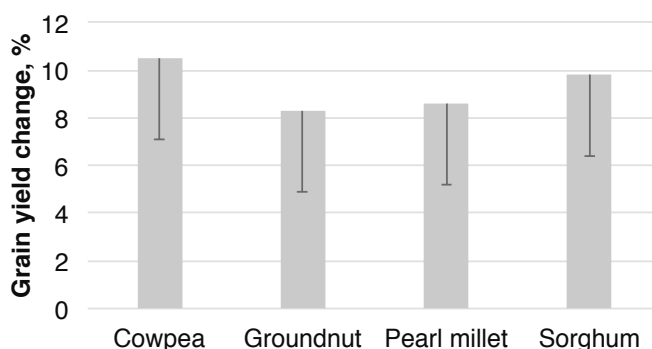


Figure 11.2b: Yield increase due to diagnostic treatment.

for cowpea, sorghum, groundnut and pearl millet (Figure 11.2b). Further investigation is needed to determine which of these four micro- and secondary nutrients are most commonly deficient in the Niger upland soils. Other nutrient deficiencies are likely to gain in importance as fallow is reduced and crop residue is removed from the fields.

11.3 Optimizing fertilizer use in Niger

Farmers want fertilizer use to be sufficiently profitable. Farmers with adequate finance strive to maximize net returns per hectare resulting from fertilizer use. For the finance constrained farmer, investment in fertilizer use competes with other livelihood needs. Therefore, investments in fertilizer must give high benefit to cost ratio with little risk. Fertilizer use optimization in this context refers to maximizing profit from fertilizer use: profit per hectare for farmers with adequate finance; and maximum benefit to cost ratio on the small investment in fertilizer by the financially constrained farmers.

Crop yield response to applied nutrients can be captured with a curvilinear to plateau yield response as shown for sorghum response (vertical axis or y-axis) to applied P (horizontal axis or x-axis) (Figure 11.3) with a steep yield

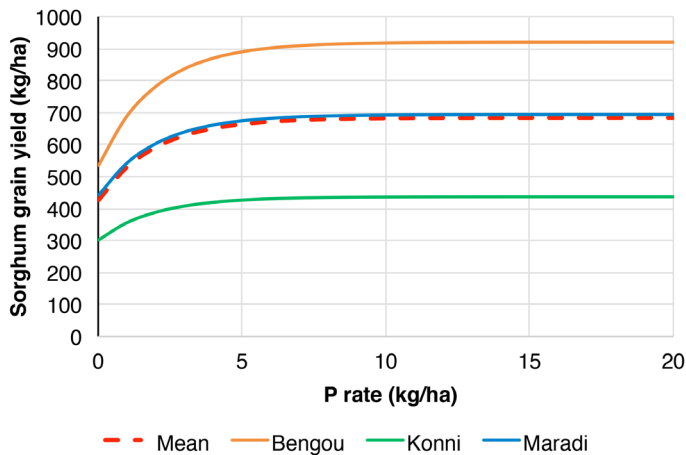


Figure 11.3: Sorghum sole crop with 2.5 t/ha manure P response.

increase with increasing P at low rates and a lesser rate of yield increase at higher P rates until yield reaches a plateau with no more yield increase.

This type of response is captured by the equation $\text{yield (kg ha}^{-1}\text{)} = a - bc^r$, where a is near maximum yield for application of that nutrient, b is the gain in yield due to application of that nutrient, and c^r determines the shape of the curvilinear response where c is a curvature coefficient and r is the nutrient rate. This function tells us that the benefit

relative to cost for P application is expected to be greater with low compared with high P rates. Such response curves are typical for most crops and nutrients.

Once crop-nutrient response functions have been determined for an AEZ, economics can be applied to fertilizer use to determine how crop-nutrient-rate choices affect potential profitability (Figure 11.4). The x-axis (horizontal axis) shows the amount of CFA franc per hectare (FCFA/ha) invested in a nutrient applied to a crop. The y-axis (vertical axis) shows the net returns resulting from a single nutrient applied to a crop. Therefore, each curve represents the profit potential of a nutrient applied to a crop. When the slope of the curve is steep, net returns to investment are very high. As the amount invested (the x-axis) increases the slope decreases but if still upward, profit is increasing. Where curves reach a peak and the slope is flat, the point of maximum profit per hectare is reached; the rate at the peak is considered the economically optimal rate (EOR). When slopes decline, profit is declining. The financially constrained farmer wants first to take advantage of the crop-nutrient combinations that will give the most profit.

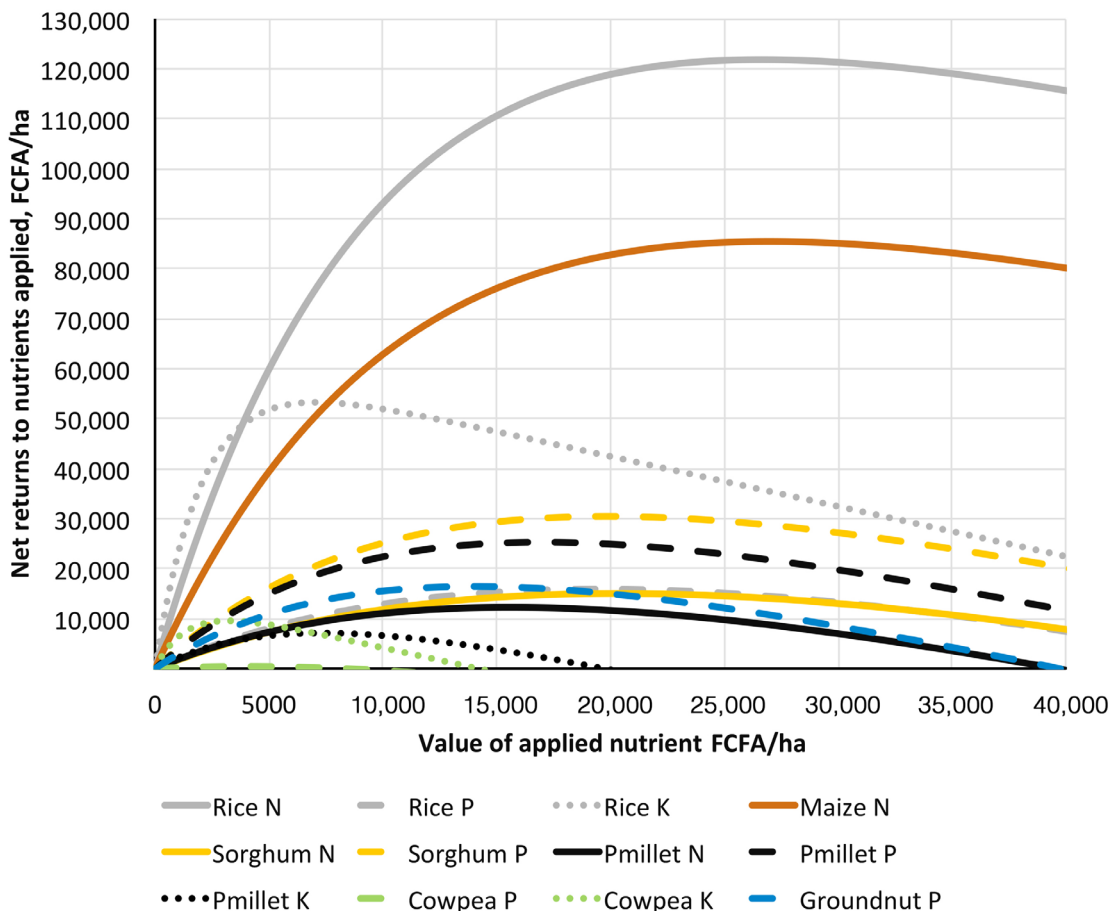


Figure 11.4: Net returns to nutrients applied for all the crops and nutrients.

The slopes are steepest for low rates of N and K applied to rice (Figure 11.4). For rice K, the EOR is reached with a low rate of application with little added profit potential for K application of more than 5000 FCFA/ha at which level the expected mean net profit is about FCFA 50,000. The net returns for investment in N applied to rice increase steadily up to 10,000 FCFA with a net return of about 90,000 FCFA. With more N applied, net return increases at a slower rate up to 20,000 FCFA with a peak in profit at about 25,000 FCFA with an expected mean net return of 125,000 FCFA.

Rice response to applied P is profitable but not nearly as profitable as for several other options. Maize N offers the third most profitable option with expected profit of about 75,000 with 15,000 FCFA invested and a profit peak at 85,000 FCFA with 20,000 FCFA investment. Below the maize N curve are several less profitable options such

as with some P applied to sorghum and pearl millet with returns of net profit of about 20,000 with 10,000 FCFA invested. Further down are even less profitable options including P applied to rice and groundnut and N applied to pearl millet and sorghum. All K application options, with the exception of K applied to rice, have little profit potential and applications should be at a maximum of about 5,000 FCFA with a peak net return of about 10,000 FCFA.

11.4 Targeted crops and cropping systems by AEZ

Niger is a Sahelian country with agriculture activities concentrated in the Sahel AEZ and North Sudan Savanna AEZ. The OFRA project targeted pearl millet, sorghum, cowpea and groundnut in the Sahel and North Sudan Savanna uplands. Sorghum is mostly produced in the southern part of the Tahoua and Maradi regions. The major production areas for

Table 11.2a: Sahel AEZ. Response function coefficients (cols 3-5), expected yield increases (t/ha) for nutrient rate increases (cols 6-9), and OFRA economically optimal rate (EOR) to maximize profit per hectare compared to current or recent recommendations (col. 10)

Crop	Nutrient	Response coefficients, Yield = a - bc'; r = elemental nutrient rate			Effect of elemental nutrient rate change, kg/ha on yield increase in t/ha				Recommended nutrient rate	
		a	b	c	0-30	30-60	60-90	90-120	EOR [†]	REC
		t/ha			t/ha				kg/ha	
Rice	N	4.461	0.564	0.942	0.470	0.078	0.013	0.002	47	92
Maize	N	1.275	0.687	0.951	0.535	0.118	0.026	0.006	48	46
Sorghum	N	1.346	0.325	0.972	0.186	0.079	0.034	0.014	30	46
P. millet	N	0.632	0.265	0.962	0.182	0.057	0.018	0.006	23	46
					0-5	5-10	10-15	15-20		
Rice	P	5.190	0.189	0.919	0.065	0.043	0.028	0.018	13	40
Maize	P	2.868	0.029	0.938	0.153	0.119	0.092	0.072	0	0
Sorghum	P	1.148	0.367	0.884	0.169	0.091	0.049	0.027	19	20
P. millet	P	1.191	0.330	0.868	0.167	0.082	0.041	0.020	26	9
Cowpea	P	0.605	0.109	0.930	0.033	0.023	0.016	0.011	0	20
Groundnut	P	0.708	0.225	0.865	0.116	0.056	0.027	0.013	0	
					0-5	5-10	10-15	15-20		
Rice	K	6.038	0.223	0.750	0.170	0.040	0.010	0.002	7	25
P. millet	K	1.259	0.128	0.905	0.050	0.031	0.019	0.011	0	25
Cowpea	K	0.477	0.063	0.650	0.056	0.006	0.001	0.000	5	
Groundnut	K	0.983	0.102	0.910	0.038	0.024	0.015	0.009	3	

[†] EOR was determined with the cost of using 50 kg in CFA: urea at 13,500; TSP at 18,000; DAP at 20,000; and 15-15-15 at 13,500. Commodity values (CFA/kg) used were: rice 280; maize 180; sorghum 170; cowpea 200; groundnut 180; and pearl millet 160. Nutrient applications for some crops are missing due to lack of evidence of response.

groundnut are in the southern part of Maradi, Dosso and Zinder regions. Maize is mostly produced in the southern part of Maradi and Dosso in valleys where soil has relatively more clay.

Crop responses to N, P and K were determined for important food crops in each AEZ using results of past and recent field research (Tables 11.2a,b). The first two columns are for crop and nutrient. Columns 3-5 have coefficients a, b, c for the curvilinear to plateau response function, $Y = a - bc^r$. The next four columns report the expected average yield increase with increased nutrient rates compared with the next lower rate, and the right most columns are for the optimized nutrient rate for maximizing profit per hectare due to fertilizer use (EOR) compared with the current or recently recommended rate (REC).

Any nutrient application in excess of the field research based EOR is expected to result in loss of profit. Any nutrient application at less than EOR means less than maximum potential net return to fertilizer use per hectare but lower rates are typically most profitable with financially constrained fertilizer use.

The greatest yield increases, the b value and for the first increment of applied nutrient, in the Sahel were with rice and maize response to N (Table 11.2a). Sorghum, pearl millet and maize had relatively large responses to P. Response to K was relatively small, but greatest with rice and least with cowpea.

RECs were generally higher than EOR but similar for maize N and P and for sorghum P, while EOR P was relatively high for pearl millet. The EOR for groundnut P and K applied to cowpea and groundnut were determined but there were no RECs for these crop-nutrient combinations.

In the North Sudan Savanna, the greatest yield increases were with N applied to maize and sorghum. Sorghum also responded well to P (Table 11.2b). Of the legume crops, groundnut response to P and cowpea responses to N and K were relatively large. The RECs were high compared with EOR except for N applied to maize.

Over all comparisons of both AEZ, the REC was more than EOR for 73% of the cases and the mean of recommended nutrient rate compared with EOR was 60% higher.

Table 11.2b: Northern Sudan Savanna

Crop	Nutrient	Response coefficients, Yield = $a - bc^r$; r = elemental nutrient rate			Effect of elemental nutrient rate change, kg/ha on yield increase in t/ha				Recommended nutrient rate	
		a	b	c	0-30	30-60	60-90	90-120	EOR†	REC
		t/ha			t/ha				kg/ha	
Rice	N	2.882	0.614	0.976	0.318	0.153	0.074	0.036	85	92
Maize	N	2.727	1.740	0.978	0.847	0.435	0.223	0.114	92	46
Sorghum	N	4.068	1.534	0.860	1.517	0.016	0.000	0.000	29	46
P. millet	N	1.293	0.093	0.919	0.085	0.007	0.001	0.000	0	46
Cowpea	N	1.860	0.178	0.770	0.178	0.000	0.000	0.000	0	
					0-5	5-10	10-15	15-20		
Sorghum	P	2.435	1.103	0.894	0.474	0.270	0.154	0.088	20	40
P. millet	P	1.761	0.600	0.884	0.276	0.149	0.080	0.043	2	20
Cowpea	P	0.929	0.040	0.700	0.033	0.006	0.001	0.000	0	9
Groundnut	P	1.831	0.399	0.872	0.198	0.100	0.050	0.025	13	20
Rice	K	1.951	0.091	0.800	0.061	0.020	0.007	0.002	10	25
Sorghum	K	2.016	0.114	0.902	0.046	0.027	0.016	0.010	12	25
P. millet	K	1.583	0.044	0.899	0.018	0.011	0.006	0.004	0	25
Cowpea	K	0.938	0.280	0.908	0.107	0.066	0.041	0.025	23	
Groundnut	K	1.272	0.068	0.285	0.068	0.000	0.000	0.000	3	

Application of an N-P-K blended fertilizer could only be justified for sorghum in both AEZ and, at low rates, for rice in the Sahel. Otherwise, crops had economic response to only one or two of the three nutrients.

11.5 Fertilizer use optimization tools for Niger AEZ

When a farmer has several crops of interest and is financially constrained in fertilizer use, consideration of the various crop-nutrient response functions together with information about the farmer's financial ability and agronomic interests is very complex. Therefore fertilizer optimization tools (FOTs) were developed to adequately consider the farmer's financial and agronomic situation in determining optimal use of fertilizer (<http://agronomy.unl.edu/OFRA>).

Crop nutrient response functions (Tables 11.2a,b) are the backbone of the FOTs for the Sahel and Northern Sudan Savanna AEZ. The FOTs use linear programming (Chapter 1) with Excel Solver[®] (Frontline Systems Inc., Incline Village, NV, USA) to consider an indefinitely large number of fertilizer use scenarios and recommends the combination of nutrient rates for each crop to maximize the net returns on the farmer's investment in fertilizer use.

The FOTs use complex mathematics to integrate the agronomy of the responses to applied nutrients for the different crops of interest to farmers, but also the farmer's land allocation to different crops, the value of the grain, the costs of fertilizer use and the money available for fertilizer use. The FOTs and other decision tools are available at <http://agronomy.unl.edu/OFRA>.

The FOTs, although of complex mathematics, are easy to use. The Solver add-in and macros must be enabled for the Fertilizer Optimization spreadsheet to function appropriately; see the 'Help and Instructions' worksheet of the FOT. When enabled the Solver add-in appears under the Data tab on the Quick Access Toolbar.

In the input panel (Figure 11.5) the user enters the hectares to be planted and the expected value for each crop on-farm at harvest time considering both that which is likely to be marketed and that which is saved for home consumption, the cost of using 50 kg bags of

available fertilizers, and the amount of money the farmer has to invest in fertilizer use. Then, the user clicks on the 'Optimize' cell to run the optimization calculations.

The output panel (Figure 11.5) displays the recommended fertilizer rate for each crop, the expected average yield increases and net returns to fertilizer application for each crop, and the expected total net return to investment in fertilizer.

Note that in this example 500,000 FCFA was made available for fertilizer use while a total of about 11 bags of fertilizer was needed valued at less than 200,000. The FOT only used the money needed to determine the EOR for all crops and nutrients. A more typical farmer may have only 50,000 available for fertilizer use, in which case the recommended rates would be much lower and some crops may not have a fertilizer recommendation.

Fertilizer costs and expected grain values are important for the results. Therefore, seasonal variation in fertilizer use costs and grain prices requires ready access to current information on fertilizer prices and grain markets to better determine the input costs and expected grain values for the season.

11.6 Paper fertilizer optimization tools

For each Excel Solver[®] FOT, there is a companion paper FOT to be used when a computer is not available (Table 11.3). The paper FOT is devised for three financial levels based on the total amount of money required to apply fertilizer at EOR for all the cropland: level 1 financial ability for the poor farmer who cannot invest more than one-third the total EOR amount; level 2 for the farmer with more money but has no more money than two-thirds of the total EOR amount; and level 3 for the farmer with enough money to apply fertilizer at EOR to at least some of the cropland and thereby at rates to maximize profit per hectare. The paper tool makes assumptions about the:

- measuring units to be used by farmers to calibrate their eyes and feel for applying the right rate of fertilizer
- crop row and plant spacing
- fertilizer use costs per 50-kg bag

Crop Selection and Prices		
Crop	Area Planted (Ha)*	Expected Grain Value/kg †
Pearl millet	1	160
Sorghum	1	170
Groundnuts, unshelled	1	180
Cowpea	1	200
Maize	1	180
Rice	1	280
Total	6	

Fertilizer Selection and Prices (N)					
Fertilizer Product	N	P2O5	K2O	xx	Costs/50 kg bag ¶*
Urea	46%	0%	0%	0%	13500
Single super phosphate, SSP	0%	18%	0%	0%	18000
Diammonium phosphate, DAP	18%	46%	0%	0%	20000
Murate of potash, KCL	0%	0%	60%	0%	15000
NPK	15%	15%	15%	0%	13500

Budget Constraint	
Amount available to invest in fertilizer (N)	500,000

Fertilizer Optimization					
Crop	Application Rate - kg/Ha				
	Urea	SSP	DAP	KCI	NPK
Pearl millet	0	0	128	25	0
Sorghum	26	0	94	0	0
Groundnuts, unshelled	0	0	0	17	0
Cowpea	0	0	0	10	0
Maize	102	0	0	0	0
Rice	75	0	66	24	0
0	0	0	0	0	0
Total fertilizer needed	204	0	287	76	0

Expected Average Effects per Ha		
Crop	Yield Increases	Net Returns
Pearl millet	882	82,772
Sorghum	618	60,655
Groundnuts, unshelled	89	10,793
Cowpea	56	8,127
Maize	622	84,413
Rice	872	190,288
0	0	0
Total Expected Net Returns to Fertilizer		
Total net returns to investment in fertilizer	436,998	

Figure 11.5: FOT panel displaying the entries and the output for investing 500,000 FCFA in fertilizer.

- expected grain values on-farm at harvest, considering the value both for home consumption and for market.

The paper FOTs address the 4Rs of fertilizer use: the right product, rate, time and method of

application. It also advises on calibration, e.g. the band length or number of planting hills per measuring unit.

For example, a level 1 maize grower from the Sahel is advised to apply urea at 48 kg/ha for

Table 11.3: Example of paper FOT

NIGER SAHEL AEZ

FERTILIZER USE OPTIMIZER:

Paper Version: February 2016



The below assumes:

Measurement for calibration is with a: Oriba bottle cap (Oriba) of 7 ml: holds about 4.9 g urea, and 7.7 g DAP, TSP or KCl.

Row spacing: 80 x 40 cm for maize and sorghum; 100 x 100 cm for pearl millet; 20 x 20 cm for rice; 80 x 50 cm for cowpea; and 40 x 20 cm for groundnut.

Grain prices per kg (FCFA): pearl millet 160; sorghum 170; maize 180; rice 280; groundnut unshelled 180; cowpea 200.

Fertilizer use costs per 50 kg bag (FCFA): urea 13,500; TSP 18,000; DAP 20,000; KCl 15,000; SSP 12,500 and NPK (15-15-15) 13,500.

Broadcast width: 2.0 m; DAS=Days After Sowing; DAT= Days After Transplanting.

Level 1 financial ability.

Lowland rice	broadcast 56 kg/ha urea at panicle initiation (1 Oriba for 0.4 m)
Pearl millet	point apply and incorporate 30 kg/ha DAP 5-10 DAS (1 Oriba for 2.6 hills)
Sorghum	point apply and incorporate 24 kg/ha DAP 5-10 DAS (1 Oriba for 7.4 hills)
Maize	point apply and incorporate 20 kg/ha urea at 8-leaf stage (1 Oriba for 7.2 hills) and 28 kg/ha urea at tasselling (1 Oriba for 5.2 hills)

Level 2 financial ability.

Lowland rice	broadcast 32 kg/ha DAP 3-7 DAT (1 Oriba for 1.2 m). Broadcast 68 kg/ha urea, (1 Oriba for 3.4 m) and 20 kg/ha KCl (1 Oriba for 2 m) at panicle initiation
Pearl millet	point apply and incorporate 82 kg/ha DAP 5-10 DAS (1 Oriba for 1 hills)
Sorghum	point apply and incorporate 63 kg/ha DAP 5-10 DAS (1 Oriba for 3.8 hills)
Maize	point apply and incorporate 30 kg/ha urea at 8-leaf stage (1 Oriba for 4.8 hills) and 47 kg/ha urea at tasselling (1 Oriba for 3 hills)
Cowpea	point apply 20 kg/ha DAP 5-10 DAS (1 Oriba for 9.6 hills)
Groundnut	band apply and incorporate 20 kg/ha TSP 5-10 DAS (1 Oriba for 9.6 m)

Level 3 financial ability (maximize profit per hectare).

Lowland rice	broadcast 66 kg/ha DAP 3-7 DAT (1 Oriba for 0.6 m). Broadcast 75 kg/ha urea (1 Oriba for 0.3 m) and 24 kg/ha KCl, (1 Oriba for 1.6 m) at panicle initiation
Pearl millet	point apply and incorporate 128 kg DAP/ha 5-10 DAS (1 Oriba 0.7 point)
Sorghum	point apply and incorporate 94kg/ha DAP 5-10 DAS (1 Oriba for 2.6 hills); point apply 26 kg/ha urea at tillering stage (1 Oriba for 5.5 hills)
Maize	Point apply and incorporate 50 kg/ha urea at 8-leaf stage (1 for 2.9 hills) and 52 kg/ha urea at tasselling (1 for 2.8 hills)
Cowpea	point apply and incorporate 25 kg/ha DAP 5-10 DAS (1 Oriba for 9 hills)
Groundnut	band apply and incorporate 27 kg/ha TSP 5-10 DAS (1 Oriba for 9.8 m)

maize. The paper FOT recommends that the urea should be point applied twice to each planting hill and covered with soil. At the 8-leaf stage, 20 kg/ha urea should be applied; the farmer calibrates his/her application so that one Oriba brand lid is enough for 7.2 hills. The second application should be 28 kg/ha urea applied pre-tassel;

the farmer calibrates application with one Oriba lid sufficient for 5.2 hills.

A constraint of the paper FOT is that it may need revision if grain prices and/or fertilizer costs are much changed. The procedure for paper FOT development and revision is given in Chapter 1.

Table 11.4: Fertilizer use in an ISFM Framework**FERTILIZER USE WITHIN AN INTEGRATED SOIL FERTILITY MANAGEMENT FRAMEWORK**

ISFM practice	Urea	SSP	KCI	NPK 15-15-15
	Fertilizer reduction, % or kg/ha			
Farmyard manure or compost applied	Both yield and response to fertilizer are expected to be increased; do not decrease fertilizer rates			
Dairy or poultry manure, per 1 t dry material*	25 kg	5 kg	17 kg	55 kg
Residual value of dairy and poultry manure applied for the previous crop, per 1 t	2 kg	2 kg	1 kg	3 kg
Previous crop was a green manure crop and plant material remained in the field	100%	70%	70%	70%
Rotation	0% reduction but more yield expected			
Cereal-cowpea or groundnut intercropping	Increase DAP/TSP by 7 kg/ha, but no change in N and K compared with sole cereal fertilizer			
Cereal-other legume (effective in N fixation) intercropping	Increase DAP/TSP by 11 kg/ha, reduce urea by 9 kg/ha, and no change in K compared with sole cereal fertilizer			
If Bray-1 >12 ppm	Apply no P			
If soil test K <40 ppm	Band apply 50 kg/ha NPK			

*The manure equivalent was calculated using the N, P and K composition of sheep and goat manure reported by Suzuki et al. 2014.

11.7 Adjusting fertilizer rates in consideration of other practices and soil test information

The Excel and paper versions of the FOTs give optimized recommendations for fertilizer use for within the farmer's context. However, these recommendations need to consider other practices that affect nutrient availability (Table 11.4). When soil test information is available, fertilizer rates may be adjusted. For example, the application of farmyard manure or compost at 2.5 t/ha is expected to result in increased yield but also increased response to fertilizer on upland soils. Therefore, fertilizer rate should not be reduced. However, application of high quality dairy or poultry manure justifies a fertilizer rate decrease and reallocation to another field. If Bray-1 P is above 12 ppm, recommended fertilizer P should not be applied to that field.

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