THE NIGER FOOD CRISIS: CAUSES AND IMPLICATIONS FOR RESEARCH AND DEVELOPMENT FROM AN INTEGRATED AGRICULTURAL ECONOMICS PERSPECTIVE

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1 Introduction: Aim and scope of the study

The 2005 food crisis in Niger demonstrated the difficulties the region has to ensure food security through own production. It has also outlined the general problems of the international community to handle such problems in terms of long term research and development issues. Questions arise whether such crises can be mitigated or avoided through research, development activities and policies. To look at this, research activities and findings have to be revisited, appropriate models and technologies for agricultural production have to be chosen, and the findings have to result in appropriate research, development and policy practices that ensure sustainability and growth of agricultural production.

The paper explains the origins of the Niger food crisis by looking at the production and marketing systems and assessing the low level of production of the main staple food, pearl millet through an integrated analysis that goes from the plot to the market. By doing this, the paper also will try to identify research gaps and suggest respective improvements for research that aims at selecting management practices to improve farming systems.

The next section gives an overview of the background of the Nigerien millet sector, including the development of a rationale for the study. The following section describes the characteristics of the study sites used for the millet production and farming systems analyses. After that, a sequence of model-based analysis is presented to assess the questions put forth in the rationale, followed by conclusions and recommendations for research, development and domestic trade policies.

Framework of the study

Millet production patterns in Niger over time and implications for research

The basic assumption of this paper is that millet is the major staple food for Nigerien households, and that improving production in a sustainable way is crucial for food security in Niger. We assume that looking at the evolution of millet production would indicate some starting points for a more detailed assessment.

Figure 1 shows the developments of millet production and related data from 1961 to 2003. Millet production has tripled during that period, mainly due to the increase of millet acreage. At the same time, hectare yields have declined, indicating that soils degrade, and that more and more marginal soils are under cultivation. In line with the high population increase, the per capita supply of millet has decreased. High variability of both hectare yields and overall production are obvious.

Figure 1 here

Specific data on fertilizer inputs to millet are not available, one can only draw some observations from statistical analysis to evaluate possible relations between millet yields and total fertilizer consumption in Niger. Fertilizer in Niger is not only used on millet, but mainly on cash crops like rice. Nonetheless, we assume that if there is a significant relationship between total fertilizer consumption and millet yields, we can conclude that at least a proportion of the overall fertilizer application is allocated to millet. Statistical analysis of the relation between fertilizer application and millet production shows the following:

Fertilizer application in Niger is one of the lowest in the world, measured in terms of kg of fertilizer applied per ha. Fertilizer application is a significant linear function of millet acreage. The variability of fertilizer application explained by the total millet acreage is relatively high with an adjusted R^2 of about 0.6, however, the coefficient is very small, which confirms the above statement of significantly low fertilizer application per land unit (Table 1).

Table 1 here

Overall fertilizer application is very erratic over time, i.e. with unexplained peaks and troughs throughout. This gives way to the assumption that fertilizer application rather follows political or development incentives than market signals.

Fertilizer application seems to have a significant impact on overall millet productivity; however, the yield variation explained by fertilizer application is relatively low, with adjusted R^2 around 0.2 for overall fertilizer (Table 2).

Table 2 here

This implies that although there seems to be a positive impact of fertilizer use on millet yield, fertilizer application seems to be overall erratic, possibly driven policy and development organisations, very low, and, possibly only to a small extend applied on the major food crop, millet.

This leads to the following rationale of the study:

- Why is the intensity of Nigerien millet production so low, which are the factors affecting fertilizer use and intensification? What role does the observed variability play?
- How can food production be increased through appropriate measures ensuring sustainable intensification?

Characterisation of study sites

The specific systems investigated in the study are situated in the Southwest of Niger, where a panel of about 100 farmers from four villages were subject to farm and household surveys. Farming systems are based on pearl millet, frequently intercropped with cowpea (Abele and Grini 1999). The systems are primarily subsistence oriented (Baidu-Forson and Williams 1996, McIntire et al. 1989, Abele 2001), as shown in Table 3 below.

Table 3 here

Production function analysis

In Niger yields are of a high variability, due to a number of factors: First, input use is of a high variability. Further, there is a temporal, but also a high spatial variability of climatic factors and soil quality. Effects between inter-crops have to be accounted for. Yield variability is an appropriate measure to quantify risk, as cropping risk can be defined as the variance and covariance of the cropping portfolio. Consequently, it is necessary to generate information on the determinants of yield variability in inter-cropping systems from farm data, so that this information can be used in further farming systems analysis. This is done by estimating production functions of an inter-cropping system for the nine main crops and crop by-products that are produced by the farmers. The database used for the analysis covers data on production in millet-based inter-cropping systems. The sample used is about 1,800 plots of farms in four villages in Western Niger taken by an ICRISAT/IFPRI research program in the eighties. The main crop is pearl millet, both sole and intercropped with cowpea, sorghum, groundnut as well as bambara groundnut, okra and hibiscus. Different intensity levels of phosphorous fertilizer, applied as SSP and rock phosphate are included. The database represents a time series from 1982 to 1987, including daily rainfall data over these years (McIntire et al. 1989).

The estimated yield functions are shown below (Table 4). Yields can be explained as a function of seeds and rainfall distribution. Considering rainfall, response differs across crops in terms of monthly rainfall response. Further factors influencing certain crops are phosphorus fertiliser application, e.g. millet or sorghum and, for some crops, the amount of inter-crop seeds applied on the same plot. Also, effects of inter-crops can be seen, as the output of e.g. millet and red sorghum is related to the output of inter-crops.

Table 4 here

Based on the yield functions for millet and cowpea, we can simulate a yield series that describes the response of the crops to rainfall variability and therefore finally the risk induced by rainfall variability. Here, it is possible to create a "ceteris paribus" situation when keeping the independent variables, except rainfall, constant. These yields are the base of further modelling that consists of two components: The first is a nonlinear *Markowitz* portfolio farm-model, which is applied to assess the profitability of the above mentioned innovations. The results are fed into an interregional trade model, to determine price and quantity reactions on markets and their impact on the decision making of farmers.

The farm model

The farm model is of a *Markowitz* type where risk is included in the objective function of the farmer. Risk is assumed to be of significant importance for farmers' decision making, as a farmer is not only interested in maximising profits but also in keeping a basic level of security (von Blanckenburg and Sachs 1982, Hedden-Dunkhorst 1993). The primary risk is production risk but also market risks due to price volatility must be added. Based on the assumption that Nigerien farmers are risk averse (Adesina and Sanders 1991, Sanders et al. 1996), the farm model can be formulated as the following nonlinear program:

$$\text{Max } U = C'X - \phi(X'\,\Omega\,X)^{1/2}$$

with U the utility to be maximised, X a vector of activities, C'a vector of gross margins, Ω the variance-covariance-matrix of the activities' gross margins, ϕ a risk aversion coefficient that is positive for the case of risk aversion (then the term including the matrix becomes negative) or zero in case of mere profit maximising

s.t.

a) Resource constraints

$$CX \leq D$$

with C a vector of the activities' resource requirements, X a vector of activities, D a vector of resource endowment

b) Nutrition requirements

$$AX \geq \nu B$$

with ν: the FAO adult equivalent, A a vector of nutrition values (protein, fat, carbohydrates), X a vector of activities and B a vector of basic nutrition requirements for protein, fat and carbohydrates

The model is calibrated by adjusting ϕ, so that the optimal solution of the nonlinear program reflects the observed production program of the farms.

After calibration, technical innovations (or technical options, TO) were integrated into the programme in order to test their economic feasibility (Table 5). Within a special research program "Adapted Farming in West Africa" of the University of Hohenheim, several innovations have been developed during 15 years of research from 1985 to 1999. These innovations have been especially designed for small scale farmers in marginal areas. The following TOs are taken from a portfolio of crop management options that were developed by the research program.

Table 5 here

Linking farms and markets

Prospected supply changes are integrated in a market model that endogenously calculates prices of the commodity under investigation. Such market models can be formulated as trade models that optimise welfare through interregional exchanges of commodities with respect to transport cost as well as demand and supply restrictions (Abele 2001). Prices are endogenously calculated as shadow values of welfare. Traded goods are in the present model millet, sorghum, cowpea, maize, wheat and rice.

We apply a set of models that reflect two subsequent cropping and trading periods, combining the above farm model and a trade model. The models are linked through the exchange of quantity and price information. Quantities marketed in the first period are taken from the farm model and extrapolated for the whole region before being fed into the trade model. The prices of the farm model in the second period are the calculated prices from the trade model in first period. In order to depict the above mentioned asymmetries and irreversibility of supply after harvest, the trade model's supply is fixed at the quantities harvested under optimal condition, so that only demand can react flexibly to post-harvest changes. The next step is then to allocate the millet surplus from the farms gained through the application of the technical innovations. Here, it is assumed that at stable prices the whole surplus is put into the markets, while at declining prices, farmers do not allocate more than necessary to cover their fertiliser expenses. The more prices decline, the more millet has to be allocated. This is modelled by increasing the fixed supply quantities stepwise until the turnover of millet covers the costs for fertiliser used for production.

In the scenario run, millet prices decline sharply throughout Niger. The farm model shows how farmers react to this decline in millet prices within the next cropping season. Table 6 shows the results of the *Markowitz* farm model after optimisation with the new market prices in comparison to the reference scenario. The decline in prices results in a sharp reduction of intensity. The application of pocket-placed fertiliser is reduced significantly, while application of crop-residue mulch is abandoned. Instead, the zero-input technology of selected weeding is applied up to the limit of self-owned plots. When risk indifference is assumed, the combination of mulch and pocket placed phosphate is still the first choice of the farmers. It is thus risk that determines the production decision and leaves even the low-input options unattractive.

Table 6 here

Conclusions

The performance of the Nigerien millet sector can be well explained by the above mentioned set of models. It can be shown that it is mainly risk, both production and market risk that keeps farmers from introducing innovations, in particular fertilizer application and hence increase productivity. Risk aversion seriously affects even technologies like small amounts of pocket-placed fertiliser, a technology that would be sustainable even at low output prices, if only risk indifference was assumed. This explains a large part of the distress and food insecurity in the Sahel. As basic explanatory variables are production risk expressed by yield variability and market risk explained by price volatility, both research and policies have to address these two issues.

The issues of production risk and the adequate improvement of the systems have to be addressed by research and development measures for the farming systems. Research has to take in to account several factors. The first one is that a complex set of models has to be used to assess a millet farming system that might be simple at first glance but that is difficult regarding its inter-cropping patterns, subsistence-orientation and risk aversion. Basically, such a model sequence not only explains the performance of the Nigerien millet sector, it also suggests measures to enhance the productivity, like low input systems such as selected weeding. It is clear that neither the large scale application of fertilizer nor the small amount application, are viable options in such an environment. Subsidies are mot likely to solve the problem, as fertilizer application only explains a part of the yield variability and hence the food insecurity. The other problem is that even subsidized fertilizer would be allocated by large scale and resource-rich producers, probably through informal markets, and hence it would not benefit the small scale resource poor and their immediate food security.

Price volatility is something that cannot be tackled on the farming systems level, as farmers plan their productivity as price takers. There has to be some intervention on the policy side to assure market stability, reduce price risks and foster intensification. Interventions should be market conform, i.e. not being subject to mere price fixations but rather the government acting as a buyer and seller. Millet could be bought in times of surplus, preventing downward surges of prices and providing incentives for farmers to actually intensify production and market surpluses, while in times of shortage, national stocks could be sold off, again stabilising prices against upward surges. This would improve food security and also prevent households from having to sell their assets, like e.g. livestock, or seed stocks, and be deprived of any means to recover from the crisis in the next cropping season.

6 References

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Tables

Table 1: Relation between millet acreage and overall fertilizer use in Niger 1961-2003

Variable	Coefficient	t-value	Sig.
Fertilizer (mt)	Dependent		
Millet acreage	3.438E-04	7.757	.000
N = 43, adjusted R^2 = 0.579 (regression through origin)			

Source: Own calculations, Data: FAO 2005.

Table 2: Relation between fertilizer use and millet yield in Niger 1961-2003

Variable	Coefficient	t-value	Sig.
Overall millet production(kg)	Dependent		
Fertilizer (mt)	109.860	3.582	.001
(Constant)	1,126,335.254	11.763	.000
N = 43, adjusted R^2 = 0.220			

Source: Own calculations, data: FAO 2005

Table 3: Production and marketing patterns of the sample farmers

Southern region				
Product	Value of production (FCFA)	Share of total production value (%)	Marketed share of value (%)	Share of value marketed of total marketed product (%)
Millet	14,482,287	80.14	7	40.87
Sorghum	472,750	2.62	23	4.38
Rice	168,000	0.93	7	0.47
Cowpea (grain and hay)	1,956,079	10.82	28	22.08
Groundnut	531,638	2.94	73	15.65
Manioc	53,000	0.29	75	1.60
Mango	377,000	2.09	100	15.20
Guava	3,750	0.02	100	0.15
Okra	27,000	0.15	0	0.00
Total	18,071,504	100.00	13.78	100.00

Source: Abele (2001).

Table 4: Yield functions in millet based intercropping systems

Dependent / Explanatory	Millet yield[a]	Cowpea grain yield[a]	Cowpea hay yield[a]	Ground-nut grain yield[a]	Ground-nut hay yield[a]	White sorghum yield[a]	Red sorghum yield[a]	Hibiscus yield[a]	Okra yield[a]
Cowpea grain	-7.6		-5.5				-0.05		
yield[a]	(-1.5)		(-2.5)				(-1.6)		
Groundnut grain					-5.0				
yield[a]					(-19.6)				
White sorghum	-0.5								
yield[a]	(-1.7)								
Hibiscus yield	19.8								
	(5.5)								
Millet seed[a]	1.8		0.2						
	(13.5)		(2.7)						
Cowpea seed[a]	99.1	0.7	55.7						
	(12.3)	(3.3)	(14.79)						
Groundnut seed[a]				2.4	15.4				
				(59.8)	(25.1)				
White sorghum						7.7			
seed[a]						(19.8)			
Red sorghum							27		
seed[a]							(53)		
Hibiscus seed[a]								2.0	
								(15.4)	
Okra seed[a]									19.7
									(11.1)
P-fertilizer[a]	16.8					0.7	0.03		
	(4.3)					(1.2)	(1.9)		
P fertilizer	-0.1					-0.04			
squared[a]	(-4.2)					(-1)			
Rain in May[b]	-3.5	0.13				-0.3			
	(-3.9)	(4.7)				(-3.0)			
Rain in June[b]	23.5	0.04	6.5			0.7			0.2
	(7.2)	(1.5)	(3.8)			(1.7)			(1.3)
Rain in June	-0.1		-0.04			-0.005			
squared[b]	(-5.3)		(-3.0)			(-1.5)			
Rain in July[b]		0.1							0.1
		(4.8)							(1.5)
Rain in August[b]							0.003		-0.08
							(1.4)		(-1.4)
Rain in	3.2		1.14	0.4	2.1	0.2	0.01	0.03	
September[b]	(4.5)		(3.3)	(3.4)	(6.5)	(1.8)	(2.3)	(3.3)	
Rain in		-0.2							
October[b]		(-2.2)							
Constant	-751.9	-9.8	-271	-13.6	-88.6	-17	-0.9	-1.3	-8.4
	(-6.5)	(-3.8)	(-4.5)	(-1.7)	(-2.9)	(-1.1)	(-2)	(-1.8)	(-0.7)

[a]$kgha^{-1}$, [b]mm in respective month, System R^2 = 0,97, t-values in brackets, source: Own calculations based on ICRISAT Data

Table 5: Description of technical options (TOs)

Technical option (TO)	Description	Millet yield (millet sole cropped) in t ha^{-1}	Millet yield (millet/cowpea intercrops) in t ha^{-1}	Cost structure assessment	Qualitative risk assessment
0	Traditional millet system	0.40	0.47	No inputs except seed and labor	Low risk
1	Pocket -placed phosphate fertilisation with 1.5 kg P ha^{-1}, or 20 kg SSP fertiliser respectively	0.72	0.79	Mineral fertilizer	High risk, as fertilizer purchases have to be reimbursed through millet sales
2	Selective weeding by leaving specific shrubs on the field	0.50	0.58	No inputs, less labour costs	Decreased risk
3	Mulching with crop residues in form of millet stalks	0.60	0.85	Mulch costs, labour costs for mulching	High risk
4	TO 3 and 1 combined	0.80	0.90	Mulch costs, labour costs for mulching, Mineral fertilizer	Highest risk of all options

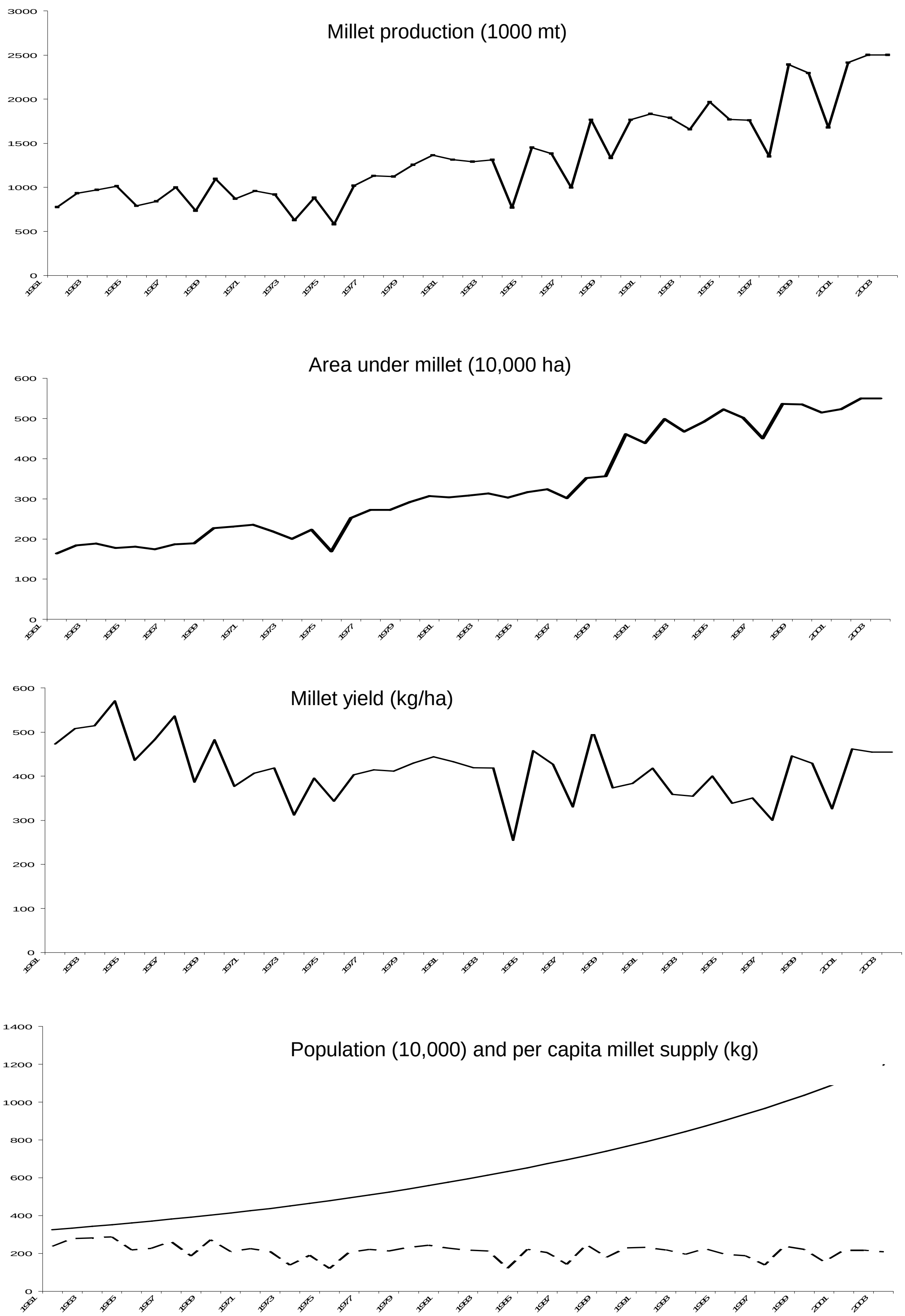
Source: Own calculations based on ICRISAT data.

Table 6: Gross margins and production portfolio in different scenarios

Reference run: At old prices without innovations	
Total gross margin[1]	355,378
Production portfolio (percentage of area cultivated)	
Millet sole cropped (ha)	3.2
Millet inter-cropped with cowpea (ha)	4.8
Millet production in mt (8 ha farm)	
Scenario 1: At old prices with innovations	
Total gross margin[1]	540,297
Production portfolio (percentage of area cultivated)	
Millet inter-cropped with cowpea, application of pocket placed phosphorous fertiliser and mulch of crop residues (ha)	8
Millet production in mt (8 ha farm)	7.2
Scenario 2: At new prices with innovations	
Total gross margin[1]	295,837
Production portfolio (percentage of area cultivated)	
Millet inter-cropped with cowpea under selective weeding (ha)	5.8
Millet inter-cropped with cowpea, application of pocket placed phosphorous fertiliser (ha)	2.2
Millet production in mt (8 ha farm)	5.1
Scenario 3: At new prices with innovations, assumption of risk-indifference	
Total gross margin[1]	330,930
Production portfolio (percentage of area cultivated)	
Millet inter-cropped with cowpea, application of pocket placed phosphorous fertiliser and mulch of crop residues	8
Millet production in mt (8 ha farm)	7.2

[1]Gross margins are FCFA ha^{-1} Source: Own calculations based on ICRISAT data.

Figure captions: Figure 1: Millet production patterns and per capita supply over time



Source: FAO 2005