Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 6 (4): 892-897, 2006
ISSN 1812-5654

Food Self Sufficiency: Maize Production in Southern Mali

Dicko Mahamet
Economics School of HuaZhong University of Science and Technology,
Wuhan, Hubei province 430074, People's Republic of China

Abstract: According to several studies on the improvement of cereals varieties, in order to respond to the variability of the local conditions and production objectives, farmers in Sikasso (Southern Mali) grew several varieties of maize representing different characteristics. Always within the framework of the promotion of this culture we have led a study of the relationship between maize yields; high yielding varieties; rainfall; fertilizers use and irrigation. Through this research we have found that the growth of maize yields can be largely attributed to the introduction of the new dwarf high yielding variety, as well as the use of the associated complementary modern inputs, particularly fertilizers and irrigation. From the correlation results, it appears that the regression procedure may find it difficult to separate the effects of these three inputs on yields.

Key words: Maize, southern Mali, on-farm, maize production yield, correlation

INTRODUCTION

In order to secure food self sufficiency, the agricultural research institute in Mali (IER: Institut d'Economie Rurale) has put major emphasis on variety selection of cereals. Traditionally, thematic researchers test new varieties on-station, followed by multi-location on-farm trials managed by researchers. Their principal selection criteria are yield maximization and agro-climatic stability. As such, several high yielding varieties have been selected for extension but failed to be widely adopted.

Only 30% of the farmers grow one of the several promoted maize varieties in southern Mali (Boughton, 1994). For sorghum, the results are even worse: less than 5% of the total area of sorghum and millet of West Africa is under improved varieties (Matlon, 1985). Cereals, which are mainly subsistence crops, receive less inputs in terms of labour and cash and are grown under a wide diversity of farming systems. Neglection of this diversity is one of the major reasons for the low adoption of improved varieties (Stoop *et al*., 1982).

In order to respond to the variability of the local conditions and production objectives, farmers grow several varieties with different characteristics (Matlon, 1991). Their selection criteria have been reported to be quite different from those of the breeders. Since domestic activities are a major part of women's tasks (Perquin, 1993; Dembele *et al*., 1996), their criteria related to processing, storing and consumption are likely to influence farmers' selection of varieties. Ashby (1994) has shown the importance of including rural women in the evaluation of varieties, whether the crop is grown for household consumption or for marketing. However, the complexity and diversity of farmers' production strategies and objectives, both men's and women's, make it difficult to grasp their selection criteria (Chambers, 1992). Participatory tools and methodologies that facilitate communication between farmers and researchers are, therefore, urgently needed in order to improve adoption rates of new varieties.

To cover this need, the Farming Systems Research (FSR) Team of IER in southern Mali is developing a participatory research methodology to identify systems parameters that are essential for the selection of improved cereal varieties. The methodology mainly consists of an assessment of local varieties to quantify their importance, distribution and characteristics. At the same time, farmers' preferences and criteria for selection are studied. The aim is to help the varietals breeding program in prioritizing farmers' selection criteria. Early incorporation of farmers' criteria into the breeding program will allow more efficient use of research resources (Galt, 1989).

The methodology has initially been developed for maize, a food crop becoming increasingly important in southern Mali (Boughton and de Frahan, 1992). Maize has the potential to meet the country's food self-sufficiency needs, and it highly responds to intensive cropping and fertiliser application (Kamara *et al*., 1994).

The Farming Systems Research (FSR) Team covers the administrative region of Sikasso, in southern Mali. We distinguish two climatic zones. The climate of the region is dominated by one pronounced rainy season. The region has mostly poor sandy soils in a gently rolling landscape (Sidibe, 1996).

One zone is characterized by a traditional slash and burn farming system based on cereal crops and organic fertilizer is rarely used. Maize, which forms the basis of the cereal nutrition, is more suited to this zone. It occupies 34% of the cultivated area. The household land is cultivated using animal traction. Farmers who grew more than one variety preferred varieties of different cycle lengths. This diversification strategy makes farmers less vulnerable to climatic changes and helps to decrease the risk of a poor harvest due to erratic rainfall. They are horrified by birds attacks and Striga. Early maturity was the first important in this zone: early varieties helped to bridge the shortage resistance to drought, resistance to bird attack. Size of the cob was the second most important preference criteria.

The agriculture of second zone is based on maize representing 78% of the cultivated area. This zone has several immense surface waters; almost maize is grown on common household land and they use tanks irrigation.

The main objective of this project is to study the relationship between maize yields; high yielding varieties; rainfall; fertilizer use and irrigation in order to find out which variables best explain maize yields.

MATERIALS AND METHODS

Houck and Gallagber (1976) estimated a yield function for corn in the US using a yield function with relative fertilizer price, an index of moisture conditions, land acreage, dummies for acreage restrictions and a time-trend (for technology) as the explanatory variable (1950-early 1970s). Guise (1969) used a Cobb-Douglas wheat yield function for New Zealand (1917-67) with variables reflecting such factors as soil type, virus incidence, HYV proportion, relative fertilizer price, acreage, livestock, a time-trend, temperatures and rainfall as explanatory variables. Hamblin and Keyneur (1993) related Australian wheat yields to rainfall, water availability in the root zone, water use efficiency, per cent under semi-dwarf varieties, growing areas, a time-trend (for which a degree four polynomial was used), soil organic matter and nitrogen. Byerlee and Traxler (1995) related experimental wheat yields to the release of varieties related or unrelated to CIMMYT germplasm for different regions of the world.

High yielding varieties, irrigation and rainfall are selected to be the major determinants of maize yield to test for in a production function framework. Data on some of the other variables emerging from the literature reviewed above are very difficult to get and some of them are not particularly relevant for the present Sikasso maize agriculture. Many alternative functional forms are possible. The Cobb-Douglas functional form is selected as the function to use because of its reasonable theoretical assumptions (Fuss, *et al.*, 1978; Lau, 1986) good record, simplicity of form and the limited degrees of freedom available.

The yield function is specified as below:

$$\text{yield} = \alpha(\text{fert})^{a_1}(\text{hiv})^{a_2}(\text{irrg})^{a_3}(\text{rain})^{a_4}$$

This is lineralized by taking logs.

$$\text{Log}(\text{yield}) = \alpha' + a_1\text{Log}(\text{fert}) + a_1\text{Log}(\text{hiv}) + a_3\text{Log}(\text{irrg}) + a_4\text{Log}(\text{rain})$$

Where:

yield	=	Maize yield in kilograms per hectare
fert	=	Fertilizer use on maize (estimated) in nutrients, kg/hectare
hvt	=	Percentage of maize gross cropped area under high yielding varieties
irrg	=	Percentage of maize gross cropped area which is irrigated
rain	=	Index of rainfall based on rain received during the main monsoon season of June to September (usually 85% of the rainfall).

a, a_1, a_2,a_3, a_4 are parameters to be estimated.
Mathematical considerations are shown in Annex.

RESULTS

Maize yields increased fourfold from 663 kg ha^{-1} to 2583 kg ha^{-1} between 1955/56 and 2003/04. Whilst there was some growth in yield between 1955/56 and 1965/66 the growth was substantial after that there was a significant acceleration in production growth after 1971/72 with the advent of the green revolution. The growth can be largely attributed to the introduction of the new dwarf high yielding variety, as well as the use of the associated complementary modern inputs, particularly fertilizers and irrigation. The IER research system also played a major role in adapting this technology to suit the local conditions. The 1995/96-2003/04 period shows an annual growth rate of 3.24%, but both the yield and the production growth rates appear to show some deceleration in recent years. This could be indicative of constraints to yield growth (Table 1).

What has made the yield growth possible in this zone in Sikasso. Numerous studies such done by DNSI-IER have indicated that modern technology and inputs have played the major role. Table 2 shows the trends in the major inputs and resources used in maize production.Fertilizers, high yielding varieties (HYV) and

Table 1: Maize productions in Mali

Year	Area (m ha)	Production(m t)	Yield (kg ha^{-1})
1955/56	9.8	6.5	663
1965/66	12.9	11.0	851
1975/76	18.2	23.8	1307
1985/86	22.3	36.3	1603
1995/96	24.2	55.1	2281
2002/03	26.7	66.3	2485
2003/04	27.4	70.8	2583
2004/05		68.7	
Annual growth rates			
1955-2002	2.15	5.33	3.17
1971-2002	1.65	4.67	3.03
1985-2002	0.89	3.50	2.61
1995-2002	1.69	3.24	1.56

Sources: National Directorate of Informatique and Statistics (DNSI)

Table 2: Trends in major resources and inputs used in maize production

Years	Area (m ha)	Fertilizers (kg ha^{-1})	Percent area under HYV	Percent area Irrigated	Rainfall index (Normal = 100)
1955/56	9.8	1.8	0.0	34.0	104
1965/66	12.9	5.7	0.0	32.7	99
1975/76	18.2	31.2	35.5	54.3	113
1985/86	22.3	63.7	72.3	76.5	104
1995/96	24.2	118.3	86.8	81.1	119
2003/04	26.7	127.4	86.2	87.4	102
2004/05	27.4	137.4	87.6	89.3	106

* Fertilizer use on maize is estimated based on fertilizer use and crop statistics., Sources: DNSI; Ministary of Finance

irrigation all show substantial increase. Estimated fertilizer use on maize has increased from less than 2 to 137 kg ha^{-1} between 1955/56 and 2003/04 HYVs were non-existent in 1955/56 and 1965/66 but now cover 88% of the area. Irrigation has risen from 34 to 89%. Thus, clearly, substantial technological change has taken place in maize production.

PRODUCTION BEHAVIOUR ANALYSIS

This section seeks to examine the relationship between major factors, particularly inputs, in determining maize production in Sikasso, at the aggregate level. It is common practice in the analysis of grain production to separate area and yield effects and to focus on the yield function. In the case of Sikasso, the area available for production has not reached limits but some lands are very far from the water sources. Tanks are used to irrigate the fields (culture all season). It is yield growth that is mainly driving production growth and this will continue in the future.

Production function estimation is frequently affected by multi co linearity. This depends principally on the correlation between explanatory variables. To assess this problem, correlations were calculated, and the correlation matrix of the explanatory variables is given in Table 3. The matrix shows that the correlations are very high. The correlation between fertilizer and irrigation is 0.9607 and

Table 3: Correlation between explanatory variables (1971/72-2003/04)

	FERT	HYV	IRRG	RAIN
FERT	1.0000			
HYV	0.8499	1.0000		
IRRG	0.9607	0.9327	1.0000	
RAIN	0.1748	0.1595	0.1450	1.000

Table 4: Results of GLS Regression Analysis with Correction for Auto-correlation:Cobb-Douglas Production Function

Period	Estimated Coefficients of the Logs of Each Variable						
	FERT	HYV	IRRG	RAIN	R^2	DW	N
1971/72-2003/04	0.3801 (3.934)***	0.0598 (1.715)*	0.2295 (0.957)	0.1011 (1.401)	0.97	2.13	33
1985/86-2003/04	0.1705 (1.464)	0.8864 (3.166)***	0.7233 (2.557)**	0.0749 (0.806)	0.94	2.00	19
1995/96-2003/04	0.1893 (1.156)	1.0099 (2.817)**	1.1184 (3.156)**	0.1065 (0.839)	0.88	2.77	9

this may be because the rise in irrigation and fertilizer use often goes together. Similarly the correlation between fertilizer and HYV is also high at 0.8499 since fertilizer use may increase substantially with HYV use. Correlation between irrigation and HYV is at 0.9327 since irrigation helps HYV adoption. From these results it appears that the regression estimation is likely to be influenced by multi-co linearity and the regression procedure may find it difficult to separate the effects of these three inputs on yields. Therefore, their coefficient magnitudes could be unstable and may reflect the effects of each other. It may also be noted that rain does not have a high correlation with any of these inputs, perhaps because of the high degree of irrigation in maize.

Since the Durbin-Watson statistics indicated a high degree of auto-correlation, the production functions were estimated by the GLS regression procedure with the Cochrane-Orcutt procedure for correction of auto-correlation (see in annex the OLS; GLS process). The main time period used was 1971/72 to 2003/04 which was the entire period since the new green revolution technology arrived. Two sub-periods 1985/86 to 2003/04, and 1995/96 to 2003/04 were also experimented with to examine the more recent environments. The earlier period of 1955/56 to 1970/71 was not used since it represented a markedly different technology and institutional environment, not considered relevant or useful for analyzing the present and future scenario.

The estimated R-square indicates a good fit of the function. Even though multi co linearity between fertilizer, HYV and irrigation is affecting the results, all of these variables show positive coefficients and each emerges as an important determinant in at least one of the equations. For the 1971/72-2003/04 period fertilizer emerges with a large and highly significant coefficient (Table 4). This indicates that over the longer period, fertilizer use has played a major role in determining maize production. HYV is also significant in this period, indicating its important role. However, irrigation does not emerge as a significant determinant of yield in this equation.

For the more recent 1985/86-2003/04 period, fertilizer becomes non-significant but both HYV and irrigation emerge to be significant. The coefficients of both these variables come out to be much larger, indicating a strong role in determining maize yields. In the very recent 1995/96-2003/04 period both HYV and irrigation emerge as very significant. This indicates that in more recent year's irrigation or water seems to have emerged as a major determinant in maize production growth. This would be a significant concern for future growth: as indicated earlier, 89% of maize area is already irrigated and therefore there is less scope for growth in it. The other key determinant, HYV, will be another major constraint as HYV is already 88% in coverage. In the case of fertilizers, even though there is scope for expansion (rate stands at 137 kg ha^{-1}) the productivity is not very high. Better soil fertility management may help to improve this. A somewhat comforting finding from the estimates is that the relationship between maize production and rainfall is not significant. This indicates that the maize yield is not affected very much by the vagaries of rain, which hence would provide stability to food grain production in Sikasso

CONCLUSIONS

Mali, country, which has agricultural and pastoral vocation, can have as ambition to be the cereals attic of Western Africa. To succeed this noble aspiration the results of the econometric estimations prove that the solution is the judicious use of surface water; the access to new technologies and the use of the HYV; on all arable ground if economically possible. ($R_{1971/72\text{-}2003/04}$ = 0.97; $R_{1985/86\text{-}2003/04}$ = 0.94; $R_{1995/96\text{-}2003/04}$ = 0.88. The three periods specifications are good. All the variables used to explain the yield have positive coefficients. The result proves that the rainfall cannot constitute any more obstacle to our food self sufficiency. The varieties of cereals which have short period of maturity and which resist the attacks of the depradeurs must be popularized.

However it will be necessary to prevent the danger of degradation (salinization) of the grounds; contamination of surface waters and the intoxication of animals by an abusive use of fertilizers and pesticides.

ANNEX

K-variable linear Equation:

$$Y_t = \beta_1 + \beta_2 X_{2t} + \beta_3 X_{3t} + \ldots\ldots + \beta_k X_{kt} + \mu_t \quad t = 1, \ldots, n$$

Matrix formulation of K-variable model

$$y = X\beta + \mu$$

$$X = \begin{bmatrix} 1 & X_{21} & . & X_{k1} \\ 1 & X_{22} & . & X_{k2} \\ . & . & . & . \\ 1 & X_{2n} & . & X_{kn} \end{bmatrix}, \quad y = \begin{bmatrix} Y_1 \\ Y_2 \\ . \\ Y_n \end{bmatrix}, \quad \beta = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \\ \beta_k \end{bmatrix}$$

when, β is unknown we guess b to replace it,
the residuals error:
e = y - Xb residual sum square: RSS = e'e which we minimize to obtain normal equation: (X'X)b = X'y
decomposition of the sum of squares gives:

$$(y'y - nY^2) = (b'X'Xb - nY^2) + e'e$$
$$TSS = ESS + RSS$$

We note R as correlation coefficient

$$R^2 = \frac{ESS}{TSS} = 1 - \frac{RSS}{TSS}$$

$$\text{Estimate R: } \bar{R}^2 = 1 - \frac{RSS/(n-k)}{TSS/(n-1)}$$

$$\bar{R}^2 = 1 - \frac{(n-k)}{(n-1)}(1 - R^2)$$

when R is large denotes good specification of the model partial correlation measures the relationship two variables when one or the others explanatory variables are kept constant more partial correlation coefficient is high more it explains the model

$$\nu_t \rightarrow N(0; \sigma_\nu^2)$$
$$H_0 : \hat{\rho} = 0 \rho = 0$$
$$H_1 : \rho \neq 0 \quad t_1 \text{ is t of Student}$$
$$\varepsilon_t = \rho \varepsilon_{t-1} + \nu_t$$
$$d_2$$

this relation is only for order k-1.
In the case of three variables such as:
r_{12} : Correlation coefficient between x_1 and x_2
r_{13} : Correlation coefficient between x_1 and x_3
r_{23} : Correlation coefficient between x_2 and x_3

$$r_{12,3} = \frac{r_{12} - r_{13} r_{23}}{\sqrt{(1 - r^2_{13})(1 - r^2_{23})}}$$

$$r_{13,2} \frac{-r_{12}}{\sqrt{(1 - r^2_{12})(1 - r^2_{23})}}$$

$r_{12,3}$: Correlation coefficient between x_1 and x_2 when x_3 is ignored
$r_{13,2}$: Correlation coefficient between x_1 and x_3 when x_2 is ignored

The estimator of Generalized Least Squares (GLS): Let us consider the general linear model:

$$Y = X \quad a + \varepsilon$$

(n;1) (n;k+1) (k+1;1) (n;1)

Which $E(\varepsilon\varepsilon') = \Omega_\varepsilon = \sigma_\varepsilon^2 I$ (dimension of Ω_ε is n,n).

We wish to determine an estimator of a which has the same properties as the estimator of the MCO: without skew, linear function of y and with minimal variance. It is showed that this estimator is given by:

$$\hat{a} = (X'\Omega_\varepsilon^{-1}X)^{-1}(X'\Omega_\varepsilon^{-1}Y)$$
$$\Omega_{\hat{a}} = (X'\Omega_\varepsilon^{-1}X)^{-1}$$

This estimator is called estimator of the least generalized squares (GLS) or estimator of Aitken

Remark: when the traditional assumptions are satisfied we find the estimator of the MCO:

$$\hat{a} = (XX)^{-1}(X'Y) \text{e.g.} \Omega_\varepsilon = \sigma_\varepsilon^2 I$$

In practice one does not know the matrix Ω_ε, the above formulars are not usable except in exceptional cases.

Test of Durbin and Watson detects order 1 auto correlation error:

$$\varepsilon_t = \rho\varepsilon_{t-1} + \nu_t \text{ , where } \nu_t \to N(0;\sigma_\nu^2)$$

We test the hypothesis:

$H_0 : \rho = 0$
$H_1 : \rho \neq 0$

For that we compute Durbin Watson Statistics

$$DW = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_1^n e_t^2}$$

Where e_t : residuals of the model estimation
$0<DW<4$

$\hat{\rho} = 0$ if DW = 2 ($\hat{\rho}$ is the estimation of observed ρ)
DW tables give the value of d_1 and d_2 such as:
$0<d_1<d_2<2$
$d_2<DW<4-d_2$ H_0 accepted $\rho = 0$
$0<DW<d_1$ H_0 rejected $\rho>0$
$4-d_1<DW<4$ H_0 rejected $\rho<0$
$d_1<DW<d_2$ or $4-d_2<DW<4-d_1$ we cannot conclude about H_0

Conditions of apply

- The model must imperatively include a constant term;
- The variable to explain must not be among the explanatory variables (as lagged variable);
- For the models in instantaneous cross-cut, the observations must be ordered according to the variable to explain

The test of Durbin and Watson is a presumptive test of independence of the errors because it uses the residues; further, it only tests a relationship of order 1.

REFERENCES

Ashby, J.A., 1994. Evaluation of bean varieties by men and women in small farm systems. In: Tools for the Field: Methodologies Handbook for Gender

Boughton, D., 1994. A Commodity Sub sector Approach to the Design of Agricultural Research: The Case of Maize in Mali. Ph.D Thesis, Agricultural Economics, Michigan State University.

Boughton, D. and B. de Frahan, 1992. Agricultural Research Impact Assessment: the Case of Maize Technology Adoption in southern Mali. IER, Mali.

Byerlee, D. and G. Traxler, 1995, 'National and international wheat improvement research in the post-Green Revolution period: Evolution and impact'. Am. J. Agric. Econom., pp: 268-278.

Chambers, R., 1992. Methods for Analysis by Farmers: The Professional Challenge. Keynote presentation at the 12th Annual Association for Farming Systems Research Extension Symposium, September 13-18, 1992, Michigan State University, East Lansing, USA.

Dembele, I., H. De Groote and T. Hilhorst, 1996. Women Role in the Cotton production in Southern Mali. Research report ESPGRN-Sikasso, Natural resources Production and Management Team and PROFED/Malian Textile Development Company-Bamako.

Fuss, M., D. McFadden and Y. Mundlak, 1978. A Survey of Functional Forms in the Economic Analysis of Production. In: Melvyn, F. and D. McFadden, (Eds), Production Economics: A Dual Approach to Theory and Applications, Vol. 1, The Theory of Production, North-Holland Publishing Company, New York.

Galt, D., 1989. Joining FSR to commodity programme breeding efforts earlier: increasing plant-breeding efficiency in Nepal. Agren. Network Paper 8. ODI, London.

Guise, J.W.B., 1969. Factors associated with the aggregate average yield of New Zealand wheat. Am. J. Agric. Econom., 51: 866-81.

Hamblin, A. and G. Kyneur, 1993, 'Trends in wheat yields and soil fertility in Australia'. Bureau of Resource Sciences, Canberra, Australian Government Publishing Service, National Capital Printing, Fyshwick ACT.

Houck, J.P. and P.W. Gallagher, 1976. The price responsiveness of U.S. corn yields. Am. J. Agric. Econom., pp: 731-734.

Kamara, A., H. Doucoure and T. Defoer, 1994. Maize in the systems of production: Case of the zones of Koutiala and Kadiolo. Research report. Document No 94/29. Natural resources, Production and Management Team - ESPGRN) of Sikasso, IER, Mali.

Lau, L.J., 1986. Functional Forms In Econometric Model Building. In: Zvi, G. and M.D. Intriligator (Eds.), Handbook of Econometrics, Vol. 3, Elsevier Science Publishers, B.V., The Netherlands, pp: 1515-1566.

Matlon, P.J., 1985. A critical Review of Objectives, Methods and Progress to date in Sorghum and Millet Improvement: Case Study of ICRISAT/Burkina Faso. In: Appropriate Technologies for Farmers in Semi-Arid Africa. Ohm, H.W. and J.G. Nagy, (Eds.), International Programs in Agriculture, Purdue University, West Lafayette, USA, pp: 154-178.

Perquin, B., 1993. Women in the Rural Production Systems in Mali. Research report. DRSPR (Natural resources Production and Management Team-ESPGRN) of Sikasso, IER, Mali.

Sidibe, M.C., 1996. Villages of Research Socio cultural Values: Village monographs. (Natural resources, Production and Management Team-ESPGRN) of Sikasso, IER, Mali.

Stoop, W.A., C.M. Pattanayak, P.J. Matlon and W.R. Root, 1982. A strategy to raise the productivity of subsistence farming systems in the West African semi-arid tropics. In: Sorghum in the Eighties. Proceedings of the International Symposium on Sorghum, 2-7 Nov 1981, Patancheru, A.P. and ICRISAT, INDIA.