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Farmers' Production and Marketing Response to Rice Price Increases and Fertilizer Subsidies in the *Office Du Niger*

by

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David Mather and Valerie Kelly

December 2012

This report was prepared by the Food Security Group (FSG) in the Department of Agricultural, Food, and Resource Economics (AFRE) at Michigan State University with financial support from the Bill and Melinda Gates Foundation for the Guiding Investments in Sustainable Markets in Africa (GISAMA) project and the USAID-funded project PROMISAM II Associate Award to the USAID/MSU Food Security III Cooperative Agreement (GDGA-00- 000021-00) between Michigan State University and the United States Agency for International Development (USAID), Bureau for Food Security, Office of Agriculture, Research, and Technology.

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FOREWORD

Joint funding by USAID Mali and the Bill and Melinda Gates Foundation made it possible to undertake a detailed farm-level investigation to describe how different types of farms in different zones interact with cereal markets. This puts us in a better position to assess the extent to which improvements in cereal markets are likely to improve incomes and reduce rural poverty across the three principal cereal cropping systems in Mali. The analyses reported in this working paper focus on the irrigated rice zone of the *Office du Niger*, while other reports provide details for the cotton zone (Murekezi and Mather, forthcoming) and a synthesis of findings for the rice, cotton, and a traditional coarse grain production zones (Kelly et al. 2012).

Most of the research and analysis for the paper was completed prior to the March 22, 2012 military takeover of the Malian Government, the subsequent declaration of independence by the northern half of the country, and external military intervention. These events have inevitably had a negative impact on the ability of cereal markets to function in the northern half of the country. Although the zones most directly concerned are north of our main study zones, the ongoing war, pillaging, and destruction of infrastructure has reduced the capacity of private sector actors, government services, and humanitarian organizations to supply the north with cereals. The disruption of trade patterns and the economic disruption in Mali due to all the political events will likely have a strong impact on the organization of the cereals value chains for the next few years. Donor support in the future will need to be mindful of the previous progress made in cereal market development via private sector actors and focus on rebuilding that capital and capacity rather than replacing it with an externally managed donor approach.

ACKNOWLEDGMENTS

This paper is the result of work by a large number of international collaborators and MSU colleagues who contributed to the collection and management of the farm survey data that are analyzed and reported in the paper.

Special thanks go to the farm survey team at ECOFIL in the *Institut d'Economie Rurale* (Bamako). The team was led by Amadou Samaké, with supervisory assistance from Moumouni Sidibé and Fassory Sangaré. Two members of MSU's Bamako-based team (Niama Nango Dembélé and Sidibé Thiam) played a major role in supervising the survey implementation and managing the data base.

MSU's Margaret Beaver and Juha Sohlberg spent many long TDYs in Bamako helping the team set up the data base and training Bamako staff to manage it. CIRAD's Jean François Bélières was always available via the Internet to resolve any questions we had about the first year of the panel data that he had cleaned and analyzed so that we could ensure consistency in methods used across the three survey rounds.

Farm survey research and analysis support was provided by Brenda Lazarus and Mariam Sako, both MS graduate students based in East Lansing. MSU's Steve Longabaugh provided assistance with designing maps used in the report.

Duncan Boughton provided overall guidance throughout the farm survey work, and he and John Staatz provided helpful comments on earlier drafts of this paper. Patricia Johannes provided much needed assistance with final editing and formatting.

EXECUTIVE SUMMARY

Many African governments responded to the dramatic increases in international and domestic grain prices of 2008 and 2009 through a mixture of trade policy changes and input/output market subsidies. In the case of Mali, the Government put in place a rice promotion program at the beginning of the 2008/09 production season. The program, called *Initiative Riz* (IR or Rice Initiative), made subsidized fertilizer available to rice producers nationwide with a particular focus on farmers in the *Office du Niger,* where roughly 50% of Mali's rice is produced. The goal of the program was to increase domestic rice production by 50% over the 2007/08 level, thereby increasing marketable surpluses and putting downward pressure on cereal prices.

Whether the program met its production goals is unclear because of conflicting numbers reported by two different Ministry of Agriculture sources. What is not disputed, however, is that rice prices did not fall as much as anticipated in 2008, with the government and other observers suggesting that rice producers were 'hoarding' their production to take advantage of the higher price environment– i.e., they held onto more of their annual production than usual.

This paper aims to inform the debate about farmers' response to the IR and rising rice prices through empirical analysis of household survey data on crop production and marketing that permits comparison of farmers' behavior before (2006/07) and after the price spikes and the introduction of the IR (2008/09 and 2009/10). The survey includes production and sales data for both the rainy and dry seasons during the three agricultural production years mentioned above as well as a wealth of demographic, asset, and non-farm income data. We use descriptive and econometric analysis of this data to investigate the following research questions:

1. When did cereal prices begin to rise in Macina markets, and to what extent did they increase?
2. How did farmers respond to rising cereal prices and the IR with respect to their area cultivated to rice and coarse grains?
3. How did rising cereal prices and/or the IR affect fertilizer use?
4. Did the IR and higher expected cereal prices lead to higher yields and more aggregate rice production, as anticipated by the GOM? If not, does econometric analysis of the observable determinants of rice yields explain why?
5. Did households reduce the percentage of their rice production that they sold over time? If yes, does econometric analysis of the observable determinants of household rice sales explain why?

For each of these questions, we test for differences in response by different types of farm households. Although the focus is on how responses are shaped by farm size (access to more or less irrigated land) and the quality of irrigation (full or partial water control), we also look at the role of other factors such as demographic characteristics and ownership of assets (e.g., durable goods and agricultural equipment).

Descriptive analyses brought to the forefront some of the salient differences between farmers located in the *casiers*, where most rice plots benefit from improved quality irrigation, and *bord de casiers*, where access to good quality irrigation is more restricted. In terms of land access, the average ON household of roughly ten people is thought to need at least five hectares of irrigated land to make ends meet. The average *casiers* farm in the sample has secure access to a total of only 4.2 hectares, which are predominantly irrigated parcels; this is less than the recommended minimum size of 5 hectares, but includes substantially more good quality irrigation land than farmers in the *bord du casier* villages (4 ha for *casiers* farms versus only 2.2 ha for *the bord de casiers*). In brief, b*ord de casiers* farmers have significantly less high quality irrigation land with fully controlled water and more of the lower quality parcels with partial control.

While the *casiers/bord de casiers* distinction does not differentiate households by food security status (roughly 29% of *casiers* and *bord de casiers* farms fail to meet minimum cereal needs after accounting for sales, in-kind production payments, and purchases), land ownership patterns differentiate farms in terms of net cereal availability. Households meeting the 214 kg/capita benchmark for food security have more total land, more land per capita, and more irrigated land—both improved and unimproved. A similar pattern differentiates net sellers (those who sell more cereals than they purchase) from all other farms. Net sellers have access to 3.4 hectares of improved irrigation land and 0.7 hectares of the less productive *hors casiers* land while other farmers (net buyers and autarkic households) have access to only 0.9 hectares of improved irrigation and 0.43 ha of *hors casiers* land, suggesting that access to irrigated land may be an important determinant of whether one becomes a net seller.

Multivariate analyses of the Macina data base identify the factors influencing rice yields and rice marketing decisions. The principal observable determinants of rice yield in Macina include nitrogen, the amount of hired transplanting labor per hectare, and reported household-level production problems such as poor water control. As expected, nitrogen has a strong, significant, and positive effect on rice yield. At the mean level of nitrogen use in the sample (79.6 kg of nitrogen/ha), an additional kg of nitrogen/ha increases rice yield by 11.3 kg/ha. Given prevailing price relationships, the value cost ratio for this response would have been 2.3 in 2008 and 2.2 in 2009.

While the mean/median quantity of nitrogen applied to rice increased slightly from 2008 to 2009, the yield benefits from nitrogen appear to have been more than offset by various reported household-specific production problems, which have large and significant negative effects on rice yields. For example, problems with water control reduced yield by 477 kg/ha, late planting reduced yield by 356 kg/ha, and 'other' undefined problems reduced yield by 610 kg/ha. These findings help explain the decline in rainy season rice yields from 2008 to 2009, as we found a larger percentage of households reported problems with water control and 'other' problems in the latter year.

The marketing models revealed that the principal observable factors affecting the household quantity of rice sold were household rice production and the level and source of input credit that season. Because a principal factor explaining rice sales is rice production, it's not surprising that quantities of rice sold fell over time as production and yields fell. What is perhaps surprising from this analysis is that even after controlling for the amount of rice and coarse grains produced, the level of input credit, and demographic and wealth measures, variation in the household's rice sale price does not have a significant effect on the quantity sold. This suggests that either there is considerable heterogeneity of price responsiveness across different kinds of households or that household rice sales are simply not very responsive to changes in the rice price. Another hypothesis might be that the price responsiveness is linked to the production decision based on price expectations. The model eliminates quantifying this effect by using production as an explanatory variable. Because the ability of a farmer in the ON to change land area is limited, the main production response would probably be through more fertilizer to increase yields. Such a response was facilitated by the fertilizer subsidy that began in 2008/09, but there was little evidence of a substantial increase in fertilizer use and/or yields for sample households as a result of the fertilizer subsidy despite rising output prices. Analyses by cereal production groups also returned non-significant price coefficients for both the lower 1/3 and the upper 2/3rds of cereal producers, suggesting that the problem is not heterogeneity based on levels of cereal production.

There are a number of practical policy implications that flow from this study with respect to the government's goal of increasing marketed rice supply:

1) Because the study confirmed that increased fertilizer use can increase rice yields significantly, the GOM should be able increase marketable surpluses of rice by focusing its attention on improvements in fertilizer supply (particularly timeliness and reducing delivery costs), input credit, and better monitoring and evaluation of the costs and benefits of the input subsidy program for both farmers and private sector suppliers.
2) Efforts to increase fertilizer use are not likely to achieve significant increases in rice production or marketed supply unless they are accompanied by improvements in water control and other management practices to avoid the significant yield reductions reported in survey data. This implies a need to balance budgetary support for input subsidies and support for services that render those inputs more effective.
3) Although this paper did not address the contribution of other technical production issues (e.g., improved varieties, particularly for dry-season production; lower-cost approaches to fertilizer use; improved management practices to avoid soil acidification), continued benefits from fertilizer will be contingent on continued research and extension on these topics to ensure that fertilizer is being used as efficiently as possible and not having negative impacts on soil quality.
4) Roughly one third of ON farms are unable to provide for their own minimum cereal needs of 214 kg/capita after paying for production costs; this is not a sustainable situation and appears to be more of a problem for small farms than for large farms, suggesting that more attention needs to be given to policies concerning access to irrigated land for family farms and/or increasing opportunities for income diversification through off-farm employment that does not compete with farm demands for labor.
5) OPAMs role in rice marketing since the beginning of the IR has been unpredictable and not very helpful to rice producers; the GOM needs to reconsider its policy of OPAM intervention in rice markets, making it more transparent and predictable; reliable funding must be part of the picture or marketing is better left entirely to the private sector.
6) Although more research is needed to better understand farmers' production and marketing responsiveness to output prices, the survey results suggest that factors such as production costs and credit repayment scheduling (particularly fertilizer and water payments) may be more important influences on production levels and marketing behavior than output prices.
7) Mali is far behind many other African countries in its ability to systematically monitor and analyze the performance of its agricultural sector through the use of longitudinal data bases. Despite the many caveats mentioned about the panel data underlying the analyses presented in this paper, the data set is unique in its coverage of both production and marketing information for the same set of farms over the span of three years. There is a need for the GOM to invest in Mali's capacity to collect and analyze longitudinal data on the agricultural sector at a scale that is large enough to obtain representative results for at least the main production zones of the country; to date these types of investments have been made by donors and have not endured.

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LIST OF ACRONYMS

AE	Adult equivalent
AFRE	Department of Agricultural, Food, and Resource Economics, Michigan State University
APE	Average partial effects
BMGF	Bill and Melinda Gates Foundation
CIRAD	A French research institute; CIRAD collaborated on the collection and analysis of the first year of the farm survey data *(Centre de coopération internationale en recherche agronomique pour le développement)*
CRE	Correlated random effects
DAP	Diammonium phosphate fertilizer
EAC	Agricultural Survey *(Enquête Agricole de Conjoncture*)
ECOFIL	IER's agricultural subsector research division (*Programme d'économie de filières)*
FCFA	Currency managed by the *Banque Centrale des Etats de l'Afrique de l'Ouest* (BCEAO) for the WAEMU (UEMOA) monetary union to which Mali belongs
FE	Fixed effects estimation procedure
FSG	Food Security Group in the Department of Agricultural, Food, and Resource Economics at Michigan State University
GISAMA	Guiding Investments in Sustainable Markets in Africa—a project funded by BMGF and implemented by the FSG
GOM	Government of Mali
HH	Household
IER	Mali's national agricultural research institute (*Institut d'Economie Rurale*)
IR	Mali's input subsidy program; it started in 2008 (*Initiative Riz*)
MSU	Michigan State University
MT	Metric ton
MVCR	Marginal value cost ratio
NGO	Non-governmental organization
OLS	Ordinary least squares multivariate regression
OMA	Mali's market information system (*Observatoire du Marché Agricole*)
ON	Mali's largest irrigation system located in the Ségou Region (*Office du Niger*)
OPAM	Mali's cereal marketing board (*Office des produits agricoles du Mali*)
PA	Producer association
PROMISAM	FSG Food Security Project in Mali funded by USAID, (*Projet de Mobilisation des Initiatives en Matière de Sécurité Alimentaire au Mali***)**
RS	RuralStruc, a World Bank research program which provided the first year of our panel data set for Mali
SSA	Sub-Saharan Africa
TDY	Temporary duty assignment
USAID	United States Agency for International Development
VAT	Value added tax

1. INTRODUCTION

Governments in Sub-Saharan Africa are widely viewed as bearing responsibility for ensuring their citizens' access to food (Bratton and Mattes 2003). Food prices and availability are therefore highly politicized issues in much of SSA. Given this context, many African governments responded to the dramatic increases in international and domestic grain prices of 2008 and 2009 through a mixture of trade policy changes and input/output market subsidies. In the case of Mali, the Government put in place a rice promotion program at the beginning of the 2008/09 production season. The program, called *Initiative Riz* (Rice Initiative), made subsidized fertilizer available to rice producers nationwide with a particular focus on farmers in the *Office du Niger,* where roughly 50% of Mali's rice is produced. The goal of the program was to increase domestic rice production by 50% over the 2007/08 level, thereby increasing marketable surpluses and putting downward pressure on cereal prices. The program called for 1.62 million tons of paddy production that would increase the marketable surplus to 1 million tons, of which 900,000 tons would be marketed domestically and 100,000 tons would be available for export to neighboring countries (*Bureau du Vérificateur Général* 2009).

Whether the program met its production goals is unclear because of conflicting numbers reported by two different Ministry of Agriculture sources. The *Enquête Agricole de Conjoncture* (EAC), the usual source of survey-based production statistics, reported a total paddy harvest in 2008/09 of 1,304,618 tons while the *Bilan de la champagne 2008/09,* which usually reports EAC statistics, chose to do their own estimates in 2008/09 and reported 1,607,647 tons. While both estimates are higher than the 1,080,000 tons produced in 2007/08, the EAC estimate suggests that the *Initiative Riz* (IR) fell about 300,000 tons short of its goal while the second estimate approximates the goal (*Bureau du Vérificateur Général* 2009).What is not disputed is that rice prices did not fall as much as anticipated, with the government and other observers suggesting that rice producers were 'hoarding' their production to take advantage of the higher price environment– i.e., they held onto more of their annual production than usual.

This paper aims to inform the debate about farmers' response to the IR and rising rice prices through empirical analysis of household survey data of crop production and marketing that permits comparison of farmers' behavior before (2006/07) and after the price spikes and the introduction of the IR (2008/09 and 2009/10). The survey includes production and sales data for both the rainy and dry seasons during the three agricultural production cycles mentioned above as well as a wealth of demographic, asset, and non-farm income data. We use descriptive and econometric analysis of this data to investigate the following research questions:

1. When did cereal prices begin to rise in Macina markets, and to what extent did they increase?
2. How did farmers respond to rising cereal prices and the IR with respect to their area cultivated to rice and coarse grains?
3. How did rising cereal prices and/or the IR affect fertilizer use?
4. Did the IR and higher expected cereal prices lead to higher yields and more aggregate rice production, as anticipated by the GOM? If not, does econometric analysis of the observable determinants of rice yields explain why?
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For each of these questions, we test for differences in response by different types of farm households. Although the focus is on how responses are shaped by farm size (access to more or less irrigated land) and the quality of irrigation (full or partial water control), we also look at the role of other factors such as demographic characteristics and ownership of assets (e.g., durable goods and agricultural equipment).

The paper proceeds as follows: we provide some background on the study zone in Section 2 and then describe the data base in Section 3. In Section 4, we discuss the methods of analysis, and then present descriptive analysis in Section 5. We present results from econometric analysis of the household determinants of rice yields in Section 6, followed by econometric analysis of rice sales (both the quantity of rice sold and the percentage of total household production sold) in Section 7. Finally, we present conclusions and policy implications in Section 8.

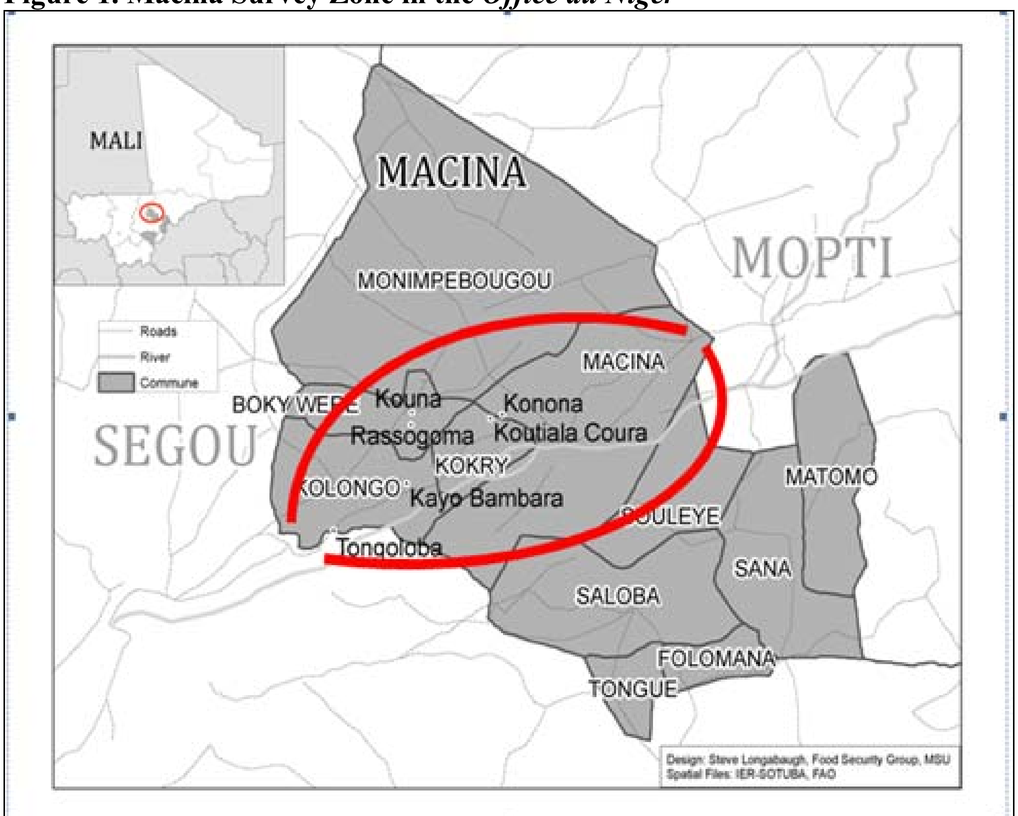
2. THE STUDY ZONE AND SAMPLE VILLAGES

The study zone is located in the Macina *Cercle* of the Segou Region of Mali (Figure 1).

The *Cercle* of Macina (grey area of the Figure) covers 11,750 square kilometers in the Sahelo Sudanian agroecological zone where rainfall is low (350-600 mm/year). Millet-cowpea intercrops and nomadic grazing predominate in this zone. However, the study sample is limited to a small part of the Macina *Cercle* that is located along the left bank of the Niger River in the *Office du Niger* (red circle in Figure 1), an area with a gravity-fed irrigation system constructed during the colonial period. Since independence, the ON has received a variety of farmer support programs (research, credit, extension, and capacity building for producer organizations). Farmers in the *ON* grow primarily irrigated rice during the rainy season and horticultural crops (e.g., onions and tomatoes) along with some rice (water permitting) during the dry season.

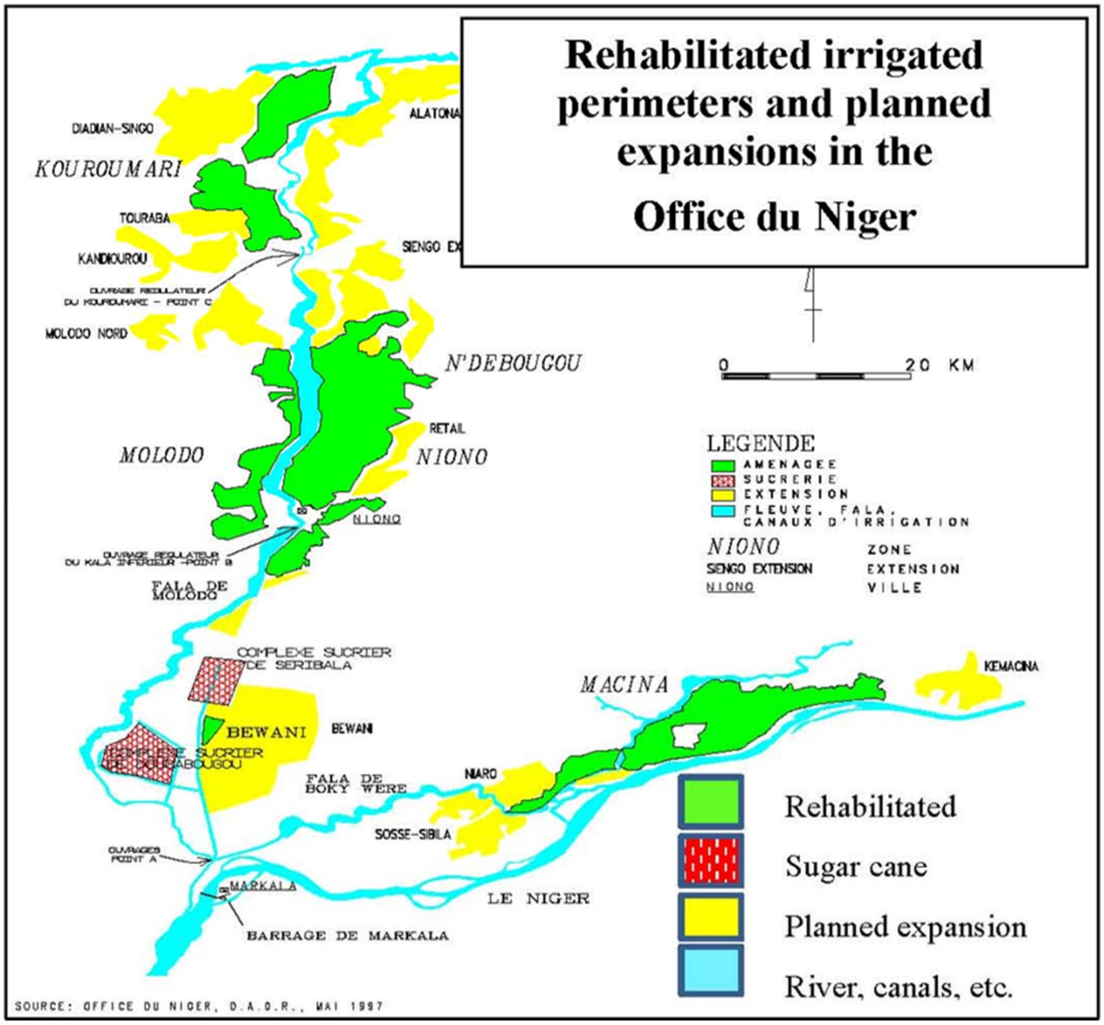
The *Office du Niger* portion of the *Cercle* of Macina comprises 17,500 irrigated hectares, representing roughly 1.5% of the *Cercle* of Macina's land area. Most of the irrigation infrastructure (13,000 ha) was developed prior to the 1980s (primarily during the colonial period); the remaining 4,500 ha have been developed since 2000. The Macina sector represents roughly one quarter of the irrigated land *already* developed in the ON (see Figure 2).

Figure 1. Macina Survey Zone in the *Office du Niger*



Source: Map prepared by Steve Longabaugh, MSU.
Note: Survey villages are shown in small black type within the red oval.

Figure 2. Map of the *Office du Niger* Irrigated Perimeters, Actual and Planned: 1997

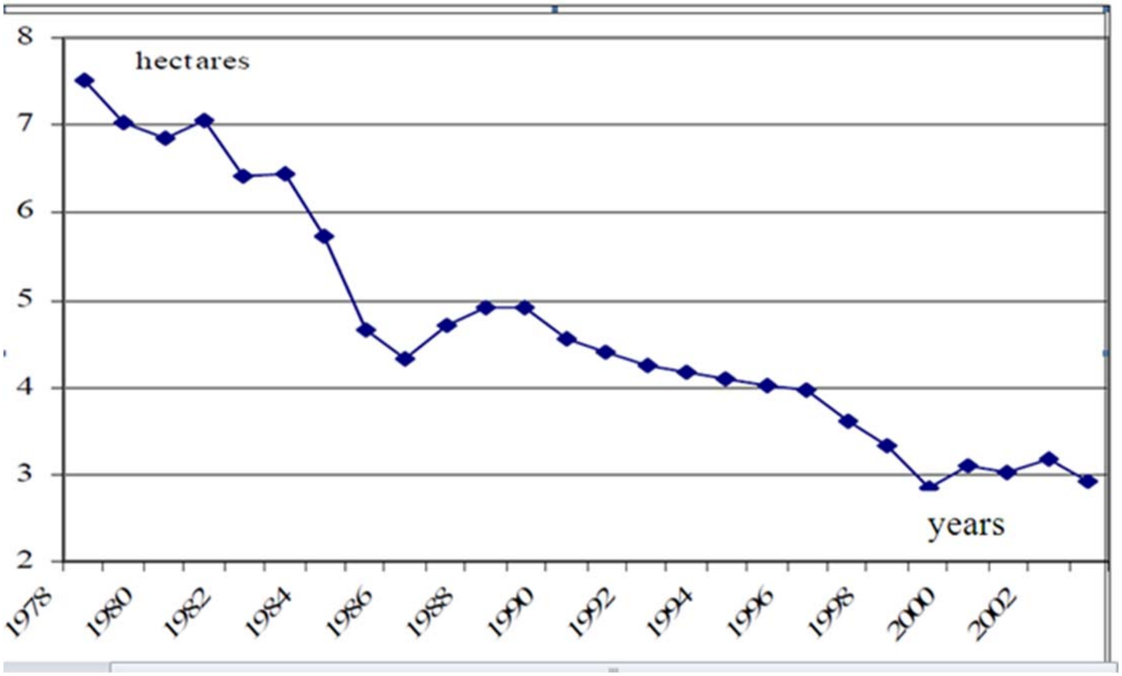


Source: *Office du Niger* 1997.
Note: Much of the area planned for expansion in 1997 (yellow on the map) has already been developed.

The main cereal cropping season in the *Office du Niger* starts in May/June just before the beginning of the rainy season with both the rice and coarse grain harvests taking place from late September through November. Farmers planting a second (dry season) crop of rice usually aim to plant in December and harvest in late March or April. Horticultural crops can be grown year-round, but are concentrated in the dry season. The rainfed land and much of the irrigated land is not used for the second (dry) season crop because of inadequate water supply.

Access to irrigated land throughout the ON is a growing problem. Families who were originally allocated five to eight hectares have had to subdivide that land among their children. Also, improvements in the irrigation infrastructure over time led to significant yield increases that prompted the ON to assign less land per active adult than previously on the assumption that farmers would be able to earn higher incomes with less land.

Figure 3. Declining Farm Size in the Office du Niger: 1978 to 2003



Source: Kébé et al. 2005, using official ON statistics from annual reports.

Figure 3 illustrates these trends in access to irrigated land in the Office du Niger. The combined effect of these two changes is that the average farm size (now less than three ha) is considered too small to support an average family of roughly 10 people (Bélières et al. 2003).

With these growing land constraints in mind, the six villages in the Macina sample were purposively selected in order to represent two different types of land access in the ON—three villages represent farms located in the center of the irrigation perimeters and three represent farms located at the edges. Villages located in the center (referred to as *casiers villages*) cultivate rice primarily on land with fully controlled irrigation and are generally able to grow a dry season rice crop on at least some of their irrigated land. Most farmers in these *casiers* villages do not have access to land for rainfed production; they also have limited access to pasture land. The farmers located in the three villages on the edges of the irrigated zone (referred to as the *bord de casiers villages*) cultivate rice on a combination of irrigated plots with full water control (*casiers)* and partial water control *(hors casiers),* with the *hors casiers* plots dominating.

Irrigated plots supporting a dry season crop exist in the *bord de casiers* villages, but are much less common than in the *casiers*. This second group of villages also has access to rainfed plots, where farmers cultivate millet, and to pasture land for their animals. The villages in the *bord de casierss* also tend to have more difficult access problems (poorer quality roads, often cut off during the rainy season) than the *casiers* villages. The 50-50 split in the sample between these two types of villages is expected to provide adequate observations on each type of farm to permit analysis of the tradeoffs between better access to fully controlled irrigation coupled with few alternatives for other types of agricultural production versus poorer access to high quality irrigation coupled with greater opportunities for diversification through rainfed crop production and animal husbandry.

Given the purposive nature of the village selection, we cannot conclude that the sample is representative of the Macina sector in the ON. Although there are no official ON statistics on the share of households located in the *casiers* and *bord de casiers* areas, results from a 2000 survey considered to be representative of the ON in general suggest that the 50-50 split of our sample most likely over-represents the *bord de casiers* farms. The 2000 survey (Bélières et al. 2003) found that the area cultivated in the Macina zone was 22% rainfed and 77% irrigated (of which 95% *casiers* and 5% *hors casiers* fields). The data set we are working with has 36% of the land rainfed and 63% irrigated (of which 84% *casiers* and 16% *hors casiers*). While growing land constraints in the ON would support a decline in the *casiers* area relative to the *hors casiers* and rainfed areas from the early to the late 2000s, the *bord de casiers* farms are most likely over-represented in the data.

Because of the importance of understanding the different responses of *casiers* and *bord de casiers* farms, we disaggregate the descriptive analysis of rice production and input use by village types (*casiers* and *bord de casiers)* and use dummy variables in the regression analysis to separate out the effects of living in a *casiers* versus a *hors casiers* village or cultivating a *casiers* versus *hors casiers* plot. Although we do discuss results for the overall sample, we do not focus on these results because of the likely over-representation of the *bord de casiers* farms.[2]

[2] Because the overall sample statistics for the shares of different types of irrigated land are not radically different from the 2000 survey results for the ON in general (88% *casiers* and 12% *hors casiers*), it is possible that the overall sample results may better approximate the general situation in the ON than the situation in the Macina sector, but we prefer to focus on the statistics for each subset of villages rather than interpreting the overall sample results as representative of either the Macina sector or the ON in general.

3. DATA

This analysis uses the Macina zone subset of household survey data that was collected by a consortium of three institutions: IER (Institut d'Economie Rurale du Mali), CIRAD (Centre de coopération internationale en recherche agronomique pour le développement) and Michigan State University. The panel data covers three cropping seasons (2006/07, 2008/09 and 2009/10), with a gap between the first and second year (2007/08 was not covered). The first year of data was collected as part of the World Bank RuralStruc research program on the structural transformation of seven economies at different stages of development (Mali, Kenya, Senegal, Madagascar, Morocco, Nicaragua, and Mexico).[3] Consequently, the survey design and approach to data analysis is strongly influenced by rules initially set up to ensure cross-country comparability for the RuralStruc study. Household attrition from the sample in the second two survey years was very small; of the 151 Macina households successfully interviewed in 2006/07, 149 were re-interviewed in 2008/09, and 150 were re-interviewed in 2009/10.

The primary sampling unit is the family farm enterprise, which is defined as a group of individuals who are engaged in common/joint production and consumption activities implemented under the direction of a single patriarch who makes the major production and consumption decisions for the entire group and manages the group's assets (e.g., land, labor resources and agricultural equipment) and finances. A family farm enterprise can be a single nuclear family unit or it can be multiple nuclear families (e.g., a father plus all of his unmarried children and all of his married sons and their families). Nuclear family units account for 42% of the Macina sample, while 23% is comprised of two nuclear units, 21% of three, and the remaining 13% of four or more. Household sizes range from 2 to 51 individuals. The word "household" in this report should be understood as shorthand for the concept of the family farm enterprise just defined.

Households were interviewed once during the first two survey years and twice during the last year. Because using a yearlong recall for the first two years resulted in very long interviews and respondent fatigue, the questionnaire was divided into two sections for the last year with most of the questions about agricultural production for the rainy season covered in the first interview and questions about dry season agriculture, livestock, and non-farm income covered in the second interview. The data set contains the following categories of information:

- Household demographics: age, gender, education, marital status, and whether the person was economically active or not; economically active was defined as participation in productive activities such as crop production, animal husbandry, and nonfarm activities, but excluding housekeeping tasks conducted for one's own family;
- Household assets: ownership of or ensured access to farm land and other real estate; ownership of agricultural equipment, livestock, vehicles, selected household durable goods and indicators of the quality of housing;
- Crop production (cultivated area and production by plot, input use by crop for 2008/09 and 2009/10 (combining all plots of the same crop) and input use by

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[3] http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/0,,contentMDK:21079721~pagePK:146736~piPK:146830~theSitePK:258644,00.html

household (combining all plots regardless of crop) for 2006/07; farmers' qualitative assessments of their yields and reasons for good/bad yields;
- Tree crop ownership, production costs, and sales;
- Crop sales (quantities and receipts from all sales by crop);
- Livestock sales, purchases, deaths/losses, births;
- Qualitative questions about the household's food security and well-being asked independently of both the household head and spouse (2006/07 only) and some indicators of levels and adequacy of household cereal consumption (all years); and
- Non-farm income (enumeration of net incomes from different activities; some reported at the household level (e.g., agricultural labor and migration remittances) and others attributed to individual members of the household.

Table 1 presents summary statistics on the demographic characteristics and assets of sample households, with a breakdown by the household's location in either the *casiers* or the *bord de casiers* areas.

Table 1. Household Characteristics of Macina Sample, 2008/09

Household characteristic	HHs in *Casiers*	HHs in *Bord du Casiers*	All HHs	HHs in *Casiers*	HHs in *Bord du Casiers*	All HHs
Physical productive assets	-------- mean --------			-------- median --------		
Total landholding, irrigated (ha)	3.96	3.41	3.68	3.25	2.90	3.00
Total landholding, rainfed (ha)	0.20	3.97	2.14	0.00	3.00	0.20
Total landholding/AE, irrigated (ha/A	0.35	0.31	0.33	0.29	0.28	0.28
Total landholding/AE, rainfed (ha/AE	0.03	0.39	0.21	0.00	0.31	0.02
HH owns animal traction eq/animal (%	72.9	89.2	81.3			
Tropical Livestock Units (TLU)	9.0	5.0	7.0	4.82	2.32	3.62
Demographics & welfare						
HH size	14.3	13.6	13.93	13.00	11.50	12.00
HH size (adult equivalents)	11.8	11.1	11.44	10.68	9.83	10.43
Head's education level (years)	1.5	0.6	1.03	0.00	0.00	0.00
HH has individual in producer org (%	62.8	56.7	59.7			
HH has individual in coop (%)	2.8	14.9	9.0			
HH durables index (range 0 to 2.5)	1.19	1.02	1.11	1.23	1.09	1.19
Shares of total HH income by source						
Crop production (retained + sales)	80.4	81.5	80.9			
Livestock sales and products	1.4	0.5	0.9			
Ag wage income	1.8	2.7	2.3			
Non-farm wage income	1.6	1.4	1.5			
Own business income	12.3	9.9	11.0			
Remittances/pensions	2.6	4.1	3.4			
% of households in sample	47.3	52.7	100.0			
Cases	70	74	148			

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.

We note that *casiers* households have a half hectare more of irrigated land per farm, but this translates to only 0.04 of a hectare more per AE because *casiers* farms have slightly larger family sizes. Rainfed land is much more common for the *bord de casiers* farms, which have 0.39 hectares per AE compared to only 0.03 hectares in the *casiers*. *Casiers* farms own less agricultural equipment, which makes sense because they cultivate less total area, and tend to be members of producer associations (63% versus only 56% in the *bord de casiers*). *Bord de casiers* farmers, however, tend to favor cooperatives more than the *casiers* farmers (15% are members versus only 3% in the *casiers*). *Casiers* households own more livestock and earn a larger share of their income from livestock than the *bord de casiers* farmers. The livestock results were surprising given more limited access to pasture land in the *casiers*. The *bords de casiers* farmers have a larger share of income from agricultural wages and from remittances than the *casiers* farmers, but a smaller share of income coming from non-farm wages and self-employment.

We also draw on results from focus group interviews as well as market price data from Mali's national market information service (OMA).

4. METHODS

4.1. Descriptive Analysis

We begin the descriptive analyses with a discussion of the overall policy and price environment of relevance to sample farmers during the survey period. We then use monthly market data on cereal prices in the Macina market (a major assembly market serving the zone) to investigate price levels and seasonality and to establish when cereal prices began to rise in the survey zone. This is supplemented by a descriptive analysis of the Macina household survey data from 2006/07, 2008/09 and 2009/10 to investigate the extent to which household cropping decisions, fertilizer use, and cereal production and sales responded to both increases in domestic rice prices and the availability of subsidized fertilizer via the Initiative Riz (which began in 2008/09).

4.2. Modeling Rice Yields

We conduct two separate analyses of rainy season rice yields differentiated by the level of the data used (household vs. plot) and the time periods covered. The first yield model examines total paddy production per hectare at the household level using the 2008/09 and 2009/2010 rainy season data, where each household is represented in the model by one observation per year. The second yield model examines paddy production per hectare at the plot level using only 2009/10 data, where each household is represented in the data base by one observation for each rice field cultivated during the rainy season of 2009/10 (number of plots ranges from 1 to 7).

4.2.1. Model Specification: Household- and Plot-level Analyses

Although a plot level analysis is the preferred approach for understanding the determinants of rice yields, rice input data for 2008/09 was collected at the household/farm rather than the plot level, forcing us to use a household approach when combining the two years of data. The plot level model uses only the 2009/10 data because that was the only year for which plot-level input data were collected. The 2006/07 data is not used in these models because we were unable to separate inputs used for rice from inputs used for other crops (the RS questionnaire asked a single question about total household agricultural input use).

We restrict the analysis to yield observations from the rainy season given that this is the principal season for rice production in the ON, and because nearly every household in the sample grew rainy season rice in both years. By contrast, only about half of Macina households grew rice in the dry season. We use a quadratic functional form for both rice yield functions because it allows for concavity and diminishing returns and is a good first order approximation to many functional forms.

As one of the key factors expected to affect rice yields is fertilizer use, we include the quantity of nitrogen (kgs) applied per hectare of rice in the rainy season as an explanatory variable. We also include its square to control for diminishing marginal returns to fertilizer use. In addition, we include the number of carts of manure applied per hectare as well as its square. While nearly all rice-growing households apply at least some inorganic fertilizer to their rice, only about one-third also apply manure. As a measure of the household's timely access to land preparation equipment, we include the household's equipment index.

We include the number of adults in the household between 15 and 59 years of age per hectare of rice cultivated in the rainy season as a proxy for available family labor, as well as its square. Transplanting is both a highly labor-intensive and time-sensitive task and nearly 90% of our sample hired transplanting labor each year. We, therefore, include the log of the total cost per hectare paid by the household for hired transplanting labor, anticipating that household use of hired transplanting labor may have positive effects on rice yields. We also include the square of this variable to control for diminishing marginal returns to hired labor costs.

To control for differences in irrigated field quality for the household-level model, we include a binary variable equal to one if the household grew rice that year on one or more fields defined as *hors casiers*. For the plot level model, a binary variable equal to one identifies each *hors casiers* field. Because farmers pay higher water fees for better quality *casiers* fields, we would expect fields defined as *hors casiers* would have lower yields, after controlling for other observable factors.

We also include binary variables that equal one if the household reported a specific problem that reduced their rice yields in a particular year. For example, one binary variable is for water control problems (flooding or poor water control), another for late planting, and a third for other problems. For the household model any occurrence of a problem results in the binary variable for that problem being set to one; for the plot level model, each plot with a problem is assigned a binary variable equal to one.

We also include a variable that measures the household's total irrigated area per adult equivalent (AE)[4] (excluding land which is rented or gifted in). There are two hypotheses about the anticipated sign for this variable. Although crop productivity research from developing countries has often found a negative relationship between farm size and yields, based on the premise that smaller farms tend to achieve higher production levels per hectare than larger ones (see Heltberg (1998) for a recent review), previous studies of rice production in the ON (Bélières et al. 2011) have found that households with lower land area per capita are unable to meet their consumption needs via agriculture alone and are therefore more likely to have household members working off the farm at critical labor demand times—a practice that will negatively affect yields unless the household has surplus labor. If the latter effect is stronger than the former one, we may find that yields increase as land per adult equivalent increases.

Finally, for the household model we include a binary variable equal to one for the 2009/2010 production season. This dummy variable controls for the average effect on yields of any other unobserved factors that may have changed from 2008 to 2009.

4.2.2. Estimation Issues: Household-level Rice Yield Model

The panel nature of the household survey data offers the analytical advantage of enabling us to control for time-constant unobservable household characteristics. If these types of characteristics (e.g., farm management ability, unmeasured land/soil quality, etc.), are correlated with observable determinants of household rice yields, this can lead to biased estimation of the effects of variables included in the model to the extent that they are

[4] Adult equivalent is a measure that adjusts the size of a household to reflect its caloric consumption needs based on the age and gender or each individual in the household (WHO 1985).

correlated with the unobservables (Wooldridge (2002) refers to this as omitted variable bias). The Fixed Effects estimator is usually the most practical way to accomplish this, since doing so requires no assumption regarding the correlation between observable determinants and unobservable heterogeneity, and the availability of two years of panel data on household rice yields enables us to estimate a rice yield function using OLS with household fixed effects (FE). However, because the FE estimator essentially drops explanatory variables that remain constant over time, it does not provide partial effect estimates for these constant (or nearly constant) variables. Thus, while the household FE *controls* for land quality across households, it does not enable us to estimate the partial effect of land quality itself on rice yields, as our land type binary variable is nearly constant over time for most households in our sample.

In order to measure the partial effect of land quality on rice yields (while still using two years of data), we also present results from a pooled OLS regression which includes correlated random effects (CRE) terms (Mundlak 1978; Chamberlain 1984). The inclusion of CRE terms explicitly accounts for unobserved heterogeneity and its correlation with observables (contingent on the assumption below), while yielding a fixed-effects-like interpretation. In contrast to traditional random effects, the correlated random effects (CRE) estimator allows for correlation between unobserved heterogeneity (c_i) and the vector of explanatory variables across all time periods (X_{it}) by assuming that the correlation takes the form of:

$c_i = \tau + X_i\text{-}bar\xi + a_i$, where

$X_i\text{-}bar$ is the time-average of X_{it}, with $t = 1, \ldots, 3$

τ and ξ are constants, and

a_i is the error term with a normal distribution, $a_i \mid Xi \sim$ Normal(0, σ^2_a).

We estimate a reduced form of the model in which τ is absorbed into the intercept term and $X_i\text{-}bar$ are added to the set of explanatory variables. CRE essentially involves including the time-average of each time-varying regressor as an additional explanatory variable. Under the assumption that the CRE terms are correlated with any unobserved, time-constant household-level factors, inclusion of the CRE terms will control for such unobserved factors that otherwise might bias our partial effects estimates. One advantage of CRE is that it enables us to include explanatory variables that are time-constant, such as our binary measures of land quality.

4.2.3. Estimation Issues: Plot-level Rice Yield Analysis

Our plot-level model includes observations of plot-level paddy yields for the 2009 rainy season and plot-level measures of all of the explanatory variables noted above. We estimate the plot-level yield function using first OLS with household fixed effects (FE) and then pooled OLS with CRE. The latter approach permits us to estimate partial effects of household- or village-level explanatory variables that are constant over time. There are various reasons why plot-level data is preferable to household-level data for investigation of the determinants of rice yield. For example, the data on field irrigation quality is plot-level, quite a few households have fields of more than one quality type, and levels of input use on rice for a given household may vary by field quality. The disadvantage of using the plot-level data is that it is available for only one year (2009/10).

We, therefore, face several trade-offs between using household versus plot-level data on rice yields. Using household-level data enables us to use FE (the best option for controlling for potential omitted variable bias) and to investigate why rainy season rice yields fell dramatically from 2008 to 2009. On the other hand, the plot-level data from 2009 enables us to better measure the effect of field type and levels of input use on rice yields.

4.3. Modeling Rice Sales

4.3.1. Data Issues: Survey Round Comparability for Sales Data

While most rice sales in the ON occur during in the months of February and March for rainy season production, and then in June and July for the dry season production, some farmers do stock rainy season rice and continue to sell it after the next rainy season begins in June. Because of the timing of the RuralStruc survey, which was administered 17 months after the 2006 rainy season harvest began, and the manner in which the sales question was asked, the RS survey should have captured all rice sales from the 2006/07 rainy and dry season harvests sold up through the lean season (July-September 2007) and may also have captured some sales of carry-over stocks from 2005/06. By contrast, the surveys that covered the marketing of crop production from 2008/09 and 2009/10 do not include sales of carry-over stocks from a prior season and, because the interviews were conducted in July, do not include any sales that might have been made during the lean season but after the interview date.

The impact of this discrepancy on the analyses depends upon how long Macina households hold onto their rice before selling it, particularly (1) whether there are substantial sales during the lean season that were captured in 2006/07 but missed in subsequent years and (2) whether there were substantial sales from prior year carryover stocks reported for 2006/07 but not for other years. Fortunately, the RS survey included information on the timing of each sale using the following four categories1) *A la récolte* (at harvest); 2) *Début de campagne* (at the beginning of the campaign); 3) *A la soudure* (during the hungry season); and 4) other. According to our understanding of the zone, *à la soudure* refers to the period between planting and harvest of the rainy season crop (July-September). This information permits us to isolate the hungry season sales for 2006/07 from the other sales and make the three surveys roughly comparable with respect to the time period covered. The issue of whether 2006/07 might include carry-over stocks from 2005/06 could not be fully resolved. However, information collected about sales of carry-over stocks from 2007/08 during the 2008/09 production season revealed that only four households sold carry-over stocks from 2007/08 during 2008/09, and that these sales accounted for an average of only 4% of total rice sales for those four households in 2008/09. This evidence leads us to conclude that any reporting of sales from carry-over stocks captured in the 2006/07 data is not likely to influence the overall results.[5]

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[5] However, we note behavior regarding carry-in stocks from 2007/08 sold in 2008/09 may not be representative of such behavior in other years. For example, it is possible that the reason we found very few sales of carry-in stocks in 2008 is because households chose to hold on to larger quantities of cereals during this period because of the unusually large increase in rice prices that began in late 2007.

4.3.2. Conceptual Framework for Modeling Household Rice Sales

As in other developing countries, rice producers in the ON are semi-subsistence in nature as an important share of their production is used to meet household consumption needs. The agricultural household models pioneered by Singh, Squire, and Strauss (1986) are designed to provide a theoretical framework to describe the interaction between a household's production and consumption decisions, in the context of a subsistence or semi-subsistence family farm. One of the more basic household models assumes that if semi-subsistence households have access to local markets, then it is also reasonable to assume that they make production and consumption decisions recursively – not simultaneously. That is, household rice production is a function of expected market prices, input use or prices, household productive assets, and agroecological factors, while household rice consumption is a function of the income derived from crop production and other sources as well as post-harvest prices of rice and other commodities. Thus, in a recursive agricultural household model, consumption depends on production, but production does not depend on consumption.

The conditions for a recursive model include: the existence of local input and output markets; a situation where rice producers are price takers in those markets; a relatively fixed land base; and a situation where farmers sell surplus rice production. Because these conditions are met in the Macina context, we use a recursive approach to investigating household rice sales behavior. Following work by Buschena, Smith, and Di (2005), Carter and Zhong (1999), and Saha and Stroud (1994), we model the determinants of household rice sales in Macina assuming that the sales decision is made after production from the main harvest is realized. Using a two-step approach we first investigate rice productivity and household rice production using both descriptive and econometric analysis. We then model the determinants of household rice sale quantities, where household rice production serves as an explanatory factor along with prices, household wealth, etc.

4.3.3. Model Specification: Household Rice Sales

Dependent Variables: We use two different dependent variables in our econometric analysis of the determinants of household rice sales. The first is the quantity of rice sold per AE from harvest through June, for each of the three survey years. The second dependent variable is the percentage of annual rice production that is sold by June of each marketing year; this is computed as the quantity of rice sold by household *i* through June of marketing year *t*, divided by the annual quantity of rice production of household *i* (adjusted downward for in-kind payments for threshing). As noted in section 4.3.1. above, limiting the analysis to sales made by June of each year was necessary to ensure compatibility of the data set across survey rounds.

Explanatory Variables: The following eight categories of explanatory variables were used in the model:

- Rice and coarse grain production levels (standardized to production per AE);
- Demographic information (dependency ratio and education of the household head);
- Indicators of household assets (durable goods index, land);
- Indicators of income diversification outside of agriculture;
- Membership in producer associations;
- Geographic location (proxied by *casiers*/*bords de casiers* locations that reflect both proximity to markets and different access to land);

- Input use and costs (fertilizer, water fees, hired labor); and
- Household's average rice sales price (weighted by quantity sold).

A description of the data and hypotheses about the role played by each variable follows:

Rice Production: Following Buschena, Smith and Di (2005), we include as explanatory variables rice harvested per AE (in both rainy and dry seasons) as well as its square. We also include the quantity of other coarse grains harvested per AE (i.e., maize, millet, and/or sorghum, which are only produced during the rainy season).

Demography: Although our dependent variable and the cereal quantities harvested are in AE terms, we include the household's dependency ratio on the assumption that households with a greater ratio of dependent individuals will tend to sell less rice per AE as these dependent individuals are not likely bringing in cash or in-kind income to the household. We also include the education level of the household head on the assumption that more educated heads may be more likely to have better negotiating/marketing skills and thus sell more rice, controlling for other factors.

Assets: We use an index of durable goods owned by the household to serve as a proxy for household wealth. In order to avoid potential endogeneity issues due to interaction between sales and durable goods in any given year, we include the three-year household average of this durable goods index in our sales regressions. It is difficult to predict *a priori* if wealthier households will sell more rice (because they have the means to buy rice back later if needed) or if they will sell less rice because they are able to pay for their input costs and other necessities through non-rice sources of cash.

Income Diversification: We include a binary variable that equals one if the household has earned nonfarm salaried income consistently over the 3-year panel (and zero otherwise), as well as a binary variable that equals one if the household earned other regular nonfarm income over the 3-year panel (and zero otherwise). We include these variables on the assumption that households with alternative sources of cash income may sell less rice.

PA Membership: We also include a binary variable that equals one if anyone in the household was a member of a producer association in 2006/07 and another binary variable that equals one if anyone in the household belonged to a cooperative in2006/07. The assumption is that membership in such organizations facilitates market transactions for individual farmers and thus increases the quantity of rice they sell and theoretically the prices obtained for those sales.

Location: We include a binary variable that equals one for households located in villages with good market access, these villages happen to be the three villages in the *casiers*. Because we are controlling separately for the household's harvested quantity of rice per AE, this dummy variable should be picking up the market access character of the *casiers* and not its productivity advantages. Since our rice price variable is the household's weighted average sale price, it is questionable whether this 'good market access' dummy variable will have a significant positive effect on rice sales, given that our household sale price variable likely captures the price advantage faced by households in the *casiers* (due to lower transport costs for traders as they move rice from their purchase point to the assembly market). The market access dummy may, however, pick up the effect of farmer-incurred transport and other transaction costs associated with getting the rice to a local market—these costs are expected to be higher in the *bord de casiers* villages.

Production Costs: Because rice production entails considerable costs in terms of labor, fertilizer and other expenses such as water fees, every household will likely make some rice sales to repay these input costs, either in cash or in-kind. We, therefore, include the following variables to measure the effects of different kinds of production costs on rice sales: hired transplanting labor, water fees paid to the ON and fertilizer loans, all represented in natural logs. We include the hired labor cost for transplanting as this is the task most frequently involving hired labor, even for smaller farmers who rely primarily on family labor. For services paid in cash, such as transplanting labor and water fees, we expect that the level of these inputs will have a positive effect on sales quantities. The case of fertilizer is more complicated, as a previous ON study suggests that some loans are repaid in-kind (such as to producer associations) while others may be paid in cash. We, therefore, create separate fertilizer loan value variables by source: those owed to producer organization, those to input dealers, and those to the ON (we leave out loans received from other groups, such as NGOs). Loans that are repaid in-kind would likely have a negative effect on sales quantities, while those repaid in cash would have a positive effect.

We also include a binary variable that equals one if the household hired any seasonal labor paid partially in kind via the provision of food and lodging; and another that is equal to one if the household provided food and lodging to any labor hired for the whole year. It is difficult to assume *a priori* how hiring such guest workers will affect household rice sale quantities. On one hand, if households provide rice to such guest workers as food, then hiring such a worker would tend to reduce quantities of rice sold. On the other hand, given that coarse grains are a cheaper calorie source, households that hire such guest workers may actually sell more rice in order to purchase coarse grains with which they feed their guest worker.

Rice Sale Prices: We include the household's average weighted sale price of rice, which is computed as the household's total revenue from rice sales divided by its total sales volume (using all household rice sale observations from September through June). For households that did not make a rice sale, we use the village average sale price. Because households sell at different times during the post-harvest period, using the household-specific (weighted) price should better capture the effect of changes in market prices on the household's quantity of rice sold through June. While the household sale price might be considered endogenous due to potential correlation with unobserved household-specific factors, we note that our use of the time-average of the household sale price as an additional regressor (details below in Section 4.3.4.) should enable us to estimate the partial effect of the time-varying component of the household price free of such potential bias.

4.3.4. Estimation Issues

Modeling Rice Sales as a Corner Solution: An econometric concern for modeling household rice sales is the fact that some rice-producing households do not sell rice (4 to 8% in our sample, depending on the year), thus the rice sales of such households is zero. Because the remainder of the distribution is quite large in magnitude, this dependent variable exhibits a rather large positive skew, which can create problems for standard ordinary least squares (OLS) regression. In this paper, we approach the statistical challenge posed by cases where rice sales equal zero not as a missing data problem (which is typically modeled using a variant of the Heckman two-step approach, as in Goetz (1992)), but rather as a corner solution dependent variable (modeled as a Tobit). The rationale for a corner solution model in this case is that a sales quantity of zero is a valid economic choice to be explained, not a reflection of missing data.

Controlling for Unobserved Heterogeneity: The panel nature of the household survey data offers the analytical advantage of enabling us to control for time-constant unobservable household characteristics. However, using a fixed effects (FE) estimator for a Tobit has been shown to be biased when T<5 (Greene 2004). We, therefore, estimate a Tobit of household rice sales that includes correlated random effects (CRE) terms. To facilitate interpretation of the Tobit results, we compute average partial effects[6] (APE) for each regressor.

While our second dependent variable, 'the percentage of household rice production that is sold by June', also has some cases lumped at zero, this distribution has a much lower positive skewness. We, therefore, estimate this model using OLS with household fixed effects (FE). However, use of FE causes any time-constant variables to drop out of the model, such as our binary variables indicating household non-farm income earning in 2006/07, the hiring of seasonal labor, household membership in producer associations or cooperatives, and the market access status of the village.

Panel Attrition: As noted in section 3, the re-interview rate in Macina was quite high (98% in 2009 and 2010) so we do not test for attrition bias in any of the analyses.

[6] Because the effect of an explanatory variable in a nonlinear equation depends on the level of all explanatory variables, not just its own coefficient, analysts sometimes compute the marginal effects for a given variable using the mean of all regressors. By contrast, we compute the partial effect for each household, and then take the average partial effect across the entire sample (or subsample), which is preferred by Wooldridge (2002) for the simple reason that the mean of any given regressor may not represent a 'typical' value among the sample households.

5. DESCRIPTIVE ANALYSIS

5.1. Price and Policy Environment

The key elements of the price and policy environment expected to affect ON rice production and sales decisions during the survey period are rising commodity prices (primarily for cereals and fertilizers) in both international and domestic markets and the policies put in place by the GOM to diminish the impact of those rising prices for both producers and consumers. We describe these price trends and policies below.

5.1.1. International Fertilizer and Cereal Prices

The rapid escalation in world market cereal prices in 2007 and 2008 was accompanied by an even larger increase in international fertilizer prices. We analyze these price increases by comparing 2007, 2008, and 2009 prices to a seven-year "base period average" covering 2000-2006. For example, the real prices of urea (Black Sea, f.o.b.) and diammonium phosphate (DAP) (U.S. Gulf port, f.o.b.) in 2007 were 80%% and 91% higher (respectively) than the average prices for the base period—an increase more than five times as large as the comparable increase of 23% in the international price of rice (Bangkok, f.o.b.) between 2007 and the base period (Table 2). Price increases for maize and wheat outstripped those for rice in 2007 (37% and 38%, respectively, compared to 23% for rice).

In 2008, international fertilizer prices surged even higher to an average level that was 166% to 296% higher than the base period—an increase that was one and a half to three times larger than the 2008 increase in the international rice price, which itself surged to a level 128% higher than the base year average. In 2008, maize and wheat price increases relative to the base period were lower than those for rice: 73% for maize and 45% for wheat.

Table 2. International Fertilizer and Grain Prices, 2000-2009

	DAP	Urea	Maize	Rice	Wheat
Price Year(s)	Annual average real price ($US per MT)				
7-year average (2000-2006)	$209	$159	$110	$244	$160
2007	$398	$285	$151	$301	$220
2008	$826	$421	$191	$555	$232
2009	$295	$228	$151	$508	$170
	% price increase relative to 2000-2006 average price				
2007	90.7%	79.8%	36.7%	23.4%	37.8%
2008	295.4%	165.5%	72.8%	127.9%	45.4%
2009	41.5%	44.0%	37.3%	108.3%	6.6%

Source: World Bank (www.worldbank.org/prospects/commodities)
Notes: DAP (diammonium phosphate), bulk, spot, f.o.b. US Gulf; Urea (bulk, spot, f.o.b. Black Sea); Maize (US no. 2, yellow, f.o.b. US Gulf port); Rice (Thai 5% broken white rice, milled, f.o.b. Bangkok; Wheat (US hard red winter no. 1, f.o.b.US Gulf port)

In 2009, international fertilizer prices declined somewhat. By this point, fertilizer price increases relative to the base period were actually a bit lower (42% to 44% above the base period average) than international rice price increases, which were 108% above the base year averages. Maize and wheat prices also continued to decline, settling at 37% and 7% above the base year averages.

5.1.2. GOM Policy Responses to Rising Prices

The GOM responded to rising cereal prices with a number of measures. First, rice imports were exonerated from all value added taxes (VAT—an 18% tax) and customs duties during the 2007/08 cereal marketing campaign. This was a stronger policy than that in place during the 2005/2006 production season when only the VAT was dropped. Surprisingly, the quantities imported under the 2007/08 exoneration were lower (only 5,504 MT) than tax exempt imports in 2005/06 (201,194 MT). These tax exemptions remained in effect through October 2009 with a total of 84,452 MT exempt in 2008 and 204,000 MT in 2009 (Traoré and Diarra 2010).

Other policy measures that targeted the coarse grain sector rather than the rice sector included:

- the continuation of the Cereal Bank program begun in 2005; and
- the imposition of administrative hurdles that made it more difficult for traders to obtain cereal export permits from December 2007 through the end of 2008.

The net impact of the export ban was to increase the transactions costs associated with exports. Some analysts argued, however, that the measures did contribute to a stabilization of coarse grain prices (Traoré and Diarra 2010). The cereal banks stocked decentralized warehouses with GOM supplied cereals (primarily coarse grains) that were sold in competition with private sector sales. The program was strongly promoted in zones of deficit cereal production. Quantities available were relatively small compared to the overall market and do not appear to have had much impact on market prices in general.

The most significant policy response by the GOM to the rising price of rice was the introduction of the *Initiative Riz* (IR) at the beginning of the 2008/09 production season. The IR was designed to stimulate a 50% increase in rice production over 2007/08 levels thereby ensuring a large marketable surplus that would help bring down consumer rice prices. The principal components of the program in 2008/09 were a fertilizer subsidy (see Box 1), a GOM guarantee for fertilizer credit offered to producer associations (many associations were in default and not eligible for bank credit without the guarantee), and an increase in GOM intervention in rice markets via OPAM so that the government could build up security stocks and keep prices from falling precipitously due to excess production. The program also included credit for purchases of agricultural equipment such as motorized cultivators (*moto-culteurs*) and rice mills.

The GOM expanded the IR fertilizer subsidy in 2009/10 to cover other crops (maize, millet, and sorghum) and continued the all-important rice sector support; but a lower than anticipated credit repayment rate for 2008/09 led the GOM to drop the credit guarantee for the 2009/10 campaign.

Box 1. Modalities for Purchasing Subsidized Fertilizer

The *Initiative Riz* offered 50-kg bags of top dressing (urea) and basal fertilizers (DAP or Niéléni, a local substitute for DAP) to farmers at a subsidized price of 12,500 FCFA/bag, the equivalent of 250 FCFA/kg. To obtain the subsidized price, a farmer needed to declare the area he expected to plant in rice to the local direction of agriculture. The local authority verified that the farmer had access to the declared area then issued a *caution technique* (CT) to the farmer confirming that he had the right to purchase the recommended quantities of fertilizer (100 kg of DAP and 200 kg of urea per hectare) for the declared area at the subsidized price.

The farmer could then turn his CT over to his cooperative or producer organization, which arranged for fertilizer delivery from an authorized supplier, or go directly to a supplier. In the former case, the co-op usually provided the farmer with a line of credit until harvest time to cover the 12,500 FCFA/bag payment that was the farmer's responsibility. In the latter case, the farmer pays the 12,500 FCFA up front, but there are instances of input suppliers offering credit directly to farmers. In many cases, the actual price paid by farmers was greater than the 12,500 FCFA/bag because processing and transport costs not covered by the subsidy program were added on by producer associations and private traders. In 2008/09, fertilizer credit was guaranteed by the GOM, making producer associations that had unpaid input credit from previous years eligible for credit that they would not have been able to obtain without the guarantee. In 2009/10, delayed payment of the 2008/09 credit led the GOM to discontinue the guarantee, so members of associations with outstanding debts had reduced access to credit again.

Suppliers having sold subsidized fertilizers then bundle together all the CT that they have redeemed and submit them to the Ministry of Agriculture for payment of the subsidized portion of the price. The full market price at the beginning of the season was estimated by the GOM to be 16,000 FCFA for urea and 22,000 FCFA for DAP. Thus the subsidy paid by the government to the input suppliers represented 22% of the market price for urea and 43% of the market price for DAP (Ministry of Agriculture 2009). An official GOM review of the IR reported that the prices used to estimate the subsidy payment were too high given market prices in 2008, thus suppliers were overpaid (*Bureau du Vérificateur Général* 2009).

A GOM review of the IR implementation for the first two years made the following observations that are pertinent to understanding the response of sample households (*Bureau du Vérificateur Général* 2009):

- Subsidized fertilizer arrived late in 2008/09, forcing many farmers in the ON to forego basal applications or to purchase at unsubsidized prices;
- OPAM was barely present in local markets in early 2009 following the first IR harvest (only 143 MT purchased) because farmers were generally unwilling to sell their rice at the lower-than-market prices offered by OPAM; and
- OPAM used IR funds allocated for local purchases to import 22,000 MT of tax exempt rice the same year.

OPAM was strongly criticized for the 2009 imports, which came late and were still on the market and thus competing with the October 2009 harvest. Table 3 reveals that only in 2010 did OPAM intervene heavily in the local market. According to local news reports, OPAM consistently aimed for a price below 300 FCFA/kg while farmers felt they needed a price of 300 FCFA/kg or more to make a reasonable profit (Malijet.com 2010; Coulibaly 2010).

Table 3. OPAM Rice Purchases: 2005 to 2011

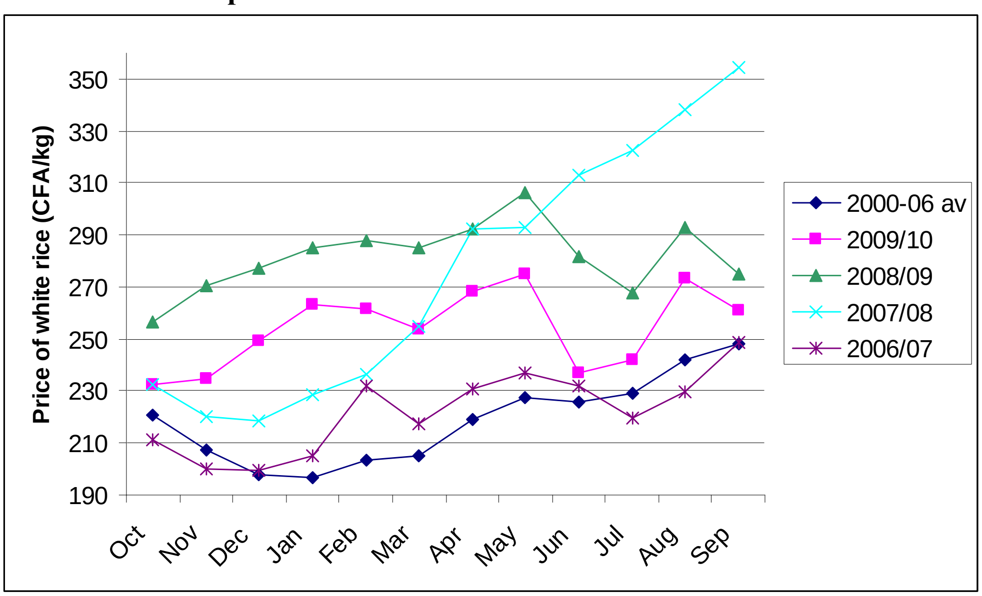
	Type of Rice Purchase		
Year	Imported	Local	Total
	----- Metric Tons -----		
2005	8,995	0	8,995
2006	32,906	0	32,906
2007	6,069	2,158	8,227
2008	11,653	6,629	18,282
2009	22,297	143	22,440
2010	0	15,328	15,328
2011	0	4,059	4,059

Source: Official data from OPAM.

5.1.3. Domestic Cereal Prices

The objective of the domestic cereal price analysis is to establish when nominal cereal prices began to rise in the Macina zone, to describe the extent of their increase during the survey period, and the level of increase compared to an average nominal base price for a six-year pre-survey period extending from October 2000 through September of 2005. We use data for the Macina market because it is the market closest to the sample villages for which the market information service (OMA) has a complete price series. Sample farmers sell their rice in many smaller markets that are linked to the larger market at Macina by assemblers who move rice along the marketing chain.

Figure 4. Average Nominal Monthly Assembler Purchase Prices of White Rice: October 2000 – September 2010



Source: Compiled by authors from OMA data base.

We look first at the seasonality of processed rice prices (the form in which most producers sell their rice) using the base period monthly prices paid to farmers by assemblers in the Macina market. Historically, the assembler price declines between September and October when the rainy season rice harvest begins to hit the market; it continues to stay below October levels through March when it begins to climb. By May the prices are generally higher than the October prices and continue to rise, reaching their peak in the hungry season (July-September), which continues until the next rainy season harvest (Figure 4).

Although we do not have OMA data on the quantities of cereals moving through the markets at different points in time, the months of February/March tend to experience a high level of sales because farmers need cash to make their water payments to the ON. High sales are also common in April/May as farmers seek cash to ensure that they have adequate food and input supplies for the upcoming production season, which begins in late May or early June.

While prices during the marketing year for 2006/07 rice production were similar to those of the six-year base period average, they were relatively high during the months after the rainy season harvest of 2007 (October – January), and increased dramatically thereafter reaching 355 FCFA/kg in September 2008 (Figure 4). Prices following the next rainy season harvest in October 2008 declined to 256 FCFA/kg but remained 24 to 59 FCFA/kg higher during the October 2008 to March of 2009 period than after the 2007 harvest. In April 2009 (as the dry season harvest took place) prices declined below the prices for comparable months in 2008, yet they remained considerably higher (20 to 60 FCFA/kg, depending on the month) than earlier in the decade. Following the October 2009 harvest, prices tracked the pattern of 2008/09, characterized by an absence of the traditional post-harvest decline, but ran roughly 25 FCFA/kg lower than the previous year.

On an annual basis, the patterns observed follow those of international rice prices: up somewhat in 2007, up dramatically in 2008, and then down a bit but still very high relative to historical trends in 2009. The other noteworthy observation is that following both the 2008/09 and 2009/10 rainy season harvests, the traditional October – December drop in prices exhibited by the 2006/07, 2007/08 and average trend for the base period did not occur.

The increases in assembler rice prices that began in early 2008 are consistent with those we find in the household survey data from Macina. For example, household sale prices of rice during 2008/09 are 25-28% higher than those in 2006/07, while those from 2009/10 are approximately 17-19% higher (Table 4).

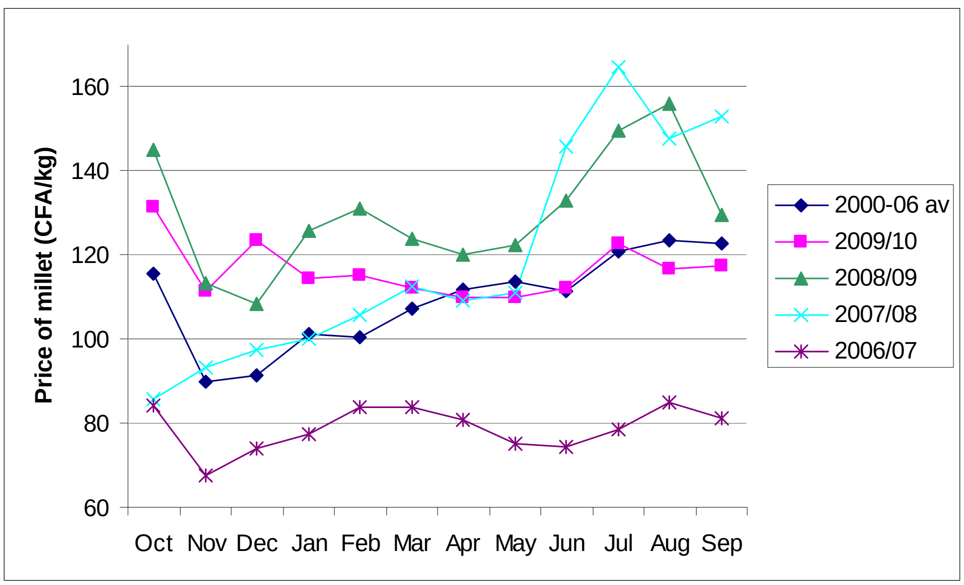
Millet prices also increased, but not as dramatically and in the same manner as rice. The nominal assembler prices of millet were at their lowest in 2006/07 following a very good harvest that year. In October of 2007 prices were identical to those in October of 2006. The first sign of price pressure is in November of 2007, when prices do not follow the usual pattern of post-harvest decline; yet they do not really begin to seriously exceed the 6-year average price line until May of 2007 (a bit later than the beginning of the rice price spike). Millet prices remained well above the base period average until March/April of 2010 when they began tracking fairly closely that average (Figure 5). Although remaining high following the 2008/09 and 2009/10 harvests, the prices did demonstrate the usual post-harvest price drop, in contrast to the situation with rice.

Table 4. Village Mean/Median Household Sale Prices of Rice, by Year

Year	Mean of village mean sale price of rice (FCFA/kg)	% change in means from 2006/07	Mean of village median sale price of rice (FCFA/kg)	% change in means from 2006/07
HHs in *Casiers*				
2006/07	206.4		201.6	
2008/09	268.2	30.0	271.9	34.9
2009/10	240.0	16.3	246.8	22.4
HHs in *Bord du Casiers*				
2006/07	215.0		214.4	
2008/09	271.0	26.1	250.0	16.6
2009/10	251.7	17.1	249.2	16.3
All HHs				
2006/07	210.7		208.1	
2008/09	269.6	28.0	260.7	25.3
2009/10	246.0	16.8	248.0	19.2

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.

Figure 5. Average Nominal Monthly Assembler Purchase Prices of Millet: October 2000 – September 2010



Source: Compiled by authors from OMA data base.

5.1.4. Domestic Fertilizer Prices

The fertilizer price analysis is based on farmers' reports of total fertilizer cost divided by the kilograms of fertilizer purchased. These costs generally include the purchase price plus procurement, transport and financing costs incurred by producer associations (PA) or individual farmers. The data set also does not differentiate between subsidized and

Table 5. Domestic Fertilizer Prices by Year and Location

Year	HHs in *Casiers*		HHs in *Bord de Casiers*		All HHs	
	Mean	Median	Mean	Median	Mean	Median
	---------- FCFA / kg -----------					
2006/07	304	296	310	302	307	300
2008/09	299	279	313	300	306	295
2009/10	298	278	296	300	297	290

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.

unsubsidized purchases, so the unsubsidized purchases (although a relatively small share of total purchases during the IR) tend to raise the overall averages (recall that unsubsidized market prices were estimated to be 22% higher for urea and 43% higher for basal fertilizers). For this reason, both the average and median prices reported in Tables 5 and 6 are generally higher than the official 250 FCFA/kg subsidized price announced by the GOM.

Table 5 reports prices paid by year and location. It shows that the average price paid for fertilizer in 2006/07 and 2008/09 was higher in the *bord de casiers* than in the *casiers*, (6 FCFA/kg difference in 2006/07 and 14 FCFA/kg in 2008/09). This pattern reversed in 2009/10 with the *bord de casierss* price being 2 FCFA/kg less than in the *casiers*. The median prices, which we believe better represent what the majority of farmers paid, show *bord de casiers* prices consistently higher than in the *casiers* (6 FCFA/kg in 2006/07 and 21 to 22 FCFA/kg after the subsidy was introduced). It is likely that the higher prices reflect higher procurement and transport costs for the *bord de casiers* villages, all of which have relatively difficult road and market access. Based on median prices, *casiers* farmers paid 6% less for fertilizer in the subsidy years than they had in 2006/07 while the price decline for *bord de casiers* farmers was <1% both subsidy years.

These statistics on fertilizer prices paid by sample farmers suggest that the main effect of the Initiative Riz was to protect farmers from full transmission of the considerably higher international fertilizer prices that began in 2007 (Table 2). However, farmers in the *casiers* were the main beneficiaries as median prices for *bord de casiers* farmers remained very close to 2006/07 levels throughout the survey period. Our hypothesis is that the combination of higher fertilizer prices (both absolute and relative to 2006/07) and more risk due to less reliable water control would have contributed to the lower levels of fertilizer use in the *bords de casiers* villages.

Table 6 reports median fertilizer prices by source. While prices in 2006/07 offered by various sources were nearly identical, those offered by input dealers in 2008/09 were considerably higher than those offered by producer organizations, the ON, and NGOs. For example, median fertilizer prices from producer associations fell from 300 FCFA/kg in 2006/07 to 280 FCFA/kg in 2008/09 (a decline of 6%), while those offered by input dealers increased from 300 FCFA/kg to 363 FCFA/kg (an increase of 21%). These relatively high prices suggest that most of the purchases made from input dealers may well have been unsubsidized purchases made because of the delayed delivery of the subsidized fertilizer reported by the *Bureau du Vérificateur Général* (2009).

Table 6. Median Fertilizer Prices by Source

	2006/07	2008/09	2009/10
Fertilizer prices by source, annual (FCFA/kg)	--------	median	--------
Fertilizer price from producer organizations	300	280	283
Fertilizer price from input dealers	300	363	330
Fertilizer price from ON	298	250	270
Fertilizer price from NGOs, other	299	280	280
Cases	148	148	148

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.

From 2008/09 to 2009/10, prices increased minimally for PA purchases (3 FCFA/kg) and by a substantial amount (20 FCFA/kg) for ON purchases while they remained unchanged for NGOs and actually declined by 33 FCFA/kg for input dealers. Interestingly, the substantial decline in international fertilizer prices between 2008 and 2009 (see Table 2) were only reflected in the input dealer prices; prices associated with GOM and NGO procurement continued to rise or remained unchanged (suggesting that GOM and NGO procurement procedures were unable to adapt to the changing market conditions fast enough to take advantage of declining world prices). Despite the downward adjustment in prices paid to input dealers during 2009/10, input dealer prices remained higher (17 to 22%) than those paid to other suppliers.

5.2. Farmers' Response to the Price and Policy Environment

Before looking at farmers' specific responses to the price and policy environment over time, it is helpful to get an overview of differences in access to land and general measures of productivity, sales, and well-being for the two sample subgroups: farms in the *casiers* and *bord de casiers* villages.

In terms of land access, the average ON household of roughly ten people is thought to need at least five hectares of irrigated land to make ends meet (Bélières et al. 2003, Coulibaly 2006, Bélières et al. 2011, Kébé et al. 2005). Analysis of the survey data shows that b*ord de casiers* farmers have significantly less high quality irrigation land with fully controlled water and more of the lower quality parcels with partial control. The average *casiers* farm in the sample owns a total of only 4.2 hectares, which are predominantly irrigated parcels; this is less than the recommended minimum size of 5 hectares needed to ensure food security and access to basic necessities, but includes substantially more good quality irrigation land than farmers in the *bord du casier* villages (4 ha for *casiers* farms versus only 2.2 ha for *the bord de casiers*).

While the *casiers/bord de casiers* distinction does not differentiate households by food security status (roughly 71% of *casiers* and *bord de casiers* farms meet minimum needs), land ownership patterns differentiate farms in terms of net cereal availability, with households meeting the 214 kg/capita benchmark having more total land, more land per capita, and more irrigated land—both improved and unimproved. A similar pattern differentiates net sellers (those who sell more cereals than they purchase) from all other farms. Net sellers have access to 3.4 hectares of improved irrigation land and 0.7 hectares of the less productive *hors casiers* land while other farmers (net buyers and autarkic households) have access to only 0.9 hectares of improved irrigation and 0.43 ha of *hors casiers* land, suggesting that access to irrigated land may be an important determinant of whether one becomes a net seller.

Keeping these general differences between *casiers* and *bord de casiers* farms in mind, we now turn to an analysis of how sample farmers changed their production and marketing behavior from 2006/07 to 2008/09 and 2009/10.

5.2.1. Area Planted in Rice

Given the land constraints and rules of access, farmers in the ON do not have a lot of flexibility when it comes to total irrigated area planted from year to year (Smale, Diakité, and Keita 2011). Irrigated parcels are officially assigned to individual farm families. Each family is responsible for paying the water fees (a substantial part of total production costs) at the end of the rainy season whether the land was cultivated or not. Renting or selling rights to an irrigated parcel is not legal; however, renting land out is a common practice, particularly for a farmer who does not have the financial and/or labor resources to adequately cultivate the land. During the rainy season, the little bit of flexibility that exists for adjusting area cultivated comes from (1) taking back land that was rented out, (2) renting land from a neighbor or (3) expanding cultivation to *hors casiers* fields that are not officially recognized by the ON and have relatively poor water control (more an option for *bord de casiers* farmers than for *casiers* farmers).[7] During the dry season, there is more flexibility. To date only a small share of the total irrigated area is planted to rice during the dry season because water control is more difficult and grain losses to birds are very high. Data presented in Table 7 (9th line) suggest that some combination of these area adjustments may have been taking place during the survey period for both the rainy and dry seasons.

Rice is the dominant rainy season crop in Macina—nearly all households in both the *casiers* and *bord de casiers* villages grow irrigated rice (Line 1 of Table 7). During the 2008 rainy season, farmers in the *casiers* had a relatively weak response to price and policy changes, planting an average of 3.9 ha of rice, which represented only a 3% increase over the 2006/07 level of 3.8 ha. They then reduced cultivated rice area by 8% between 2008/09 and 2009/10, regressing to an average of only 3.6 ha. per household (line 9 of Table 7). These changes are relatively small and may reflect measurement errors made by farmers reporting their areas rather than real changes; but the direction of the changes would be consistent with the changes in rice prices described above: extremely high prices during the 2008/09 planting season and somewhat lower prices at the beginning of the following planting season. For the *bord de casiers farmers*, the rainy season increase in 2008/09 was much larger than in the *casiers* (28% over the 2.7 ha. per household cultivated in 2007/08). The level of 3.4 ha. per household attained in 2008 was sustained in 2009/10.

Because sample means are often highly influenced by a few extreme values, in Appendix 2 we have included a table of median values comparable to the means presented in Table 7.

In 2006/07, 62% of households in the *casiers* grew rice in the dry season, compared with only 38% of those in the *bord de casiers* (Line 12, Table 7). Focus group respondents in several Macina villages said that only about 10% of irrigated fields enjoyed sufficient water in the dry season for rice production.

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[7] The ON does officially recognize and charge fees for some of the *hors casiers* fields; but farmers also unofficially expand to other fields on the edges of the irrigated area where water can be diverted from official canals; it is this latter type of expansion we are talking about.

However, the 30 percentage point increase in the share of *bord de casiers* households growing dry season rice in 2008/09—concurrent with a 20 percentage point decline in households growing 'other' crops in the dry season—suggests that these households responded to higher expected prices of rice in 2008/09 primarily through a reallocation of some dry season land from other crops to rice (Lines 12 and 13, Table 7). Yet, enthusiasm for dry season rice cultivation was short-lived, as the percentage of households growing dry season rice returned to its previous (lower) level in 2009/10 for the *bord de casiers* farms and well below the previous level for the *casiers* farms. In terms of land allocated to dry season rice (line 17 of Table 7), the 2008 expansion was more modest in the *casiers* (7% area increase) than in the *bord de casiers* (73%) as was the 2009/10 decline in area of 20% for the *casiers* farms and 49% for the *hors casiers* farms.

5.2.2. Area Planted in Other Crops

There is an important difference in rainy season cropping patterns between households in the *casiers* and *bord de casiers* areas due to differences in access to land with fully controlled irrigation. Because households in the *bord de casiers* have less irrigated area planted to rice during the rainy season (Line 9,Table 7), more than 75% of these households also grow some coarse grains (almost entirely millet) on rainfed parcels. The comparable figure for the *casiers* villages is less than 10% (Line 2, Table 7), largely because access to rainfed land is limited in the *casiers* zone. The households in the *bord de casiers* that grow both coarse grains and rice plant approximately 50 to 60% of their total area to coarse grains.

During the dry season the differences between the *casiers* and *bord de casiers* farms are relatively small, but there is a clear pattern of *bord de casiers* farms allocating slightly more land to other crops such as onions and less to rice than is the case for the *casiers* farmers (last two lines of the dry season section of Table 7).

5.2.3. Fertilizer Use, Credit, and Sourcing

We next consider household fertilizer use over time by the *casiers* and *bord de casierss* farms as an approximate measure of the extent to which the *Initiative Riz* (IR) affected fertilizer use, credit, and sourcing patterns. Recall from Section 5.1 (Box 1) that the IR provided a fertilizer subsidy of roughly 22% for urea and 43% for basal fertilizers beginning with the 2008 planting season. The subsidy appears to have protected farmers from the full impact of the 100 to 300% increase in world prices of fertilizer (Table 5, Section 5.1.3) but reductions in median prices relative to those paid in 2006/07 were small: 6% for *casiers* farmers and <1% for *bord de casiers* farmers.

We focus the analysis in this section on changes in total annual household fertilizer use per hectare of rice (combining both the rainy and dry seasons) across the three survey waves. Analysis is restricted to total annual use by the household because the 2006/07 RuralStruc survey did not collect data on fertilizer use by season or at the crop or field level (but rather at the farm level). Nevertheless, we believe that the total annual quantity of fertilizer applied to all crops approximates the amount applied to rice alone, because the crop-specific input data from 2008/09 and 2009/10 show that nearly all the inorganic fertilizer used by sample farmers was applied to rice.

Table 7. Mean Household Cropping Patterns by Year, Season, and Location (*Casiers/Bord de Casiers*)

	-- HHs in *Casiers* --			-- HHs in *Bord de Casiers* --			----- All HHs -----		
	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10
Rainy season	-------------------------------- mean --------------------------------								
% growing rice	95.8	93.0	94.4	88.2	94.7	94.7	91.8	93.9	94.6
% growing coarse grains	8.5	18.3	12.7	88.2	88.2	76.3	49.7	54.4	45.6
% growing other crops	2.8	7.0	7.0	3.9	23.7	11.8	3.4	15.6	9.5
rice area planted (ha), growers	3.86	4.18	3.79	3.03	3.62	3.61	3.45	3.89	3.69
CG area planted (ha), growers	1.92	0.79	1.19	4.30	3.84	3.74	4.11	3.35	3.40
OC area planted (ha), growers	0.23	0.47	0.14	2.04	2.00	1.09	1.13	1.67	0.80
% of CG in total area planted[1]	53.8	26.9	36.4	62.6	50.6	55.5	56.7	45.0	49.5
% of OC in total area planted	14.2	28.8	19.4	29.3	26.6	15.3	14.2	19.9	9.1
rice area planted (ha), all HH	3.77	3.90	3.57	2.68	3.43	3.42	3.21	3.66	3.49
CG area planted (ha), all HH	0.16	0.15	0.15	3.79	3.39	2.85	2.04	1.82	1.55
OC area planted (ha), all HH	0.01	0.03	0.01	0.05	0.47	0.13	0.03	0.26	0.07
Dry season									
% growing rice	62.0	64.8	46.5	38.2	71.1	42.1	49.7	68.0	44.2
% growing other crops	88.7	69.0	95.8	90.8	69.7	89.5	89.8	69.4	92.5
rice area planted (ha), growers	1.20	1.23	1.38	1.05	1.00	0.85	1.14	1.11	1.12
OC area planted (ha), growers	0.25	0.36	0.28	0.34	0.48	0.46	0.30	0.42	0.37
% of OC in total area, growers	47.5	50.3	60.0	69.3	50.6	73.0	23.9	26.7	26.1
rice area planted (ha), all HH	0.75	0.80	0.64	0.41	0.71	0.36	0.57	0.75	0.49
OC area planted (ha), all HH	0.22	0.25	0.27	0.31	0.34	0.41	0.27	0.29	0.34
Cases	72	72	72	76	76	76	148	148	148

Source: Authors' calculations based on costs in IER-CIRAD-MSU household survey data.
Notes: All computations based on sample of panel households. CG = coarse grains; OC = other crops.

Fertilizer Use: Survey results in Table 8 show that nearly every rice producer uses fertilizer each year; from 93 to 100% for *casiers* households and 88 to 91% for *bord de casiers* households, depending on the year. Average and median quantities of fertilizer applied per hectare follow the same pattern with more used in the *casiers* (averaging 293 to 300 kg/ha, depending on the year) than in the *bord de casiers* (averaging 211 to 241 kg/ha). It is not surprising that there is a difference in fertilizer application rates between the *casiers* and *bord de casierss* areas, given the predominance of fields with better water control in the *casiers* zone and the lower prices paid by *casiers* farmers (Section 5.1.2).

A surprising result is that the quantity of fertilizer applied per hectare declined in 2008/09 when the fertilizer subsidy was introduced and farmer organizations had access to government guaranteed fertilizer credit. The mean decline was quite large (117 kg/ha in the *casiers* and 120 kg/ha in the *bord de casiers*) while the median decline was more modest (7 kg/ha in the *casiers* and 16 kg/ha in the *bord de casiers*). Average use per hectare regained some ground in 2009/10, but generally remained below the 2006/07 levels while median use per hectare in the *casiers* equaled the 2006/07 levels and that in the *bord de casiers* exceeded the 2006/07 levels by 14 kg/ha. Due to high variability in the data and different results obtained looking at means and medians, we do not have a clear picture of the extent to which the quantity of fertilizer used per hectare changed during the subsidy program. It looks likely that there was some decline in use/ha for 2008/09 but an overall increase in 2009/10 for this particular sample of farmers in the ON.

Focus group discussions with farmers in the zone suggest that a primary cause of the decline in 2008/09 was late delivery of the subsidized fertilizers (Boughton and Dembélé 2010). Delayed delivery was likely due to problems encountered when implementing the first year of the *Initiative Riz* program (late IR budget approval, GOM dependence on a single supplier and confusion over how to handle producer organizations that had already ordered their own fertilizer at market prices, for example). Delayed delivery for the irrigated rice zones, which need to apply fertilizer in late May or early June, was later confirmed by a GOM audit of the program, which noted that funds to cover fertilizer distribution were not officially authorized until June 20th (*Bureau du Vérificateur Général* 2009).

Fertilizer Credit and Sourcing: In Mali, fertilizer credit is closely tied to the type of supplier the farmer uses. Farmers' supply options include purchases (1) through producer associations (PA), (2) direct from local input dealers, (3) from NGOs, and (4) from the ON. While all of these sourcing options provide some credit, the principal source of fertilizer credit in the ON has been through producer associations (PA), which obtain their financing from Malian banks (e.g., *Banque National de Developpement Agricole*), often, but not always, with a GOM guarantee.

Survey data reported in Table 8 show that most households obtained some fertilizer on credit during the survey period; 83 to 90% in the *casiers* and 74 to 82% in the *bord de casiers* (line 4 Table 8). The mean share of fertilizer obtained on credit ranged from 80 to 82% in the *casiers* and 68 to 74% in the *bord de casiers* while the average value/ha of the credit purchases ranged from 86,000 to 91,000 FCFA for the *casiers* and 69,000 to 83,000 FCFA for the *bord de casiers* (lines 5 and 6, Table 8).

The mean share of farmers purchasing on credit increased from 79% to 83% between 2006/07 and 2008/09 for the overall sample (line 4, all household columns, Table 8). This result suggests that the GOM's credit guarantee program for purchases through farmer

Table 8. Household Fertilizer Use by Cropping Year and Location (*Casiers/Bord de Casiers*)

	--- HHs in *Casiers* ---			-- HHs in *Bord de Casiers* --			----- All HHs -----		
	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10
Total fertilizer use (annual) [1]	-------------------------------- mean --------------------------------								
% HHs using fertilizer on any crop	100.0	93.0	95.8	90.8	93.4	88.2	95.2	93.2	91.8
% Rice growers using fertilizer, any crop	100.0	100.0	100.0	94.1	94.6	91.7	97.1	97.1	95.7
Quantity fertilizer applied/ha (kg/ha)[1]	401.1	284.1	308.2	333.4	212.6	240.7	368.3	247.3	274.7
% HHs obtaining fertilizer on credit	83.1	89.4	89.7	73.9	76.1	82.1	78.6	82.5	85.9
% of HH fertilizer quantity obtained via credit	79.6	80.6	82.0	68.9	68.3	74.5	74.3	74.2	78.3
Total value of fertilizer loan per ha (FCFA/ha)[2]	90,920	86,203	87,609	83,240	68,673	71,557	87,397	77,826	79,998
Fertilizer price paid (FCFA/kg)	304	299	298	310	313	296	307	306	297
	-------------------------------- median --------------------------------								
Quantity fertilizer applied/ha (kg/ha)[1]	300.0	292.7	300.0	226.8	211.3	240.9	280.8	250.0	266.7
% HHs obtaining fertilizer on credit	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
% of HH fertilizer quantity obtained via credit	98.5	100.0	100.0	96.6	100.0	96.8	97.7	100.0	100.0
Total value of fertilizer loan per ha (FCFA/ha)[2]	87,309	80,000	83,250	75,414	62,526	70,875	84,017	75,000	78,250
Fertilizer price paid (FCFA/kg)	296	279	278	302	300	300	300	295	290
Cases	72	72	72	76	76	76	148	148	148

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.

Notes: 1) With exception of first two rows, all statistics computed only among those EAs that used fertilizer that season. 2) Computed using hectares of rice. All computations based on the sample of panel households.

organizations may have had a positive impact; however, the share continued to increase to 86% in 2009/10, a year that had no GOM credit guarantee. The share of fertilizer purchased on credit was constant at 74% from 2006/07 to 2008/09 but increased to 78% in 2009/10.

Both of these 2009/10 increases (line 5, all household columns, Table 8) could be due to a spill-over effect from improvements in farmers' economic situation and credit ratings as a result of higher rice prices in 2008/09 and the fertilizer subsidy. The median values of roughly 100% for the share of farmers getting fertilizer on credit (bottom half of Table 8), illustrate some skewness in the distribution, suggesting that the majority of households obtain close to 100% of their fertilizer on credit, with little variation in the median values across years. In sum, the descriptive statistics suggest small increases in access to credit but the extent to which the IR credit guarantee contributed to this increase is not clear.

The *Bureau du Vérificateur Général* report (2009) concluded that despite problems with the IR, farmers did increase rice incomes as a result of the program; this finding suggests that farmers would also have improved their capacity to pay credit arrears and qualify for future credit.

What does seem to be more directly related to the IR program is a shift observed in fertilizer sourcing. Households that belong to a producer association (60% of the sample) or cooperatives (11% of the sample) typically obtain fertilizer on credit through these organizations. However, producer association (PA) membership does not guarantee access to fertilizer on credit in the event that the association's loans in previous seasons are not fully paid. This perhaps explains why only 35% of households obtained fertilizer through their PA in 2006/07—presumably because many associations were not eligible for credit due to prior defaults. Credit purchases were high (87%), however, for the 35% of households that did purchase through their associations. The majority (69%) of households in 2006/07obtained fertilizer from input dealers and among these households, less than half (43%) obtained fertilizer on credit.[8] The third primary source of fertilizer in 2006/07 was NGOs and other organizations (17% of households), followed by the *Office du Niger* (4%); most of the NGO and ON sales were on credit (see Table 9 for details). Because the ON technical services officially withdrew from direct intervention in input supply many years ago, the fact that some sample households indicate receiving fertilizer via ON in 2006/07 is a bit puzzling. It's possible that farmers have responded as such due to ON's on-going work with model farmers and extension efforts.

[8] Some farmers purchased both from their PA and from input dealers, thus the sum of these shares is greater than 100.

Table 9. Household Sources of Fertilizer by Year

	2006/07	2008/09	2009/10
% HHs obtaining fertilizer by source (annual) [1]	--------	% of HHs	--------
% from producer organizations	34.7	48.3	40.1
% from input dealers	69.4	40.1	42.9
% from ON	4.1	21.1	33.3
% from NGOs, other	17.0	14.3	16.3
% from any source	95.2	93.2	91.8
% of HHs obtaining fertilizer on credit (annual), computed among HHs obtaining fertilizer from that source	--------	% of HHs	--------
% from producer organizations	84.3	93.0	98.3
% from input dealers	43.1	55.9	47.6
% from ON	66.7	38.7	53.1
% from NGOs, other	88.0	81.0	87.5
% from any source	78.6	82.5	85.9
Cases	148	148	148

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.
Notes: The % of HHs obtaining fertilizer from the four source categories sums to more than 100 because some HHs obtain fertilizer from more than one source.

In 2008/09, there was a shift in household fertilizer sourcing away from input dealers (down from 69% of households to only 40%) and toward PA (up from 35% of households to 48%) and the ON (up from 4% of households to 21%). We believe the shift to PA sourcing is a result of the GOM's credit guarantee program, which made many PA previously in default eligible for credit once again. Apparently, the IR also authorized government technical services to provide subsidized fertilizer to farmers who were unable to obtain it through a PA; this component of the IR is likely the reason for an increase in households declaring purchases from the ON.

The share of farmers benefitting from fertilizer credit increased from 2006/07 to 2008/09 for all sources but the ON and NGOs. While the absolute volume of credit purchases likely increased for the ON because of the large increase in households purchasing (up to 21% from 4%), the share of purchasers who received credit declined, most likely because those added to the pool of ON clients in 2008/09 were in a much higher risk category (i.e., those who had no other means of access) than the relatively small group that was getting ON fertilizer in 2006/07.

After the relatively slow repayment of 2008/09 loans, the GOM did not renew their loan guarantee for the 2009/10 production season, but they did continue the subsidy. This raises questions about why the share of credit purchases continued to increase in 2009/10. The largest increase by source was for purchases from the ON (credit purchases from the ON were up from 39% of all ON purchases in 2008/09 to 53% in 2009/10), a surprising result. Other developments in 2009/10 included a small rise in the share of households obtaining PA and NGO credit (5% and 7% increases, respectively) and an 8% drop in the share getting input supplier credit.

Summary of Key Findings about Fertilizer Access and Use: While the descriptive analysis presented above and the fertilizer price analysis presented earlier (section 5.1.4.) does not permit broad geographic generalizations about the impact of the IR program on fertilizer use, we note the following points that are fairly well substantiated by the data analyzed for the sample of farmers under study:

1. Farmers in the *casiers* use more fertilizer/ha, have better access to credit, and pay lower prices than farmers in the *bord de casiers* both before and after the introduction of the IR.
2. There was no significant overall increase in fertilizer use following the introduction of the IR fertilizer subsidy; evidence is strong that there was some drop in use during the first year due to late deliveries of subsidized fertilizer.
3. The IR protected farmers well against escalating world prices for fertilizer in 2008/09 but the subsequent 2009 decline in world prices was not reflected in the IR program as subsidized prices remained at their 2008 level.
4. There was some improvement in farmers' access to credit as a result of the IR, both in 2008/09 when the GOM credit guarantee was in place and in 2009/10 after it was removed.
5. Producer organizations and the ON increased their fertilizer market share at the expense of private sector input dealers as a result of the IR.
6. Farmers in the *casiers* may have benefited more from the IR programs than farmers in the *bord de casiers*, primarily because their fertilizer prices declined more.

5.2.4. Household Rice Production and Productivity

Production: Total annual rice production by sample households does not exhibit the 50% increase that was anticipated by the IR. Using the 2006/07 production as our baseline, we find that *casiers* households increased average total production by 13% in 2008/09 but fell to just 89% of 2006/07 levels in 2009/10. *Bord de casiers* households saw a 4% increase in total production in 2008/09 and returned to roughly 2006/07 levels in 2009/10 (calculated from line 15, Table 10). We also examined changes in median values across time (shown in Appendix 3), finding a few differences in rates of change but movement in the same direction as the means for the *casiers* households; for the *bord de casiers* households, there is no increase indicated for 2008/09 but rather a decline in the median annual production per household for both years. Whether we use the means or the medians, it is clear that growth in average production per household was far below the IR objectives.

Productivity: We look at changes in rice productivity from two perspectives: production per hectare and production per adult equivalent (AE), comparing results for 2008/09 and 2009/10 with the base year of 2006/07. Production/AE is a rough indicator of returns to labor as well as an indicator of the extent to which rice production covers household cereal needs and creates a marketable surplus. Yield/ha is an indicator of how well the production system is performing with respect to land resources, which are in short supply in the ON.

According to ON official yield data (see Figure 6), average irrigated rice yields rose from about 2-3 MT in the 1980s to over 6 MT by the early 2000s due to improvements in the irrigation infra-structure, the introduction of transplanting, and increased fertilizer use (Samaké et al. 2007; Aw and Diemer 2004).

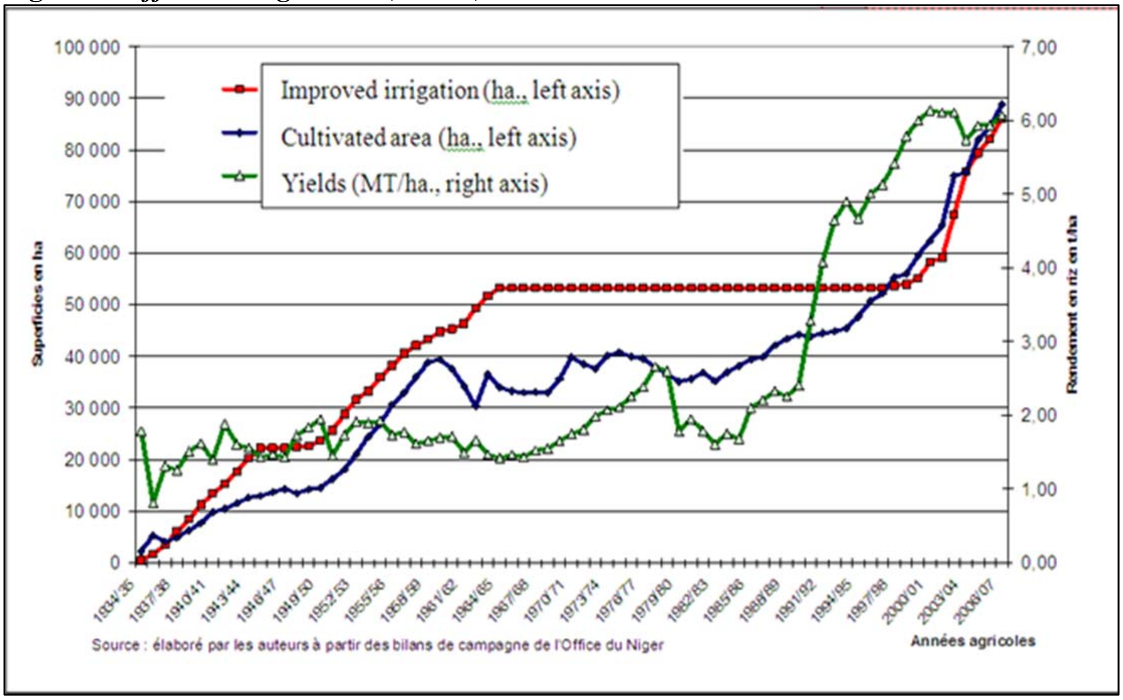
Table 10. Mean Household Rice Production Statistics by Year, Season, and Location (*Casiers/Bord de Casiers*)

	---- HHs in *Casiers* ----			-- HHs in *Bord de Casiers* --			----- All HHs -----		
	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10
Rainy season [1]	------------------------------- mean -------------------------------								
% HHs growing rice	95.8	93.0	94.4	88.2	94.7	94.7	91.8	93.9	94.6
Area planted to rice (ha)	3.86	4.18	3.79	3.03	3.62	3.61	3.45	3.89	3.69
Rice production (kg)	8,429	9,360	7,233	5,507	5,292	5,497	7,000	7,253	6,334
Rice production/AE (kg/AE)	837	813	618	511	466	495	677	633	554
Rice yield (kg paddy/ha)	3,242	3,397	2,947	2,780	2,380	2,302	3,016	2,870	2,613
Cases of rice growers	68	66	67	67	72	72	135	139	139
Dry season [1]									
% HHs growing rice	62.0	64.8	46.5	38.2	71.1	42.1	49.7	68.0	44.2
Area planted to rice (ha)	1.20	1.23	1.38	1.05	1.00	0.85	1.14	1.11	1.12
Rice production (kg)	2,139	2,457	3,092	2,129	1,957	1,843	2,135	2,190	2,477
Rice production/AE (kg/AE)	225	252	298	240	196	179	231	222	239
Rice yield (kg paddy/ha)	3,037	2,963	3,507	3,239	3,101	3,618	3,117	3,037	3,561
Cases of rice growers	44	46	33	29	54	32	76	101	65
Annual [1]									
% HHs growing rice	95.8	93.0	94.4	89.4	97.3	94.7	92.5	95.2	94.6
Area planted to rice (ha)	4.64	5.05	4.46	3.44	4.25	3.99	4.05	4.63	4.22
Rice production (kg)	9,815	11,084	8,756	6,353	6,577	6,317	8,109	8,719	7,492
Rice production/AE (kg/AE)	982	990	765	608	596	574	798	783	666
Rice yield (kg paddy/ha)	3,159	3,342	2,995	2,830	2,444	2,354	2,997	2,871	2,663
Cases of rice growers	68	66	67	68	74	72	136	139	139

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.

Notes: 1) Rice area planted and production figures computed only for rice growers that season. All computations based on the sample of panel households.

Figure 6. ***Office du Niger*** **Area, Yield, and Production Trends for Rice: 1934 – 2006**



Source: Samaké et al. 2007.
Notes: Left axis is area in hectares; right axis is yield/ha in metric tons.

Although there is no question that rice production and yields in the ON have risen significantly since the 1980s, some studies suggest that average ON yields since 2000 have been in the 3-4 MT range rather than 6 MT (for example, Kébé et al. 2005 and Bélières et al. 2011, both using survey data for the 2003/04 campaign, for which official estimates were 5.6 MT).

Macina survey results for 2006/07 through 2009/10 show yields per hectare in the 2.3 to 3.9 MT range for both the rainy and dry seasons, considerably below the 6 MT level (Table 10). As expected, *rainy* season yields in the *casiers* tend to be better than those in the *bord de casiers* villages (from 462 to 1017 kg/ha better, depending on the year). Year-to-year changes differ between the two zones with 2008/09 rainy season yields increasing by 5% in the *casiers* but declining to below 2006 levels in 2009/10. In the *bord de casiers*, the decline in *rainy* season yields occurs both years, down 14% in 2008/09 and 17% in 2009/10. We also see dry season yields declining between 2006/07 and 2008/09 for both zones; but the 2009/10 yields are up over the 2006/07 baseline for both the *casiers* (15%) and the *bord de casiers* villages (12%). Improvements in the dry season yields, however, were not enough to overcome the decline in rainy season yields; consequently, average annual yields decline in both the *casiers* (-5%) and *bord de casiers* (-17%) from 2006/07 to 2009/10.

Statistics for production/AE follow patterns similar but not identical to those of yield/ha. Relative to 2006/07, mean rainy season rice production/AE fell in the *casiers* about 3% in 2008/09 and 26% in 2009/10. The small yield increase in 2008/09 mentioned in the previous paragraph did not translate into more production/AE (Table 10). While a 12% increase in dry season *casiers* rice production/AE enabled total annual rice production/AE to increase by roughly 1% in 2008/09, this was not the case the following year when a 32% increase in dry season production/AE was not adequate to compensate for the 26% decline in rainy season production/AE. Total annual rice production/AE in the *casiers* fell by 22% from 2006/07 to 2009/10.

An analysis of net cereal availability (total consumable coarse grain and rice production minus sales and in-kind payments + purchases) reveals that despite the very high average cereal production per capita for the Macina sample, 29% of households did not meet the minimum 214 kg/capita of consumable cereal availability, with the average annual gap being 73 kg/capita during the 3-year survey period. This result may reflect the growing land constraints mentioned previously and may be at least partially responsible for lower than expected cereal sales. However, the percent not meeting basic cereal needs was relatively constant across the three years (ranging from 28 to 30%, with 2009/10 having the best results) and therefore not likely to explain the drop in sales observed in 2008/09 and 2009/10 (see Kelly et al. 2012 for more details on net cereal availability).

Rainy season production/AE in the *bord de casiers*, fell by less than yields (9% in 2008/09 and 3% in 2009/10), largely because area cultivated increased from a mean of 3 ha to 3.6 ha (Lines 2 and 4, Table 10). The 33 point increase in the percent of *bord de casiers* households cultivating dry season rice in 2008 had no net positive effect, however, on total annual production/AE, which declined by 2% (Line 16, Table 10). The percent of *bord de casiers* households participating in dry season production declined to roughly the 2006/07 level in 2009/10 and total annual production/AE was roughly 6% below 2006/07 levels.

While the 2009/10 decline in rice yields is consistent with the decline in the mean fertilizer rate for both production zones, lower fertilizer use alone does not appear to explain why households experienced such a large drop in rice yields in 2009/10. To address this question, we consider the reasons reported by respondents in the event that they had low rice yields in each year (Table 11). In 2006/07, a total of 33.8% of rice growers in the *casiers* and 43% in the *bord de casiers* reported having a problem which resulted in low rice yields. Insufficient supply of fertilizer was a key problem in both the *casiers* (17.6%) and *bord de casiers* (13%), though poor water control was more likely to be cited in *bord de casiers* (19.4%) relative to the *casiers* (4%).

When we look at the frequency of production problems reported by households over time, it is clear that these problems were more frequent in the latter two survey years, as a total of 52 to 55% of households reported problems in 2008/09 and 78 to 82% in 2009/10. Problems with flooding and poor water control were more frequently cited by households in both areas in the latter two years, with these problems being especially acute in 2009/10. These problem areas raise questions about the IR focus on input subsidies and whether there is not a need to address some of the water management problems simultaneously to ensure that farmers realize the full potential of the inputs they are using.

5.2.5. Household Rice Sales

Given the caveats described above with respect to the comparability of our survey data on household rice sales over time, we look first at the timing of sales made in 2006/07 (Table 12). Forty-nine percent of rice-selling households in the *casiers* and 36% in the *bord du casiers* sold rice at harvest in 2006/07, and these sales accounted for an average of 25% and 20% of total quantities sold, respectively.

Table 11. Respondents' Reasons for Lower Rice Yields by Year and Location (*Casiers/Bord de Casiers*)

	2006/07				2008/09			2009/10		
Reported reasons for rice production loss	*Casiers*	*Bord de casiers*	All HHs	Reported reasons for rice production loss	*Casiers*	*Bord de casiers*	All HHs	*Casiers*	*Bord de casiers*	All HHs
	----- % of growers ------				----- % of growers ------			----- % of growers ------		
Climatic conditions	7.4	4.5	5.9	Drought	0.0	8.3	4.3	3.0	2.8	2.9
Water management	4.4	19.4	11.9	Flooding	11.9	25.0	18.7	19.4	18.1	18.7
				Poor water control	7.5	5.6	6.5	29.9	23.6	26.6
Input supply	17.6	13.4	15.6	Supply of fertilizers	10.4	15.3	12.9	10.4	11.1	10.8
Phytosanitary attack	0.0	0.0	0.0	Poor quality seeds	4.5	0.0	2.2	0.0	1.4	0.7
Other	4.4	10.4	7.4	Late planting	13.4	2.8	7.9	7.5	15.3	11.5
				Other	4.5	2.8	3.6	13.4	12.5	12.9
TOTAL % of rice growers reporting problem(s)	33.8	43.2	38.5	TOTAL % of rice growers reporting problem(s)	52.2	55.6	54.0	82.1	77.8	79.9
Cases	68	67	135		67	72	139	67	72	139

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.
Notes: 1) Figures only consider the principal reason reported for low yield by each household.

Table 12. Timing of Household Rice Sales: 2006/07

	------------ 2006/07 -------------			
	HHs in *Casiers*		HHs in *Bord de Casiers*	
Time period of rice sale	Among rice sellers, % HHs selling rice	HH mean share of annual HH rice sales	Among rice sellers, % HHs selling rice	HH mean share of annual HH rice sales
At harvest (Oct-Nov 2007; April 2008)	48.5	25.4	35.5	20.1
During next planting season (May-June 2008)	79.4	62.0	83.9	65.1
During next lean season (July-Aug to Sept 2008)	23.5	9.1	35.5	14.5
Other	1.5	0.5	1.6	0.3
Cases	68	68	62	62

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.

Notes: Computations use panel households that sold rice in 2006/07.

The dominant sale period for 2006/07 was during the next planting season (May-June 2008), as 79% of *casiers* and 84% *bord de casiers* rice-selling households sold rice during that period, and these sales accounted for an average of 62% and 65%, respectively, of these household's annual rice sales. These sales were likely made both to finance fertilizer purchases (for those who do not obtain 100% of their fertilizer on credit) and hired transplanting labor. While 24% of *casiers* and 36% of *bord de casiers* rice-selling households sold rice during the next lean season (July-September 2008), these sales accounted for only of 9% and 15%, respectively, of average annual rice sales.

We next look at data from 2008/09 and 2009/10 on rice sales by month, with the caveat that these surveys only recorded sales up through July of 2009 and 2010, respectively (Table 13). While the 2006/07 information on rice sales by period suggests that 87% of household rice sales were made before July, we cannot be certain that this sales behavior has remained constant over time (especially given dramatic increases in cereal prices beginning in 2008). The bulk of sales from the rainy season harvest in October 2008 were made from January through April 2009, with March accounting for 35% of all sales transactions. In the focus group interviews from July 2009, farmers in three Macina villages noted that they normally pay rainy season water fees to the ON in February or March, which may explain the large number of sales in March. However, rice sales from the October 2009 harvest started earlier (November/December) than in the prior year, peaked in February, and were considerably more evenly distributed over time. Sales from dry season production start in May and continue through (at least) July (right side of Table 13), though we note that only about half of rice producers in Macina cultivated dry season rice in 2009/10.

Given the caveats noted above with respect to the limitations in the comparability of the rice sales data recorded by the three years of household survey data, we next compare annual rice sales across the three years. For comparative purposes, we define annual sales as those made through June; thus, for 2006/07, we include sales made at harvest and at the beginning of the campaign, which generally begins in May/June.

Table 13. Timing of Household Rice Sales: 2008/09 and 2009/10

	Sales from Rainy season production				Sales from Dry season production			
	-- 2008/09 --		-- 2009/10 --		-- 2008/09 --		-- 2009/10 --	
Month of sale	# of sale cases	% of sale cases	# of sale cases	% of sale cases	# of sale cases	% of sale cases	# of sale cases	% of sale cases
September	2	1.0	4	1.8	0	0.0	0	0.0
October	0	0.0	9	4.0	0	0.0	0	0.0
November	2	1.0	15	6.7	0	0.0	0	0.0
December	1	0.5	23	10.3	0	0.0	0	0.0
January	22	10.9	39	17.4	1	1.5	0	0.0
February	40	19.9	43	19.2	0	0.0	0	0.0
March	70	34.8	26	11.6	2	3.0	0	0.0
April	32	15.9	19	8.5	4	6.1	0	0.0
May	15	7.5	24	10.7	12	18.2	7	13.0
June	13	6.5	12	5.4	22	33.3	32	59.3
July	4	2.0	8	3.6	25	37.9	15	27.8
August	na	na	2	0.9	na	na	0	0.0
Total	201	100.0	224	100.0	66	100.0	54	100.0

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.
Notes: Computed using only sales from common field production.

Because the latter two years recorded the month of sale, we are able to restrict 'annual' sales to those made by the end of June of each year. We also note that in the following tables, the denominator used to estimate the percent of rice production sold is total harvest minus the 10% in-kind payment that is made to cover threshing services (in other words, rice available for sale is production minus the 10% fee). We do not deduct in-kind threshing payments when reporting household rice production or estimating yields.

We find that most rice producers in Macina (92 to 93%) sell at least some rice by July of each year. This is not surprising given that all households pay water fees to the ON in March,[9] and the majority of rice producers obtain fertilizer on loans that must be paid back before the next production season. While the percentage of rice-growers that sell rice remained relatively constant from 2007 to 2010, this comparison of sales through June shows that mean and median quantities of rice sold per AE fell over time, as did the median household percentage of rice production that is sold (Table 14). Although the numbers in Table 14 are generally more favorable for farmers in the casiers than in the *bord de casiers* (higher percent of farmers producing rice, more rice sales total and per AE), the same general pattern is observed across years (substantial drop in sales from 2006/07 to 2009/10).

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[9] This includes payments to the ON for water use on officially registered *hors casiers* fields as well as the *casiers* fields; there are some unofficial *hors casiers* fields that are not subject to ON payments.

Table 14. Rice Sales Statistics for October through June by Location and Year

	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10
	-------- mean --------			-------- median --------		
HHs in the Casiers						
% rice-growing HHs selling rice	95.6	97.0	97.0			
Quantity rice sold (kg)	4,938	4,638	3,379	4,065	3,033	2,104
Quantity rice sold/AE (kg/AE)	479	410	300	382	281	191
% of HH rice production sold	55.0	45.2	39.3	53.3	38.4	34.4
Village rice price received (FCFA/kg)	206.2	268.1	240.0	207.7	269.5	239.4
HHs in Bord de Casiers						
% rice-growing HHs selling rice	89.7	90.5	87.5			
Quantity rice sold (kg)	2,902	3,191	2,665	1,873	1,890	1,750
Quantity rice sold/AE (kg/AE)	276	270	235	203	177	188
% of HH rice production sold	44.9	49.2	41.9	42.3	41.1	37.6
Village rice price received (FCFA/kg)	215.0	271.0	251.7	214.6	273.6	251.3
All HHs						
% rice-growing HHs selling rice	92.6	93.6	92.1			
Quantity rice sold (kg)	3,662	3,648	2,788	2,387	2,064	1,668
Quantity rice sold/AE (kg/AE)	353	317	246	265	215	166
% of HH rice production sold	46.4	44.5	37.9	48.3	39.1	34.9
Village rice price received (FCFA/kg)	210.8	269.6	246.1	208.1	260.6	248.1
Cases	148	148	148	148	148	148

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.
Notes: Rice sales figures computed only for rice sellers that year, and only including sales made between the rainy season harvest (October) and the beginning of the next rainy season (June of the following year). All computations based on the sample of panel households.

Although this evidence appears to support the complaints by the government that rice producers hoarded rice after prices rose in 2008, we note that these data do not allow us to definitively measure the percentage of production sold in the latter two years, as we do not have full data on sales in the lean season (July-September of 2009 and 2010, respectively). However, it is clear from our descriptive analysis in earlier sections that rice production/AE fell in 2009 and 2010 on account of lower rice yields, and that rice yields appear to have fallen through a combination of lower fertilizer rates and poor water control.

There are various hypotheses for the decline over time in the median percentage of household rice production sold through June. For example, lower than usual yields and production can push households to retain a larger share of production than usual for home. Another hypothesis is that higher prices in January 2008 allowed households to meet their needs for cash by selling a smaller quantity of rice than usual early in the season; this permitted them to hold on to stocks with the expectation of getting even higher prices during the hungry season (July – September) when prices traditionally reach their peak (this peak period is, unfortunately, the period for which we do not have sales data for the second and third survey round).

Table 15. Rice and Coarse Grain Production, Sales, and Purchases, by Terciles of Cereal Production/AE and Year

Household production characteristic	------ 2006/07------			------ 2008/09 ------			------ 2009/10 ------		
	HHs with no rice sales[4]	HHs with rice sales[4]	All HHs[1]	HHs with no rice sales[4]	HHs with rice sales[4]	All HHs[1]	HHs with no rice sales[4]	HHs with rice sales[4]	All HHs[1]
	---------- median ----------			---------- median ----------			---------- median ----------		
Lowest tercile, three-year average of annual cereal production/AE									
Rice yield, hiv (kg/ha)[2]	2,035	2,880	2,757	560	2,500	2,405	750	1,925	1,761
Rice yield, cs (kg/ha)[2]	2,438	2,813	2,813	2,100	2,700	2,588	2,100	3,000	2,813
Rice production/AE (kg/AE)	177	389	368	76	362	338	63	293	275
Rice retained/AE (kg/AE)[3]	159	163	163	68	179	137	57	150	135
Rice sold/AE (kg/AE)[4]	0	158	139	0	128	120	0	89	77
% of rice production sold	0	55	49	0	40	40	0	32	31
Coarse grain production (kg/AE)	0	35	27	14	59	54	115	0	1
Cereal production (kg/AE)	295	450	431	88	393	383	144	333	296
Cereals retained (kg/AE)	295	225	235	88	251	204	144	183	183
Coarse grain purchases (kg/AE)	71	21	27	20	27	27	65	47	49
Cereal purchases (kg/AE)	101	32	34	58	28	28	89	50	54
Net cereals available (kg/AE)[5]	421	253	260	151	254	241	254	264	259
Cases	7	38	46	4	44	48	7	41	48
Middle tercile, three-year average of annual cereal production/AE									
Rice yield, hiv (kg/ha)[2]	4,938	3,000	3,000	1,575	3,112	3,088	1,500	2,461	2,461
Rice yield, cs (kg/ha)[2]	.	2,856	2,856	4,200	2,601	2,625	.	3,000	3,000
Rice production/AE (kg/AE)	433	635	614	375	690	685	254	516	512
Rice retained/AE (kg/AE)[3]	390	279	279	338	361	361	228	276	276
Rice sold/AE (kg/AE)[4]	0	275	255	0	243	238	0	189	185
% of rice production sold	0	47	46	0	39	38	0	40	39
Coarse grain production (kg/AE)	423	31	43	258	14	14	103	0	0
Cereal production (kg/AE)	813	665	695	596	705	705	331	625	617
Cereals retained (kg/AE)	813	375	398	596	420	425	331	341	341
Coarse grain purchases (kg/AE)	10	32	25	91	12	12	68	31	31
Cereal purchases (kg/AE)	17	32	32	116	14	14	68	35	35
Net cereals available (kg/AE)[5]	830	406	427	712	453	459	398	386	386
Cases	2	44	46	2	44	46	2	44	46
Highest tercile, three-year average of annual cereal production/AE									
Rice yield, hiv (kg/ha)[2]	4,084	3,338	3,375	3,138	3,200	3,169	1,600	3,029	3,022
Rice yield, cs (kg/ha)[2]	2,500	3,300	3,150	4,300	3,375	3,375	.	3,875	3,875
Rice production/AE (kg/AE)	2,665	1,130	1,136	957	1,198	1,177	287	1,037	1,019
Rice retained/AE (kg/AE)[3]	2,399	482	491	861	563	572	258	572	571
Rice sold/AE (kg/AE)[4]	0	502	500	0	448	395	0	339	329
% of rice production sold	0	50	50	0	40	39	0	36	36
Coarse grain production (kg/AE)	0	0	0	260	0	0	535	0	0
Cereal production (kg/AE)	2,399	1,069	1,073	1,121	1,201	1,195	793	949	949
Cereals retained (kg/AE)	2,399	570	576	1,121	634	637	662	644	644
Coarse grain purchases (kg/AE)	46	46	46	0	51	42	12	37	36
Cereal purchases (kg/AE)	46	53	52	0	51	42	47	52	52
Net cereals available (kg/AE)[5]	2,444	648	654	1,121	688	696	210	676	670
Cases	1	44	45	3	43	46	2	43	45

Notes: 1) Figures only computed among households which grew rice that year. 2) Rice yield is reported as kg of paddy per hectare; rice production as kg of grain. Rice yield in dry season only computed among subset of EAs which grew rice then. 3) Rice retained = rice production - rice sales. 4) Rice sold for 2006/07 only includes sales made at harvest and the beginning of the next rainy season; Rice sold for latter two years only includes sales through June. 5) Net cereals available = cereal production + cereal purchases - cereal sales.

To better understand the relationship between cereal production and sales over time, we rank households by their three-year average annual cereal production/AE and group them into terciles.[10] We then compare the median values of various measures of productivity and sales for both rice and coarse grains across terciles and years (Table 15).

An analysis of the differences between the base year of 2006/07 (a year that preceded cereal price spikes and input subsidies) and each of the subsequent survey years is then presented in Table 16, which uses data from Table 15 to calculate absolute and percent changes in key indicators by tercile.

In this discussion of production and sales behavior by cereal production tercile, we focus on the median and percent changes over time summarized in Table 16 for each tercile group, with some references back to Table 15 (the 6th line of data in each tercile group) for the shares of total production sold.

Among all households in the lowest tercile (data lines 1-3 in Table 16), rice yields in the rainy season of 2008/09 were 352 kg/ha lower than those from 2006/07, a reduction of 12.8%. Total rice production/AE in 2008/09 also fell by 30 kg/ha, a decline of 8%.

For the same year, the quantity of rice sold fell 18 kg/AE, a decline of 13%, while the percentage of production sold fell from 49% to 40% (line 6 of Table 15). The lowest tercile households experienced even greater yield and production losses in 2009/10—a 996 kg/ha yield decline and a 92 kg/AE production decline compared to 2006/07 (down 36% and 25%, respectively). These 2009/10 production losses were accompanied by even larger reductions in rice sales (62 kg/AE for a 44.6% drop) and shares of production sold (down to 31%). The declines in rice production experienced by the lowest tercile households, many of whom probably failed to meet the 214 kg/capita cereal requirements from production net input payments in 2006/07, may explain why these households sold less rice both absolutely and relatively in the latter two survey years.

By contrast, the rainy season rice yield for households in the middle tercile increased by 2.9% in 2008/09, and their rice production/AE increased by 11.4%. Despite these increases, the quantity of rice sold by the middle tercile actually fell 17 kg/AE (a decline of 7%) and the percentage of rice production sold fell from 46% in 2006/07 to 38% in 2008/09 (Table 15).

As was the case for the lowest tercile, 2009/10 rainy season rice production fell sharply relative to 2006/07: yields declined by 538 kg/AE (18% drop) and production/AE declined by 102 kg/ (16% drop). The 2009/10 quantity of rice sold by the middle tercile fell by 170 kg/AE (a 34% decline compared to 2006/07). Surprisingly, the percentage of 2009/10 rice production sold by this tercile stayed at roughly the 2008/09 level (39%) despite the sharp drop in production.

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[10] Ideally, we would like to rank households by their retained cereals quantity/AE; but we cannot do this accurately because we do not have data on which input payments were paid in-kind using part of the rice harvest. The ideal statistic would have been total production minus cash sales minus all in-kind payments for inputs, labor, etc.

Table 16. Absolute and Percentage Changes in Household Rice Yields, Production, and Sales, by Cereal Production/AE Terciles and Year

Household Production Characteristic	2006/07 median[1]	-------- 2008/09 -------- Absolute change between median in **2006/07** and 2008/09	% change between median in **2006/07** and 2008/09	-------- 2009/10 -------- Absolute change between median in **2006/07** and 2008/09	% change between median in **2006/07** and 2008/09
Lowest tercile, three-year average of annual cereal production/AE					
Rice yield, hiv (kg/ha)[2]	2,757	-352	-12.8%	-996	-36.0%
Rice production/AE (kg/AE)	368	-30	-8.1%	-92	-25.0%
Rice sold/AE (kg/AE)[3]	139	-18	-13.3%	-62	-44.6%
Middle tercile, three-year average of annual cereal production/AE					
Rice yield, hiv (kg/ha)[2]	3,000	88	2.9%	-538	-17.9%
Rice production/AE (kg/AE)	614	70	11.4%	-102	-16.6%
Rice sold/AE (kg/AE)[3]	255	-17	-6.8%	-70	-27.3%
Highest tercile, three-year average of annual cereal production/AE					
Rice yield, hiv (kg/ha)[2]	3,375	-206	-6.1%	-352	-10.4%
Rice production/AE (kg/AE)	1,136	40	3.5%	-117	-10.3%
Rice sold/AE (kg/AE)[3]	500	-105	-20.9%	-170	-34.1%

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.
Notes: 1) Figures in this table are based on medians by tercile from Table 15. 2) Figures only computed among households which grew rice that year. 3) Rice sold for 2006/07 only includes sales made at harvest and the beginning of the next rainy season; Rice sold for latter two years only includes sales through June.

Households in the highest tercile of cereal production/AE experienced a 206 kg/AE decline in rainy season yields in 2008/09 (a 6% decline relative to 2006/07). Although yields declined, rice production/AE for this tercile actually increased by 40 kg/AE in 2008/09 (a 3% increase) suggesting that the lower yields may have been related to a reduction in household labor availability. The net result, however, was a reduction in the quantity of rice sold by 105 kg/AE, (down 21%) and a reduction in the share of production sold from 50% in 2007/08 to 39% in 2008/09. Like households in the other terciles, those in the top tercile also experienced significant rice yield (10%) and production (10%) reductions in 2009/10 relative to 2006/07. They also reduced the 2009/10 quantity of rice sold/AE by 34% relative to 2006/07 and the share of rice production sold, which fell to 36% from 39% in 2008/09 and 50% in 2006/07.

In creating the production/AE terciles, we noticed that households located in the *bord de casiers* were somewhat more likely to fall into the lowest tercile, which was 60% *bord de casiers* farms, and less likely to fall into the upper tercile, which was 60% *casiers* farms. As a result we created tables similar to Tables 15 and 16, but using the locational categories rather than the production/AE terciles as the grouping variable. The negative tendencies over time continue to predominate in this supplementary analysis (see Appendix 4), but there are two exceptions: relative to 2006/07, *casiers* farms increased yields by 8% in 2008/09 and *bord de* *casiers* farms increased production/AE by 3% in 2009/10. We also note that although the 2009/10 decline in rice yields was more severe (-19%) for the *bord de casiers* farms than for the *casiers* farms (-10%), the better production/AE results for the *bord de casiers* farms seem to have contributed to a smaller decline in rice sold/AE for that group (-8%) compared to the *casiers farms* (-54%).

Given that the retained rice production/AE for households in the upper two terciles is well above household consumption requirements, this begs the question of why households would reduce their rice sales to such a large extent – especially in 2008/09, when their production levels had increased slightly. One explanation might be that the data for retained production are upwardly biased because the estimate does not take into account the possibility that households paid for inputs and labor with rice rather than with cash (in-kind payments were not enumerated in the survey). To the extent that in-kind rice payments were made, the retained production will be over-estimated. If, on the other hand, households have retained quantities of rice significantly in excess of their 214 kg/capita cereal needs, the higher prices received for their initial sales to cover input credit and basic necessities may have given them enough of a cash cushion to postpone sales of the remaining stocks in anticipation of further increases in price as the hungry season advances (recall that in Table 4, the average sale price received by sample farmers in 2008/09 was 28% higher than that in 2006/07). Since our sales data does not cover the hungry season period, we are unable to ascertain if farmers made additional sales during that time. It is also possible that the dramatic cereal price increases beginning in 2008 made households more cautious about reserving rice for food and future in-kind payments for production expenses. Although we cannot resolve this issue entirely due to data problems, we do try to control for the potential effect of some factors that might have caused a reduction in sales (e.g., changes over time in production costs, prices, and harvested quantities) in Section 7 where we turn to multivariate regression analysis.

5.2.6. Household Costs of Rice Production

One potential explanation for why households appear to be selling a smaller percentage of their rice post-2008 could be that production costs have changed in such a way as to require households to hold on to more rice (e.g., to pay hired labor in-kind during the next growing season). To investigate this question, ideally we would want to compare the shares or levels of different components on rice production costs over time. However, the recording of some key crop production costs in the survey instrument are not very compatible between the first year (RS) relative to the latter two surveys. In addition, the first survey only recorded crop production costs at the farm level. We thus consider the share of each cost component in the total costs of production of rice (rainy season only) for the latter two survey years. There is an important caveat to these figures: while labor costs were recorded in each of the surveys, unfortunately the instrument was not designed to ask the farmer to specify whether hired labor was paid in cash or in-kind. Thus, there may be more than the usual level of measurement error in the value of hired labor.

The results show that two-thirds of the costs of rice production in Macina appear to be due to fertilizer costs and water fees (Table 17). Since we have already shown that fertilizer costs only increased slightly over time, and since water fees per hectare have not increased over these years (to our knowledge), this suggests that changes in costs of production over time would not explain why, on average, households are selling less of their rice production by June in 2009 and 2010.

Table 17. Relative Importance of Selected Production Costs in Total Rice Production Costs: Rainy Seasons 2008/09 and 2009/10

Shares by component of the total costs of production of rice (rainy season)	2008/09		2009/10	
	mean	median	mean	median
Fertilizer	36.5	36.6	38.8	38.8
Water fees	30.2	30.7	30.0	29.8
Labor, transplanting	10.1	10.3	10.2	9.7
Labor, harvest	3.0	0.9	2.2	1.6
Labor, other	0.2	0.0	0.4	0.0
Threshing	15.7	14.9	13.5	13.4
De-hulling	4.3	3.8	4.8	4.2
Cases	139	139	139	139

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.

5.2.7. Summary of Key Farm-level Responses to the Price and Policy Environment

- Price response by households is limited by a lack of flexibility for increasing rainy season irrigated area from year to year; but there were ups and downs in the dry season area planted.
- The *Initiative Riz* helped farmers with credit and protected them from rising world market fertilizer prices but did not increase fertilizer use; it had some influence on fertilizer sourcing as farmers relied more on their PA and on the ON and less on the private sector after the IR began.
- Declining productivity and production is evident both during survey period and relative to past ON benchmarks.
- Rice sales in absolute quantities and as a share of total production declined in 2008/09 and 2009/10 relative to 2006/07.
- Relatively constant costs of production prevailed for major inputs and services during the survey period.

6. ECONOMETRIC ANALYSIS OF THE DETERMINANTS OF HOUSEHOLD RICE YIELDS

6.1. Introduction

In this section, we use multivariate regression analysis to investigate the determinants of rainy season rice yields in Macina (see Section 4.2 for details on model specification and estimation issues). More specifically, we investigate potential explanations for both the sharp decline in mean and median household rice yields from 2008/09 to 2009/10 and for the large differences in rice yields between farms of different sizes and with different types of access to irrigated and rainfed land.

We run various sets of multivariate regressions, the first of which uses household-level (crop-level) data from the subsample of Macina households (n=136 households) that reported rice cultivation in the rainy seasons of both 2008 and 2009. This set of regressions identifies factors affecting rice yields and compares results from OLS and CRE modeling approaches. We next run a second set of regressions on the same data set in order to investigate whether the partial effects of various explanatory factors vary by farm size or over time. The last regression dealing with rice yields is a plot level analysis conducted on data for 2009/10 only. Because irrigated field type (e.g., *casiers vs. hors casi*ers) is a plot-level variable, using plot-level data enables us to better measure the partial effect of field quality on rice yields. In addition, by better controlling for the effect of field quality on rice yields, this may improve our estimates of the partial effects of some explanatory variables such as nitrogen use.

6.2. Descriptive Statistics

We begin by presenting descriptive statistics for the dependent and independent variables used in the household-level and plot-level regressions for rainy season rice production (Table 18). For the farms covered by this analysis, household rice yields (kg of paddy per hectare), fell by about 190 kg/ha between 2008 and 2009, while the median fell about 500 kg/ha. As noted earlier, this decline is not explained by a change in fertilizer use, as we find that mean household nitrogen use per hectare actually increased slightly from 76.4 kg/ha in 2008/09 to 84.8 in 2009/10. Rather, it appears that what changed was an increase in the frequency of production-related problems such as poor water control. Our multivariate regression analysis will enable us to quantify the yield losses due to such events, while separately controlling for other important factors such as fertilizer, hired labor, and field quality.

For 2008/09 we see a rather large difference in rice yields by farm size (hectares/per adult equivalent) (Table 19). The median rice yield for the lowest land tercile was 450 kg/ha below that of the upper tercile. The median yield gap in 2009/10 was considerably smaller (150 kg/ha). There are no clear explanations for this yield gap offered by the means/medians of other variables reported in Table 19. For example, nitrogen and manure application rates are very similar for farms regardless of total irrigated area. Frequency of reported production-related problems is actually greater for the larger farms, as is the probability that larger farms have one or more lower-quality irrigated fields (*hors casiers*). Smaller farms have roughly double the potential family labor per hectare of larger farms, though a lower value of the farm equipment index (lower by roughly .20 points on a scale of 0 to 2.5). In summary, these simple descriptive statistics do not offer an obvious explanation for the yield gap between households in the bottom irrigated land tercile relative to those in the upper two terciles.

Table 18. Descriptive Statistics of Variables Used in Regressions of Rainy Season Rice Yield, 2008/09 and 2009/10

	---------------- Rainy Season 2008 ----------------						---------------- Rainy Season 2009 ----------------					
HH rice production characteristic	cases	mean	SD	min	max	median	cases	mean	SD	min	max	median
Rice yield (kg paddy/ha)	136	2,838.0	1,036.3	0	5,419.1	2,946.9	136	2,654.1	1,146.2	0	6,000.0	2,548.3
Nitrogen applied to rice (kg/ha)	136	76.4	34.2	0	162.0	81.4	136	84.8	36.8	0	218.5	89.4
Nitrogen applied to rice^2 (kg/ha)	136	6,996	5,232	0	26,244	6,623	136	8,547	6,724	0	47,725	7,999
Manure applied to rice (# of carts/ha)	136	3.0	5.4	0	22.5	0.0	136	2.8	6.2	0	40.0	0.0
Manure applied to rice^2 (# of carts/ha)	136	37.3	96.8	0	506.3	0.0	136	46.6	172.0	0	1,600.0	0.0
HH farm equipment index	136	0.668	0.579	0	2.5	0.6	136	0.742	0.680	0	3.3	0.7
Head's education (years)	136	1.05	2.58	0	12	0.0	136	0.38	0.92	0	4	0.0
Maximum adult education in the HH (yrs)	136	4.56	4.54	0	20	4.5	136	5.65	4.07	0	21	5.5
1=HH hired labor for transplanting	136	0.890	0.314	0	1	1	136	0.868	0.340	0	1	1
Cost of hired transplanting labor (FCFA/ha)	136	19,300	10,374	0	40,000	20,000	136	19,085	10,711	0	51,000	20,000
ln(cost of hired transplanting labor/ha)	136	8.8	3.1	0	10.6	9.9	136	8.6	3.4	0	10.8	9.9
ln(cost of hired transplanting labor/ha)^2	136	87.1	32.1	0	112.3	98.1	136	85.6	34.4	0	117.5	98.1
# of adults age 15-59 per hectares of rice	136	2.6	1.9	0.3	16.7	2.0	136	2.8	2.4	0.4	20.0	2.3
# of adults age 15-59 per ha, squared	136	10.6	25.4	0.1	277.8	4.0	136	13.1	38.3	0.1	400.0	5.2
Total landholding, irrigated (ha)	136	3.869	3.234	0	24.3	3.0	136	3.911	3.238	0	23.7	3.2
1=HH has non-remenage field(s)	136	0.088	0.285	0	1	0	136	0.088	0.285	0	1	0
1=HH has hors casier field(s)	136	0.368	0.484	0	1	0	136	0.353	0.480	0	1	0
1=HH reported water control problem	136	0.066	0.250	0	1	0	136	0.265	0.443	0	1	0
1=HH reported flooding	136	0.176	0.383	0	1	0	136	0.191	0.395	0	1	0
1=HH had water control/flooding problem	136	0.243	0.430	0	1	0	136	0.449	0.499	0	1	0
1=HH reported late planting	136	0.081	0.274	0	1	0	136	0.118	0.323	0	1	0
1=HH reported 'other' problem	136	0.037	0.189	0	1	0	136	0.125	0.332	0	1	0

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.
Notes: Table only includes households that reported rice cultivation in the rainy seasons of both 2008 and 2009.

Table 19. Household-level Descriptive Statistics of Rainy Season Rice Production by Landholding Tercile

	Farmsize: Terciles of Total Irrigated Area per Adult Equivalent			
	2008 rainy season		2009 rainy season	
Production characteristic	HHs in lowest tercile	HHs in top two terciles	HHs in lowest tercile	HHs in top two terciles
	--- mean/median value or % ---			
Rice yield (kg paddy/ha)	2,762	2,875	2,580	2,615
Rice yield (kg paddy/ha) -- median	2,559	3,000	2,400	2,548
Nitrogen applied to rice (kg/ha)	74.5	76.7	81.0	84.7
Nitrogen applied to rice (kg/ha) -- median	81.5	80.7	92.0	86.7
Manure applied to rice (# of carts/ha)	2.84	2.98	2.56	2.86
Manure applied to rice (# of carts/ha) - median	0.0	0.0	0.0	0.0
HH Farm equipment index	0.54	0.74	0.59	0.80
# of adults age 15-59 per hectares of rice	3.98	1.99	4.08	2.15
1=HH had water control/flooding problem	17.8	28.7	36.2	48.9
1=HH reported late planting	6.7	8.5	8.5	13.0
1=HH reported 'other' problem	4.4	3.2	12.8	13.0
1=HH has *hors casier* field(s)	25.5	40.4	27.6	39.1
Cases	47	92	47	92

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.

Using plot-level data, we find rather large difference in rice yields by field type (*casiers vs. hors casiers*), as the mean rice yield from 'improved' irrigated fields located in the *casiers* was 2,890 kg/ha in the 2009 rainy season, but only 1,737 kg/ha for *hors casiers* fields (Table 20). However, it is clear that multivariate regression analysis is needed to assess the effect of field quality on rice yields, given that levels of nitrogen and manure application are considerably lower for lower quality (*hors casiers*) fields. Surprisingly, the percentage of fields with reported problems with water control in 2009 was only slightly higher for *hors casiers* fields (55%) relative to improved fields (48.6%).

Given the context provided by the descriptive statistics, we now proceed with the results from our various econometric models in the hopes of identifying factors that can explain the sharp decline in mean and median household rice yields from 2008/09 to 2009/10 as well as the significant rice yield gap between smaller and larger farms.

6.3. Econometric Results

The econometric results for the yield analyses are reported in Tables 21-23. Table 21 reports results for the OLS household fixed effects (FE) (Column A) and the pooled OLS with correlated random effects (CRE) terms (Column B), which enables us to include time-constant factors such as the type of irrigated fields used by the household.

Table 20. Plot-level Descriptive Statistics of Rainy Season Production by Field Type: 2009/10

Production characteristic	Type of irrigated field *Casiers*	 *Hors casier*	Difference in group means statistically significant at p=0.001 or better
	--- mean or % ---		
Rice yield (kg paddy/ha)	2,890	1,737	yes
Nitrogen applied to rice (kg/ha)	92.42	40.40	yes
Manure applied to rice (# of carts/ha)	2.47	1.50	yes
1=HH had water control/flooding problem	48.6	55.0	yes
1=HH reported late planting	13.9	17.5	yes
1=HH reported 'other' problem	13.9	2.5	yes
cases	173	40	

Source: Authors' calculations based in IER-CIRAD-MSU household survey data.

Table 22 reports the results of the same model presented in Table 21, but run with a number of interaction terms. All the regressions in this table are estimated using OLS with household fixed effects. The first regression (Column A) is simply the initial model reported in Column A of Table 21, included here for comparison. Column B reports results for a model with a binary variable for small farm size that was interacted with all of the explanatory factors in the original yield model. This binary variable represents households in the lowest tercile of total irrigated area per adult equivalent. Column C reports results for the third regression in which we interacted a few of the explanatory variables that we expected to have different responses across years with a 2009 time dummy. The interacted variables included: number of economically active adults in the household (and its square), quantities of nitrogen and manure use (and their squares), and the three variables indicating that a household experienced a particular type of production problem (water control, late planting, other).

Table 23 reports the results for the plot level analysis using only the 2009 rainy season data. All of the regressions in this table are estimated using OLS with CRE terms that permit us to estimate the partial effects of factors that have common values for a farm regardless of the plot being cultivated (e.g., household land and equipment assets). The first regression (Column A) uses our initial model specification. For the second regression (Column B), we interact the binary variable indicating that the household is in the lowest landholding tercile with all of the explanatory factors in the rice yield model. For the third regression (Column C), we drop the binary variable indicating a *hors casiers* field and interact this with several of the explanatory factors in the rice yield model, to see if the partial effects of inputs such as nitrogen use vary by field quality.

Table 21. OLS Regressions of Household-level Rice Yield: 2008 and 2009

Explanatory variables	Dependent variable = Rainy Season Rice Yield (kg paddy/ha)	
	(A)	(B)
1=village Rassogoma (*Casiers*)		281.742
		(1.422)
1=village Kouna (*Bord de Casier*)		54.183
		(0.256)
1=village Konona (*Bord de Casier*)		533.806**
		(2.847)
1=village Koutiala Coura ou K07 (*Casiers*)		632.340**
		(2.873)
1=village Bambara (*Casiers*)		922.640**
		(4.264)
1=Rainy season 2009	65.391	84.346
	(0.545)	(0.622)
Nitrogen (kg/ha)	15.832*	16.274*
	(2.436)	(2.132)
Nitrogen^2 (kg/ha)	-0.035	-0.036
	(-1.017)	(-0.912)
Manure (# of carts/ha)	-18.773	-19.260
	(-0.692)	(-0.605)
Manure^2 (# of carts/ha)	0.514	0.517
	(0.508)	(0.435)
HH farm equipment index	561.574*	566.540*
	(2.011)	(2.191)
Maximum adult education (years)	57.584**	61.928**
	(2.979)	(3.009)
ln(Cost of hired transplanting labor/ha)	-555.261*	-564.615*
	(-2.602)	(-2.256)
$\ln(\text{Cost of hired transplanting labor/ha})^2$	59.097**	60.268*
	(2.769)	(2.407)
# of adults age 15-59 per ha	110.310	104.586
	(1.129)	(0.912)
# of adults age 15-59 per ha, squared	-3.086	-2.861
	(-0.609)	(-0.481)
Total irrigated area owned (ha)	6.729	0.715
	(0.149)	(0.014)
1=HH reported water control problem	-371.848*	-367.114*
	(-2.534)	(-2.135)

Table 21, Continued

1=HH reported late planting	-259.278	-271.368
	(-1.157)	(-1.037)
1=HH reported 'other' problem	-708.931**	-710.752**
	(-3.134)	(-2.700)
1=HH has non-*remenage* field(s)		320.959+
		(1.689)
1=HH has *hors casier* field(s)		115.664
		(0.957)
Constant	876.599+	842.371**
	(1.821)	(2.682)
Household fixed effects	Yes	No
Correlated random effects (time-averages)	No	Yes
Number of households	136	136
Number of cases	272	272
R-squared	0.439	0.594

Notes: Base village is Tongoloba (*Bord de casier*). Results presented include the partial effect for each explanatory variable with its absolute t-statistic in parentheses below. ** 0.01 level; * 0.05 level; + 0.10 level.

Table 22. OLS Regressions of Household-level Rice Yield with Interaction Terms: 2008/09 and 2009/10

Explanatory variables	Dependent variable = Rainy Season Rice Yield (kg paddy/ha)		
	(A)	(B)	(C)
1=Rainy season 2009	65.391	-136.734	-183.354
	(0.545)	(-0.823)	(-0.431)
1=Rainy season 2009 * landtercile 1 (low)		497.123+	
		(1.815)	
Nitrogen (kg/ha)	15.832*	16.898	14.437
	(2.436)	(1.636)	(1.470)
Nitrogen * landtercile1 (kg/ha)		4.273	
		(0.358)	
Nitrogen * year 2009 (kg/ha)			1.664
			(0.176)
Nitrogen^2 (kg/ha)	-0.035	-0.037	-0.033
	(-1.017)	(-0.720)	(-0.551)
Nitrogen^2 * landtercile1 (kg/ha)		-0.020	
		(-0.307)	
Nitrogen^2 * year 2009 (kg/ha)			0.007
			(0.114)
Manure (# of carts/ha)	-18.773	6.943	2.398
	(-0.692)	(0.190)	(0.049)
Manure * landtercile1 (# of carts/ha)		52.054	
		(0.637)	
Manure * year 2009 (# of carts/ha)			-25.529
			(-0.458)
Manure^2 (# of carts/ha)	0.514	-0.781	-0.723
	(0.508)	(-0.563)	(-0.281)
Manure^2 * landtercile1 (# of carts/ha)		-3.474	
		(-0.845)	
Manure^2 * year 2009 (# of carts/ha)			1.545
			(0.535)
HH farm equipment index	561.574*	308.868	562.251*
	(2.011)	(1.010)	(2.041)
HH equipment index * landtercile1		330.363	
		(1.018)	
Maximum adult education (years)	57.584**	32.298	41.567*
	(2.979)	(1.282)	(2.016)
Maximum adult education (years) * landtercile1		50.973	
		(1.028)	
ln(Cost of hired transplanting labor/ha)	-555.261*	-622.541**	-632.053**
	(-2.602)	(-2.666)	(-2.938)
ln(Cost of hired transplanting labor/ha) * landtercile1		378.293	
		(0.689)	

Table 22, Continued

ln(Cost of hired transplanting labor/ha)^2	59.097**	68.272**	69.114**
	(2.769)	(2.958)	(3.214)
ln(Cost of hired transplanting labor/ha)^2 * landtercile1		-38.834	
		(-0.691)	
# of adults age 15-59 per ha	110.310	219.765	24.600
	(1.129)	(1.559)	(0.221)
# of adults age 15-59 per ha * landtercile1		-263.271	
		(-1.604)	
# of adults age 15-59 per ha * year 2009			193.296+
			(1.789)
# of adults age 15-59 per ha, squared	-3.086	-10.892	11.699
	(-0.609)	(-1.629)	(1.627)
# of adults age 15-59 per ha, squared * landtercile1		24.669*	
		(2.286)	
# of adults age 15-59 per ha, squared * year 2009			-23.433**
			(-2.828)
Total irrigated area owned (ha)	6.729	44.528	37.135
	(0.149)	(0.894)	(0.795)
Total irrigated area owned (ha) * landtercile1		-59.617	
		(-0.539)	
1=HH reported water control problem	-371.848*	-226.411	-103.604
	(-2.534)	(-1.185)	(-0.516)
1=HH reported water control problem * landtercile1		-183.883	
		(-0.578)	
1=HH reported water control problem * year 2009			-511.968*
			(-2.002)
1=HH reported late planting	-259.278	-23.069	-88.349
	(-1.157)	(-0.083)	(-0.277)
1=HH reported late planting * landtercile1		-886.896+	
		(-1.830)	
1=HH reported late planting * year 2009			-353.989
			(-0.936)
1=HH reported 'other' problem	-708.931**	-453.550+	-314.760
	(-3.134)	(-1.693)	(-0.699)
1=HH reported 'other' problem * landtercile1		-657.346	
		(-1.240)	
1=HH reported 'other' problem * year 2009			-586.513
			(-1.112)
Constant	876.599+	528.840	685.765
	(1.821)	(0.938)	(1.307)
Household fixed effects	Yes	Yes	Yes
Number of households	136	136	136
Number of cases	272	272	272
R-squared	0.439	0.516	0.513

Notes: Results presented include the partial effect for each explanatory variable with its absolute t-statistic in parentheses below. ** 0.01 level; * 0.05 level; + 0.10 level.

Table 23. OLS Regressions of Plot-level Rice Yield with Interaction Terms: 2008 and 2009

Explanatory variables	Dependent variable = Rainy Season Rice Yield (kg paddy/ha)		
	(A)	(B)	(C)
1=village Rassogoma (*Casiers*)	-355.398	-336.303	-257.314
	(-1.409)	(-1.362)	(-1.031)
1=village Kouna (*Bord de Casier*)	-314.673	-354.892	-277.158
	(-1.266)	(-1.415)	(-1.108)
1=village Konona (*Bord de Casier*)	459.508+	429.228	502.370+
	(1.779)	(1.605)	(1.846)
1=village Koutiala Coura ou K07 (*Casiers*)	254.836	305.455	336.944
	(0.764)	(0.887)	(1.009)
1=village Bambara (*Casiers*)	362.647	271.087	494.708+
	(1.311)	(0.920)	(1.827)
Nitrogen (kg/ha)	30.406**	36.103**	32.005**
	(4.798)	(4.881)	(4.601)
Nitrogen * landtercile1 (kg/ha)		-8.497	
		(-0.779)	
Nitrogen * hors casier (kg/ha)			-24.080+
			(-1.795)
$Nitrogen^2$ (kg/ha)	-0.093*	-0.124*	-0.117*
	(-2.125)	(-2.274)	(-2.408)
$Nitrogen^2$ * landtercile1 (kg/ha)		0.065	
		(0.718)	
$Nitrogen^2$ * hors casier (kg/ha)			0.272*
			(2.251)
Manure (# of carts/ha)	26.935	45.375	-9.810
	(0.394)	(0.651)	(-0.164)
Manure * landtercile1 (# of carts/ha)		-12.104	
		(-0.176)	
Manure * hors casier (# of carts/ha)			159.176*
			(2.450)
$Manure^2$ (# of carts/ha)	0.550	-0.573	2.306
	(0.138)	(-0.139)	(0.697)
$Manure^2$ * landtercile1 (# of carts/ha)		1.439	
		(0.503)	
$Manure^2$ * hors casier (# of carts/ha)			-4.472+
			(-1.883)
HH farm equipment index	902.270*	933.204*	779.335*
	(2.587)	(2.610)	(2.066)
Maximum adult education (years)	42.245	27.010	42.992
	(0.549)	(0.373)	(0.539)

Table 23, Continued

ln(Cost of hired transplanting labor/ha)	-127.295	-73.970	-236.042
	(-0.629)	(-0.326)	(-1.080)
ln(Cost of hired transplanting labor/ha)^2	7.744	0.172	19.070
	(0.390)	(0.008)	(0.902)
# of adults age 15-59 per ha	133.786**	124.441**	111.751**
	(3.453)	(3.388)	(3.019)
# of adults age 15-59 per ha, squared	-4.363**	-3.789**	-3.903**
	(-3.044)	(-2.970)	(-2.893)
Total irrigated area owned (ha)	44.921	17.648	62.268
	(0.999)	(0.347)	(1.455)
1=HH reported water control problem	-871.762**	-685.156*	-754.781**
	(-3.358)	(-2.447)	(-2.754)
1=HH reported water control problem * landtercile1		-161.193	
		(-0.470)	
1=HH reported water control problem * hors casier			-582.422+
			(-1.806)
1=HH reported late planting	-623.634+	-606.971+	-600.217
	(-1.781)	(-1.683)	(-1.458)
1=HH reported late planting * landtercile1		-149.004	
		(-0.276)	
1=HH reported late planting * hors casier			-183.686
			(-0.560)
1=HH reported 'other' problem	-970.344*	-814.110+	-914.478*
	(-2.353)	(-1.798)	(-2.032)
1=HH reported 'other' problem * landtercile1		-58.215	
		(-0.112)	
1=HH reported 'other' problem * hors casier			-412.636
			(-0.868)
1=field is hors casier	-228.505	90.815	
	(-1.079)	(0.331)	
1=field is hors casier * landtercile1		-718.169+	
		(-1.967)	
Constant	914.125	1,112.720+	1,106.259
	(1.647)	(1.900)	(1.632)
Correlated Random Effects (time-average terms)	Yes	Yes	Yes
Number of households	137	137	137
Number of cases	213	213	213
R-squared	0.622	0.642	0.645

Notes: Results presented include the partial effect for each explanatory variable with its absolute t-statistic in parentheses below. ** 0.01 level; * 0.05 level; + 0.10 level.

In the next few pages, we discuss the implications of the yield modeling results presented in Tables 21-23 by type of effect: fertilizer, land/irrigation quality, production problems, farm assets (land, equipment, human resources), labor, and year.

6.3.1. Effect of Fertilizer on Rice Yields

As expected, nitrogen has a strong, significant, and positive effect on rice yield, and its effect is concave. Using the OLS/FE results in Column A of Table 21 and the sample mean of nitrogen use (79.6 kg of nitrogen/ha), we estimate that an additional kg of nitrogen per hectare increases rice yield by 10.2 kg/ha. The OLS-CRE results for nitrogen (and most other variables) are quite similar to those from OLS-FE, which suggests that either there are not many non-randomly distributed, unobserved household-level factors correlated with nitrogen use, or that the time-average CRE terms do a reasonable job of controlling for such factors.

The insignificance of the interaction terms between nitrogen and farm size (Table 22, Column B) and between nitrogen and year (Table 22, Column C) indicates that rice yield response to nitrogen does not appear to vary much by farm size or over these two years of data. In our plot-level regression – which enables us to better control for field quality – we also do not find differences in yield response to nitrogen by farm size (Table 23, Column B). However, we do find that an additional kilogram per hectare of nitrogen increases rice yield by 33 kg/ha on a poor quality *hors casiers* field, as compared with an increase in rice yield of 12.2 kg/ha on an improved *casiers* field (Table 23, Column C). Rather than interpreting this result to suggest that yield responses to nitrogen are higher on poorer quality fields, it is more likely that the high marginal response rate of nitrogen on poor quality fields is due to the fact that farmers are putting very little nitrogen on such fields, as noted in Table 20, and are thus operating at a relatively steep portion of the marginal response curve. Farmers may apply less nitrogen to their poorer quality fields due to the unpredictability of water control for such fields.

The mean levels of nitrogen use for both smaller and larger rice farms are below the recommended level of 100 kg of nutrient per hectare. To investigate whether farmers could profitably increase use of inorganic fertilizer, we compute a marginal value cost ratio (MVCR) for both 2008/09 and 2009/10 using the nitrogen response in Table 23 (Column A), the average sample rice sale price, and the fertilizer price (by type) for each of those years. For 2009, the MVCR for urea is 4.2 and the net gain from an additional kg of urea per hectare (at the margin) is 2,110 FCFA/ha; for 2009/10 the comparable results were a bit lower at 3.9 and 1,909 FCFA. This rough estimate of the profitability of nitrogen use for 2009 and 2010 suggest that rice farmers in Macina could have increased the profitability of their rice production by using more nitrogen fertilizer in each of those years.

The effect of manure on rice yields is not significant for any of our models. This effect is surprisingly negative (though insignificant) for the household-level model (Table 21, Column A), though positive (and insignificant) in the plot-level model (Table 23, Column A). The lack of effect may be due to variations in the quality of manure from farm to farm and plot to plot as well as to measurement errors in the quantities which are reported as “cart-loads”.

6.3.2. Effect of Land and Irrigation Quality on Rice Yields

When we use pooled OLS with CRE terms to measure the effect of the poor land quality dummy, we find that this is insignificant but surprisingly positive (Table 21, Column B). When we use plot-level data, we find that the coefficient on the poor land quality dummy is negative, yet still insignificant (Table 23, Column A). However, we find a rather large difference in the land quality effect by farm size. For example, for larger farms, yields on a poor quality field are not worse than those from higher quality fields. By contrast, for smaller farms, yields on a poor quality field are 718 kg/ha lower relative to yields on a higher quality field (Table 21, Column B). This result would appear to explain the bulk of the gap in rice yields between smaller and larger farms. This also suggests that while both smaller and larger farms are equally likely to grow rice on a *hors casiers* field, that the *hors casiers* fields controlled by farmers managing smaller farms may be of poorer quality relative to those controlled by farmers managing larger farms, who do not experience lower yields on their *hors casiers* fields. Another possibility is that the larger farms may be better equipped (e.g., more labor, more equipment, greater financial resources) to deal with the problems associated with *hors casiers* fields).

6.3.3. Effect of Production Problems on Rice Yields

While mean/median quantity of nitrogen applied to rice increased slightly from 2008/09 to 2009/10, the yield benefits from increased nitrogen use appear to have been more than offset by various reported household-specific production problems, which have large and significant negative effects on rice yields. For example, problems with water control reduced yield by 371 kg/ha, late planting reduced yield by 259 kg/ha, and other problems reduced yield by 709 kg/ha (Table 21, Column A). These findings may largely explain the decline in rainy season rice yields from 2008/09 to 2009/10, as we found a larger percentage of households reported problems with water control and other problems in the latter year.

We also find additional evidence which helps explain the yield gap between smaller and larger farms. The interaction terms between each of the problem dummies and the lowest landholding tercile are all negative, with two of them significant. For example, while larger farms having reported late planting do not experience a yield loss, smaller farms having reported late planting experience a yield loss of 886 kg/ha (Table 22, Column B). Likewise, while larger farms having reported ‘other’ problems experience a yield loss of 453 kg/ha, smaller farms with ‘other’ problems may experience an even greater yield loss of 1,110 kg/ha (this interaction effect is not far from significant) (Table 22, Column B).

There is also evidence that these production problems may have caused larger yield losses in 2009 than in 2008. For example, all of the interaction terms between the 2009 dummy and the production problem dummies are negative (Table 22, Column C), though only that for water control is significant. The water control dummy indicates a yield loss of 103 kg/ha in 2008 (though this effect is not significant), yet a significant yield loss of 512 kg/ha in 2009.

6.3.4. Effect of Farm Assets (Land, Farm Equipment, and Human Capital) on Rice Yields

A marginal increase in farm size by itself does not have a significant effect on rice yields, though this effect is nearly significant in the regression that includes interactions of some explanatory variables with field quality (Table 23, Column C). However, there is a significant positive effect of farm equipment on yields (Table 21, Column A). This suggests that households that own more equipment enjoy higher yields, perhaps because they are better able to prepare their fields and/or do so in a more timely manner. Because a one-unit increase in this index would represent a non-marginal change (i.e., it ranges from 0 to 2.5), a standard way to interpret the marginal change in such a variable is to multiply the partial effect of a one-unit change by something considerably smaller. For example, a 0.10 increase in the farm equipment index increases yield by 56 kg/ha (Table 21, Column A). This effect appears to be considerably larger in the plot-level regression, where the marginal effect of a 0.10 increase in farm equipment on rice yield is 90 kg/ha (Table 23, Column A).

An increase in the maximum years of adult education in the household leads to an increase in rice yield of 58 kg/ha (Table 21, Column A). This may indicate that households with higher levels of education are better able to adapt production techniques to new problems as they arise.

6.3.5. Effect of Family and Hired Labor on Rice Yields

The marginal effect of adding one adult age 15 to 59 to the household leads to a 174.6 kg/ha increase in yield for larger farms, yet a smaller 68 kg/ha increase in yield for smaller farms. Given that smaller farms already have double the adults per hectare relative to larger farms, this result is not surprising, and suggests that smaller farms are applying more family labor per hectare and thus have driven the marginal product of family labor closer to zero.

Contrary to what we would expect, the marginal effect of hired transplanting labor is convex for both larger and smaller farms (Table 22, Column B), though it is positive for most of the range of this explanatory variable. At the mean level of hired transplant labor cost/ha, a 1% increase in transplanting costs/ha increases rice yield by 460 kg/ha. However, the marginal effect of hired transplant labor near zero use is -460 kg/ha or larger. This suggests that this effect is picking up the difference in yield between the 86% of households that hire transplanting labor (92% for larger farms; 75% for smaller farms) and the remainder who do not.

6.3.6. Effect of Unobserved Time Factors on Rice Yields

The rainy season 2009 dummy is included to control for a potential change in the average effect of unobserved factors on rice yields from 2008/09 to 2009/10. The fact that this dummy is insignificant and of small magnitude (65 kg/ha) offers compelling evidence that production problems such as poor water control – that were both more frequent and more damaging to yields in 2009 relative to 2008 – are largely to blame for the sharp decline in rice yields from 2008 to 2009 (Table 21, Column A). The interaction between the 2009 dummy and farm size dummies shows that smaller farms apparently made up some of the 2008 yield gap by farm size through unobserved factors that had a positive effect on their yields in 2009 (but not those of larger farms) (Table 22, Column B).

6.4. Summary of Rice Yield Modeling Results

In summary, our analysis of rainy season rice yields suggests that an increase in 2009 in both the frequency and yield losses associated with poor water control largely explain the decline of rainy season yields from 2008/09 to 2009/10. We also find several explanations for the yield gap between smaller and larger farms. The most significant appears to be production problems. While smaller and larger farms both reported production problems such as poor water control, late planting and 'other' problems with relatively similar frequency, it is clear that smaller farms face considerably larger yield losses when experiencing such events. Second, while both smaller and larger farms are equally likely to grow rice on a *hors casiers* field, the small-farm *hors casiers* fields may be of poorer quality relative to the large-farm *hors casiers* fields, which do not exhibit lower yields. Third, the marginal effects of farm equipment are significant and relatively large, such that the average farmer would enjoy a 90 kg/ha increase in yield if they increased their equipment index by 0.10.

While the survey data does not permit an analysis of rice yields across all three years, our yield regression results, combined with some of the descriptive results in Section 5, suggest several factors that can explain the decline in mean and median rice yields and production/AE after 2007 in Macina. First, the percentage of households reporting one or more problems with their rice production increased after 2007, especially those related to water control in 2009/10, and our yield analysis demonstrated that problems such as poor water control, late planting, or 'other' problems can reduce household rice yields by 65 to 880 kg/ha, depending on the problem and the type of rice producer. A second and less important factor is likely the reduction in fertilizer use after 2007. Because mean and median total household fertilizer use in Macina fell after 2007 (Table 9), it is very likely that fertilizer applied to rice also fell after 2007. Based on nitrogen response estimates from yield regressions, we can estimate that the median reduction in fertilizer applied per hectare of 30 kg/ha from 2006/07 to 2009/10 could by itself explain a reduction in rice yields of 138 kg/ha (assuming the farmer uses urea fertilizer).

7. ECONOMETRIC ANALYSIS OF THE DETERMINANTS OF HOUSEHOLD RICE SALES

Recall from Section 4.3. that the analysis of rice sales looks at both the quantity of rice sold (results reported below in Section 7.1.) and the share of total production sold (reported in Section 7.2.). Table 24 presents descriptive statistics (means, standard deviations, and medians) by year for all the variables used in both of these modeling efforts. The values for some variables differ a bit from results presented in Section 5 because the sample for the sales analysis includes only the 132 farm enterprises that had a full set of data on all the variables.

The dependent variables are presented twice (first six lines of the table): once using data that covers sales from harvest through June and once using data that covers sales from harvest through July. The former permits us to run our regressions using all three years of data together, while the latter data is only available for 2008/09 and 2009/10.

The explanatory variables include demographic characteristics of the household, various measures of household rice and coarse grain production (e.g., kg/AE, kg/AE squared, and the natural logs of these numbers), asset variables (durable goods ownership, education), indicators of regular non-farm income streams, membership in producer associations, input and credit costs (some in FCFA and some in natural logs of the FCFA), and rice price variables. There is also a dummy variable that differentiates villages in the *casiers*, which have good market access, from those in the *bord de casiers*, which have poor market access. All of these variables are hypothesized to affect household decisions about rice sales (Section 4.3.3.).

7.1. Econometric Analysis of Factors Affecting the Quantity of Household Rice Sales

7.1.1. The Models

The multivariate regression analysis of the determinants of the quantity of rice sold by households is based on sales data through June of each year. June represents the beginning of the next cropping season and also the end of the period for which we have full sales data across the three survey years. We standardize quantities sold across households with different demographics by using sales per adult equivalent as the dependent variable. We chose to standardize our dependent variable (quantity of rice sold) by household size (AE) rather than farm size because we are analyzing the household marketing behavior with respect to the main staple cereal of this zone, within the context of semi-subsistence agriculture (i.e., household rice consumption each year largely comes from own production). Given this context, we therefore consider it more appropriate to investigate the sales quantity per consumption equivalent instead of the sales quantity per hectares noted in Section 4.3.4., we use Tobit models to explore the determinants of rice sales. Three versions of a Tobit model are used:

- The base Tobit model of the quantity of rice sold/AE as a function of a set of base explanatory variables;
  A modified Tobit that permits us to examine the extent to which cereal sales are affected by a household's ability to meet its own cereal needs through production; this is accomplished using all the variables in the initial Tobit and by interacting a dummy variable representing households in the lowest third of rice production/AE with all the explanatory variables; this model permits us to estimate average partial effects (APE)

Table 24. Descriptive Statistics of Variables Used in Regressions of Annual Rice Sales

	------- 2006/07 -------			------- 2008/09 -------			------- 2009/10 -------		
Household rice production/sale characteristic[a]	mean	SD	median	mean	SD	median	mean	SD	median
Dept Variable: HH rice sales through June									
1=HH sold rice	92.4	26.6	100.0	96.2	19.2	100.0	93.9	24.0	100.0
Quantity of rice sold per AE (kg/AE)	358.4	359.1	267.3	332.0	355.3	233.1	257.5	290.3	182.6
% of rice production which is sold	46.8	24.1	48.5	45.5	26.4	39.5	39.0	23.5	35.4
Dept variable: HH rice sales through July									
1=HH sold rice				96.2	19.1	100.0	94.7	22.4	100.0
Quantity of rice sold per AE (kg/AE)				348.2	358.0	248.1	273.0	294.6	194.7
% of rice production which is sold				47.6	25.9	41.1	41.9	23.4	39.2
Explanatory variables									
Rice production/AE (kg/AE)[b]	809.5	623.0	632.9	811.8	632.0	679.6	685.1	583.4	538.8
Rice production/AE, squared (kg/AE)	1,040,606	1,915,541	400,701	1,055,511	2,044,557	461,917	807,155	1,828,916	290,656
ln(Rice production/AE)	6.44	0.76	6.45	6.40	0.95	6.52	6.21	0.95	6.29
ln(Rice production/AE), squared	42.01	9.54	41.63	41.84	10.20	42.55	39.45	10.15	39.57
Coarse grain production/AE (kg/AE)	90.0	149.1	0.0	70.0	107.1	0.0	77.3	147.3	0.0
ln(Coarse grain production/AE)	2.314	2.533	0.000	2.250	2.425	0.000	1.953	2.462	0.000
Dependency ratio (kids & elderly /adults)	1.146	0.673	1.000	1.015	0.576	1.000	1.085	0.625	1.000
Durable goods index (3-year average)	0.982	0.464	1.022	0.982	0.464	1.022	0.982	0.464	1.022
Head's education (years)	1.234	2.802	0.000	1.083	2.612	0.000	0.386	0.922	0.000
1=HH has nonfarm salaried income	0.053	0.225	0.000	0.053	0.225	0.000	0.053	0.225	0.000
1=HH has other regular nonfarm income	0.045	0.209	0.000	0.045	0.209	0.000	0.045	0.209	0.000
1=HH belongs to producer association	0.621	0.487	1.000	0.621	0.487	1.000	0.621	0.487	1.000
1=HH belongs to cooperative	0.083	0.277	0.000	0.083	0.277	0.000	0.083	0.277	0.000
Water fees[c] (FCFA)	262,570	198,136	204,775	294,662	236,003	234,500	267,042	212,824	231,810
Fertilizer loan, association (FCFA)	91,963	170,615	0	158,361	240,287	0	129,748	199,078	0
Fertilizer loan, input dealer (FCFA)	107,241	248,938	0	60,008	138,760	0	45,345	132,073	0
Fertilizer loan, ON (FCFA)	14,669	129,699	0	23,773	116,791	0	52,256	133,542	0

Table 24, Continued

Household rice production/sale characteristic[a]	------- 2006/07 ------- mean	SD	median	------- 2008/09 ------- mean	SD	median	------- 2009/10 ------- mean	SD	median
Cost of hired labor for transplanting (FCFA)	68,742	63,662	56,000	91,874	77,953	74,250	84,233	72,984	67,000
ln(Water fees)[c]	11.59	2.31	12.13	11.50	3.03	12.21	11.40	3.03	12.20
ln(Fertilizer loan, association)	3.86	5.78	0.00	5.92	6.24	0.00	5.35	6.18	0.00
ln(Fertilizer loan, input dealer)	3.99	5.79	0.00	3.02	5.27	0.00	2.58	4.90	0.00
ln(Fertilizer loan, ON)	0.38	2.15	0.00	1.00	3.34	0.00	2.41	4.89	0.00
ln(Cost of hired labor for transplanting)	9.77	3.48	10.93	10.41	2.96	11.22	10.26	3.07	11.11
1=HH hired laborer, seasonal	0.273	0.447	0.000	0.121	0.328	0.000	0.182	0.387	0.000
1=HH hired laborer(s), annual	0.136	0.344	0.000	0.083	0.277	0.000	0.076	0.266	0.000
Average village rice sale price (FCFA/kg)	210.6	5.3	212.6	269.6	5.0	269.5	245.8	6.5	246.7
Avg weighted HH rice sale price (FCFA/kg)	208.3	12.4	207.5	262.3	23.8	264.8	243.3	17.9	240.0
1=village has good market access	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Cases		132			132			132	

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.
Notes: A) Table only includes HHs that reported rice cultivation in rainy seasons of 2006, 2008 and 2009; B) rice production consists of harvested quantities from both rainy and dry seasons that year; C) loan and cost data includes costs from both rainy and dry seasons.

for households with relatively poor rice production/AE and contrast these APE with those for households in the upper 2/3rds of rice production/AE.

- Another modified Tobit in which we again use the same base set of explanatory variables but also interact a binary variable for the latter two survey years (2008/09 and 2009/10) with each of our explanatory variables in order to sort out effects that might differ in the pre- and post-price spike periods.

Table 25 presents the results for the base Tobit model (first three columns) and for the results by level of rice production/AE (bottom tercile in columns 4-6 and top two terciles in columns 7-9). Table 26 presents the results that explore differences in APE between 2006/07 and the last two years of the survey (2008/09 and 2009/10). The paragraphs following the tabular presentation of the modeling results provide an interpretation of those results for the following categories of effects: rice production/AE, coarse grain production/AE, household wealth proxied by durable goods ownership, input costs and credit, hired labor, household demographics and association membership, prices and market access, and unobserved time factors.

The pseudo R-squared values for these models are very low (0.07), indicating that our observable explanatory variables simply do not explain much of the variation in household rice sale quantities. We, therefore, ran two additional regression models: first, we restricted the analysis to rainy season production only, which accounts for the bulk of the rice produced and marketed, and used only the data for 2008/09 and 2009/10, which permitted us to add sales for the month of July. Other adjustments included the addition of a dummy variable indicating that a household produced rice during the dry season. We expected these revisions to address any problems of simultaneity that might have occurred in the three-year model due to the inclusion of dry season harvest quantities and costs that might have been influenced by sales from the earlier rainy season harvest. Second, to address the lack of statistical significance for our price variables, we ran a separate regression of sales of rainy season production using four quarterly observations rather than a single annual observation for each year. This quarterly sales analysis was also restricted to the 2008/09 and 2009/10 data as we could not separate rainy and dry season production and sales for the 2006/07 data. Results for these additional regressions are discussed after those for the initial rice sales models described in the previous paragraph.

7.1.2. Effect of Rice Production/AE on Rice Sales

We find that an additional kg/AE of rice produced by the household results in additional rice sales of 0.26 kg/AE, on average (Table 25, row 4, column 1). While this result might seem obvious, it is of interest that the APE estimate differs by tercile of rice production/AE. Based on our descriptive results above in Table 15, we anticipate that households in the lowest tercile of cereal production/AE are more likely to produce a level of rice that – net of necessary sales to repay loans, water fees and hired labor – is relatively close to (or below) the quantity/AE of rice required by the household for their annual consumption needs, making them less likely to sell rice. When we run the second Tobit (that includes an interaction term for households in the lowest tercile of cereal production/AE), we find these households sell less of each additional kg/AE of rice produced (0.23 kg/AE) relative to households in the two upper terciles, who sell 0.34 kg/AE of each additional kg/AE of rice produced (Table 25, row 4, columns 4 and 7).

Table 25. Tobit Regressions of Annual Rice Sales: Base Model and Model With Household Cereal Production/AE Tercile Interaction Terms

	-------- Dependent Variable: HH quantity of rice sold per AE (kg/AE) through June --------								
	All HHs			HHs in bottom tercile of cereal production/AE			HHs in middle & upper terciles of cereal production/AE		
Explanatory Variables	APE	SE	p-value	APE	SE	p-value	APE	SE	p-value
1=year 2008/09	-29.663	32.398	0.405	19.627	43.579	0.601	-54.209	44.621	0.247
1=year 2009/10	-50.265	27.073	0.097	-14.405	35.961	0.800	-71.860	37.112	0.069
1=HH in lowest tercile, cereal production				14.376	18.506	0.437			
Rice production/AE (kg/AE)	0.264	0.042	0.000	0.227	0.133	0.048	0.344	0.050	0.000
Coarse grain production/AE (kg/AE)	-0.113	0.114	0.258	0.066	0.271	0.852	-0.176	0.149	0.272
Dependency ratio (kids & elderly /adults)	-11.186	35.690	0.912	23.369	44.754	0.608	-32.761	50.500	0.796
Durable goods index (3-year average)	-7.332	21.997	0.027	-7.951	26.846	0.789	7.036	31.952	0.006
Head's education (years)	3.216	5.748	0.745	-1.639	9.681	0.848	-0.608	7.385	0.756
1=HH has nonfarm salaried income	-30.140	33.608	0.536	11.279	58.672	0.846	-51.117	42.894	0.457
1=HH has other regular nonfarm income	-13.062	36.615	0.746	1.518	40.599	0.921	-61.132	54.416	0.235
1=HH belongs to producer association	2.543	19.136	0.837	13.750	28.573	0.867	-17.781	27.214	0.720
1=HH belongs to cooperative	34.819	31.215	0.309	31.354	47.507	0.732	33.269	41.801	0.378
ln(Water fees)	5.582	24.674	0.172	43.154	38.251	0.471	-25.126	31.530	0.220
ln(Fertilizer loan, association)	4.777	1.906	0.014	-0.183	2.663	0.824	7.713	2.576	0.002
ln(Fertilizer loan, input dealer)	-2.431	2.164	0.264	-1.199	2.871	0.748	-4.063	2.991	0.216
ln(Fertilizer loan, ON)	4.024	2.687	0.108	0.457	4.286	0.925	5.619	3.450	0.080
ln(Cost of hired labor for transplanting)	4.301	4.232	0.430	-1.297	4.480	0.938	8.411	6.735	0.496
1=HH hired laborer, seasonal	17.201	28.939	0.599	2.644	48.416	0.733	12.166	35.965	0.944
1=HH hired laborer(s), annual	78.393	38.109	0.038	8.083	74.171	0.774	86.752	43.738	0.058
HH average rice sale price (FCFA/kg)	-0.023	0.485	0.853	-0.087	0.615	0.815	-0.069	0.679	0.745
1=village with better market access	14.885	22.314	0.708	9.555	29.198	0.655	24.010	33.066	0.687
CRE (time-average) terms included		Yes			Yes			Yes	
Cases		392			130			262	

Notes: Annual rice sales = quantity sold from harvest through June; APE = average partial effect of explanatory variable on quantity sold, conditional on selling; SE = standard error.

Table 26. Tobit Regression of Annual Rice Sales with Year Interaction Terms

	Dependent Variable: HH quantity of rice sold per AE (kg/AE) through June					
	All HHs APEs in 2006/07			All HHs APEs in 2008/09 & 2009/10		
Explanatory Variables	APE	SE	p-value	APE	SE	p-value
Rice production/AE (kg/AE)[a]	0.365	0.070	0.000	0.250	0.043	0.000
Coarse grain production/AE (kg/AE)	-0.152	0.197	0.487	-0.092	0.145	0.346
Dependency ratio (kids & elderly /adults)	-7.337	63.446	0.847	-22.060	44.594	0.701
Durable goods index (3-year average)	-5.817	40.703	0.381	-16.223	25.192	0.006
Head's education (years)	-41.596	23.459	0.127	0.609	6.616	0.830
1=HH has nonfarm salaried income	-0.312	63.175	0.927	-38.493	37.845	0.422
1=HH has other regular nonfarm income	60.751	77.629	0.311	-37.976	39.051	0.198
1=HH belongs to producer association	7.365	38.082	0.651	24.557	22.245	0.457
1=HH belongs to cooperative	-3.393	55.832	0.982	50.587	37.060	0.277
ln(Water fees)	0.299	44.046	0.272	1.081	28.697	0.159
ln(Fertilizer loan, association)	3.093	4.001	0.773	4.357	2.315	0.055
ln(Fertilizer loan, input dealer)	-0.457	3.911	0.936	-5.933	2.620	0.028
ln(Fertilizer loan, ON)	1.390	7.593	0.896	2.675	3.038	0.298
ln(Cost of hired labor for transplanting)	-1.538	7.328	0.272	5.074	5.087	0.366
1=HH hired laborer, seasonal	57.295	61.283	0.260	0.736	34.314	0.879
1=HH hired laborer(s), annual	41.846	76.393	0.474	64.225	47.118	0.157
HH average rice sale price (FCFA/kg)	-2.434	1.302	0.030	0.366	0.528	0.578
1=village with better market access	11.034	41.403	0.967	5.389	25.993	0.871
Correlated Random Effect terms included		Yes			Yes	
Cases		128			262	

Notes: Annual rice sales = quantity sold from harvest through June; APE = average partial effect of explanatory variable on quantity sold, conditional on selling; SE = standard error.

It is also clear from our third Tobit (which includes an interaction term for the latter two survey years) that the APE of household rice production/AE on rice sale quantity has fallen over time (Table 26), as the interaction term on this variable is significant (p=0.07). For example, in 2006/07, households sold an extra 0.36 kg/AE of rice for each additional kg/AE of rice harvested that year (on average), yet this marginal effect fell to 0.25 kg/AE in 2008/09 and 2009/10. While this econometric result mirrors the downward trend that we see in the sample means and medians of rice sale quantities per AE over time, this result is found while also controlling for other factors that affect rice sales, such as the rice price and input costs. This means that household propensity to sell rice has declined after 2006/07 for some reason. We further investigate potential reasons for this apparent shift in sales behavior in section 7.2.

7.1.3. Effect of Coarse Grain Production/AE on Rice Sales

Household coarse grain production does not have a significant effect on rice sales quantity when averaging the partial effect of this explanatory variable across all households (Table 25, column 1, row 6). While the effect of coarse grain production on rice sales is not significant for either tercile subgroup (Table 25), the magnitude of the effect for the lowest tercile (column 4) is close to zero, whereas that for the upper terciles (column 7) suggests that an additional kg/AE of coarse grain production reduces the quantity of rice sold by the household by 0.15 kg/AE. This suggests that households in the lower tercile produce too small a quantity of coarse grains to have a significant effect on rice sales. In fact, those in the lowest tercile produce an average of 48 kg/AE of coarse grains as compared with 92 kg/AE and 97 kg/AE for the upper terciles, respectively.

7.1.4. Effect of Household Durable Goods Ownership on Rice Sales

The household durable goods index is used as a proxy for the relative wealth of households. It has a significant and negative effect on rice sales. Because the durable goods index ranges from 0 to 3.3, a one-unit change in this index is not a marginal change; consequently, we examine a marginal 0.10 unit increase in the durable goods index and find that it reduces the quantity of rice sold/AE by 7.3 kg/AE (i.e., 0.1*-73 kg/AE) (Table 24, line 7, column 1). This finding suggests that wealthier households sell less rice/AE. However, results from our second Tobit (Table 25, line 7, columns 4 and 7) show that this negative effect appears to be driven by households in the lowest tercile of cereal production/AE, and that households in the upper two terciles exhibit a significant *positive* effect of durable goods on rice sales. Since we are already controlling separately for rice production levels in this regression, this suggests that the positive effect of durable goods on rice sales for households in the upper two terciles of cereal production is due to wealth. Thus, the second Tobit suggests that among wealthier households, a 0.10 increase in the durable goods index increases rice sales quantity by 0.7 kg/AE. This is a relatively small marginal effect, but suggests that wealthier households are more likely to sell rice, perhaps because they can afford to sell rice and buy it back later (at a higher price) if necessary.

7.1.5. Effect of Fertilizer Loans and Water Fees on Rice Sales

Several of the variables measuring costs of production have a significant effect (p-value=0.10 or less) on sales quantities. For example, we find that a 1% increase in the value of a fertilizer loan from a producer association leads to an increase of 4.7 kg/AE in the quantity of rice sold (Table 25, line 14). In addition, a 1% increase in fertilizer loans owed to the ON results in a nearly significant effect (p=0.108) on rice sales of 4 kg/AE (line 16). These two results suggest that most rice producers pay back loans to associations and to the ON in cash. By contrast, the sign of the effect of fertilizer loans from input dealers is negative (though the effect is not significant), suggesting that these loans may be repaid in-kind. The average partial effect (APE) for household water fees is not significant (p=0.17) but suggests that a 1% increase in the household's water fees results in a 5.7 kg/AE increase in the quantity of rice sold (Table 25, line 13). This result simply confirms that households pay their water fees to the ON in cash—which is a legal requirement.

Given that our cost of production variables are not in per AE terms, it is not surprising that households from higher cereal production/AE terciles have higher responsiveness of rice sales to marginal changes in production costs. For example, the magnitudes of the effects of fertilizer loans on sales are much larger for households in the upper two terciles (Table 25, column 7). Likewise, the effect of housing/feeding a guest worker for a year is not significant among households in the lowest tercile, but is significant for those in the upper two terciles (Table 25, columns 4 and 7).

When we look at whether the effect of production costs on rice sales changed over time, we see that the APE of fertilizer loans from associations, input dealers, and the ON were of relatively small magnitude in 2006/07 and insignificant, though both are much larger in magnitude in the latter two years (and the former two are significant) (Table 26). The same pattern is found with the APE of water fees, which appear to become larger over time (though these effects are not significant). Recalling that there was a large decline in the percentage of household obtaining loans from input dealers post-2008, this suggests that the few households who obtained loans from input dealers in the latter two years paid pack these loans in-kind. These results also suggest that fertilizer loans have a larger effect on rice sales (positive or negative, depending on the source of the loan) in the latter two years relative to 2006/07. One explanation for this could be that in 2007, fertilizer loans may have been repaid by a combination of cash and in-kind payments, depending on the household, while they appear to have been repaid by either cash or in-kind after 2007.

7.1.6. Effect of Hired Laborers on Rice Sales

We find that households that hired one or more laborers for the entire year (and that provided lodging/food) sell 78 kg/AE more rice, on average, compared with households without guest laborers (Table 25, line 19). Since we are already controlling separately for the household's rice production/AE, this means that this variable should not be picking up the potential productivity benefits of timely labor for certain tasks. Therefore, this result suggests that these households need to sell more rice in order to cover the lodging/food expenses of their guest laborers, which are likely fed with less expensive coarse grains instead of rice. While the APE of the binary variable for seasonal guest workers is not significant, the sign of this effect is also positive, though its magnitude is much smaller than that due to a full-time guest worker.

7.1.7. Demographic and Association Membership Effects on Rice Sales

The insignificance of the APE of the dummy for membership in a producer association may be due to the fact that most households (62%) are in such an association (Table 25, line 11). In addition, if association membership does improve sales quantities, we may need to differentiate among different associations in order to find such an effect (association-specific information was not recorded by the survey). The cooperative participation dummy is also insignificant, though it is positive and of considerably larger magnitude than the association dummy (line 12). Only 8% of farmers belong to a cooperative; but cooperatives have a reputation for providing more marketing support than non-cooperative associations.

7.1.8. Effect of Rice Prices and Market Access on Rice Sales

We find that the APE of the binary variable for the three villages with 'good market access' is positive yet insignificant. This is perhaps not surprising given that our rice sale price variable is measured at the household level, and thus should capture the difference in transport costs between villages with good versus poor market access.

The APE of the household rice sale price is not close to significant for either the full sample or by household tercile (Table 25, line 20). Since we are using household-specific rather than village-level prices, lack of price variation theoretically should not be a problem.[11] Rather, this result may simply mean that rice prices do not exert a significant influence on household rice sale quantities, at least in the short run. While this explanation is contrary to the standard theoretical predictions regarding the responsiveness of farmers' production or sales to the output price, it is possible that credit constraints and the high input costs involved in producing rice are muting the price responsiveness of Macina households. For example, the majority of rice sales are likely made in order to repay input costs, and the timing of these payments is likely not negotiable for most rice producers in Macina, given credit constraints. Without such flexibility, most producers are likely to be unable to repay their labor costs,

[11] We also tried inter-acting the market access dummy with the household sale price variable, but this interaction effect was also insignificant.

fertilizer loans, and water fees without selling rice first to obtain the cash (or paying in-kind), thus most producers probably don't have the luxury of paying off loans with cash and waiting to sell the bulk of their surplus rice later in the year when rice prices are higher. This scenario may explain why we find significant (and large) effects of costs of production on the household quantity of rice sold/AE yet not rice prices. Because the results on the price variable are unexpected, we pursue additional analysis in Section 7.2 that uses quarterly rather than annual sales, so as to take better advantage of the seasonality of rice prices.

Another explanation for the lack of significant price responsiveness in our sales regressions could be our decision to model sales conditional on quantity harvested, rather than modeling price responsiveness as a two-stage process that first involves a household's decision regarding intended production levels and then second the household's decision regarding the quantity of output to sell, conditional on the quantity harvested. To our knowledge, such an approach has only been implemented in one paper (Renkow 1990), which we did not pursue here due to data limitations. In other words, there may be some limited price responsiveness at planting time via increased investment in fertilizers (if credit is available) and perhaps an effort to find land to rent in. However, at marketing time, it may well be that only price-conscious households with large marketable surpluses actively follow market prices throughout the post-harvest period and attempt to time their sales to capture the best prices. Yet, the majority of ON farmers in this sample are likely getting by on very low incomes and very limited liquidity, and thus they sell rice – both in exchange for hired labor and for cash to repay fertilizer loans and water fees.

However, we do find a significant negative effect of rice price on household rice sales for 2006/07 (Table 26), though a positive but insignificant effect for the latter two survey years. This result implies that a one-unit (FCFA/kg) increase in the rice price decreased rice sold by 2.9 kg/AE in 2006/07. Investigation of the distribution of rice prices shows that for 2007, they are lower in villages with higher sales volumes (i.e., in the *casiers*), which could explain the negative association between household rice sale prices and sales quantity. Yet, because we have separately included the time-average of the household's rice price in the model, this should enable the time-varying rice price variable to represent the partial effect of changes in rice prices around the household 3-year average of rice sale quantities. In addition, this doesn't explain why the price effect would be negative in 2006/07 but not in later years.

One potential explanation for the negative price result could be that rice producers in Macina are primarily concerned with household food security, thus they may respond to higher rice prices in the immediate post-harvest period by holding on to more rice in order to avoid paying even higher prices to buy back rice in the lean season. However, that explanation wouldn't explain why the price-sales relationship became insignificant and/or positive in the latter two survey years, unless this is simply due to the strange behavior of market prices post-2008 (i.e., the typical seasonality of rice prices in Macina did not hold in 2008/09 and 2009/10).

7.1.9. Effect of Unobserved Factors over Time on Rice Sales (Year Effects)

In the first Tobit, the two year dummies are negative as expected, and the 2010 dummy is significant (Table 24, lines 1 and 2). This effect means that – after controlling for the level of household rice production/AE, the price of rice, and household costs of production – the average effect of unobservable factors on the quantity of rice sold/AE in 2010 was a 50 kg/AE reduction in rice sold.

Finally, the signs and significance of the year dummy variables in the tercile-interaction regression suggests that the unobserved factors explaining the decline in rice sales/AE among the sample households differ by tercile of cereal production. For example, for households in the lowest tercile, the dummy variable for both 2009 and 2010 are insignificant and are of relatively small magnitude (Table 25, Column 4). By contrast, for households in the upper terciles, the dummy for 2010 is significant and suggests a rather large decline (71 kg/AE) in the quantity of rice sold in 2010, relative to the base year of 2007 (Column 7). This result is difficult to explain when combined with the fact that our earlier descriptive analysis demonstrated that the median rice production/AE for households in the second and third terciles actually increased slightly in 2009 relative to 2007.

7.1.10. Alternative Rice Sales Model of Rainy Season Production Only

To test the robustness of our results above, which use annual rice sales over the three survey years, we next run a tobit of rice sold/AE which differs from the previous base model as follows:

- the sales data cover only the rainy season harvest for 2008/09 and 2009/10, but go from harvest to July for both years;
- the fertilizer loan and labor cost variables cover costs for rice production during the rainy season only; and
- we add a binary explanatory variable that equals one if the household grew dry season rice in each of the three years and zero otherwise.

This modified sales regression enables us to avoid potential simultaneity problems that could occur in the three-year regression due to dry season harvested quantities and costs, which are included in the fertilizer loan and labor cost variables, and which may be influenced by sales from the earlier rainy season (HIV) harvest.

The results from the alternative sales model for the rainy season (not shown in a detailed table) are quite similar to those from our three-year results. For example, the APE of an additional kg/AE of rice produced in the rainy season increases the quantity of rice sold by 0.25 kg/AE, which is identical in magnitude to the APE of rice production/AE from the three-year model. When we run the same model with an interaction between each of the explanatory variables and a binary variable for households in the lowest tercile of cereal production/AE that year, the results are similar to those from the three-year model in that households in the lowest tercile sell a lower share of each additional kg/AE of production. For example, an additional kg/AE of rice production results in an increase in rice sales of 0.20 kg/AE for households in the lowest tercile, while the same increase in rice production leads to an increase of 0.25 kg/AE for households in the upper two terciles. While the magnitudes of the APEs of some variables are a bit different, the signs of key variables such as the durable goods index, water fees, fertilizer loans from associations and from input dealers are the same. As with the three-year regression, the APE of the household rice sales price is not significant. The binary variable indicating that the household grows dry season rice every year is positive yet also not significant.

7.1.11. Alternative Rice Sales Model Using Quarterly Observations

To address our lack of significant results with respect to the rice price, we next run a Tobit regression on the quantity per AE of rainy season rice sold by quarter, using only the data from 2008/09 and 2009/10 (Table 27). As those latter two survey rounds recorded the month of sale, we group sales quantities by the following 'quarters' based on the frequency distribution of sales reported in Section 5: the first period is from September-January (immediate post-harvest months); the second period is February-March (when water fees are due); the third period is April-May (when farmers start preparing for the next cropping season); and the fourth is June-July (the beginning of the hungry season). We compute the average village rice price based on sales observations in each of those time periods as well as the household's quantity of rice stocks in each time period[12]. The other explanatory variables in the quarterly sales model are household-level variables used in our earlier regressions of rice sales made from the rainy season harvests of 2008 and 2009 (i.e., cost variables only pertain to costs of production for rainy season rice in those years).

At least for these two years of data, we do find some significant price effects when we analyze rice sales behavior by quarter instead of by year. For example, households respond to a 1% increase in the rice price in September-January by reducing their quantity sold by 3.8 kg/AE, yet appear to respond to a 1% price increase in February-March by increasing their quantity sold (though this latter effect is not significant at p=0.27) (Table 27). The APEs of the price of rice are also negative in the April-May and June-July periods, though these effects are far from significant. Based on what we know about when farmers' various input loans are due to be paid, it appears that the timing of household rice sales – and thus the varying price responsiveness by quarter – is perhaps driven by farmers' need for liquidity at different times of the post-harvest period. For example, as noted above, few households sell rice in the months immediately after the rainy season harvest, most sales transactions occur between January and April, and then a few sales are made from May to July (Table 14). This pattern is seen in the results for the APEs of the quarterly dummies for these two latter time periods, which show that after controlling for other observable explanatory factors such as the rice price, the average effect of unobserved factors on rice sales results in an increase of 86 kg/AE in sales in February-March (relative to the base period of September to January), a 122 kg/AE decrease in sales in April-May, and a 298 kg/AE decrease in sales in June-July (Table 27).

The seasonal pattern of rice sales also suggests that by May, many households likely do not have rice in stock which they intend to sell; this may explain the lack of significant price response findings for the latter two time periods. In addition, the large and significant positive effects of fertilizer loans from various sources on sales in the May-June period suggest that this is the time period when such loans must be paid off (i.e., prior to the next rainy season planting) or down payments made on loans for the upcoming cropping season.

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[12] The household's rice stocks in quarter1 is assumed to be their rainy season production quantity. Their stocks in quarter2 are their rainy season production less sales quantity in quarter1, their stocks in quarter3 are their rainy seaon production less sales from quarters 1 and 2, and so on.

Table 27. Tobit Regression of Household Rainy Season Rice Sold by Quarter

	Dependent Variable: HH quantity of Rainy Season rice sold per AE (kg/AE) by time period			
Explantory variables[1]	Q1: Sept-Jan	Q2: Feb-March	Q3: April-May	Q4: June-July
1=Quarter dummy		86.002	-122.748	-298.351
		0.011	0.000	0.000
1=year 2009/10	-19.104			
	0.454			
Rice stocks from rainy season (kg/AE)[a]	-0.005	0.275	0.316	0.333
	0.969	0.007	0.044	0.083
Coarse grain production/AE (kg/AE)	-0.405	-0.241	0.281	0.230
	0.136	0.441	0.500	0.642
Dependency ratio (kids & elderly /adults)	45.148	-20.692	-58.059	27.683
	0.348	0.652	0.163	0.596
Durable goods index (3-year average)	1.125	-17.632	-36.564	166.742
	0.983	0.739	0.531	0.018
Head's education (years)	-8.146	28.952	1.338	-0.435
	0.542	0.118	0.921	0.985
1=HH has nonfarm salaried income	21.372	21.372	21.372	21.372
	0.484	0.484	0.484	0.484
1=HH has other regular nonfarm income	-10.354	-10.354	-10.354	-10.354
	0.764	0.764	0.764	0.764
1=HH belongs to producer association	13.405	13.405	13.405	13.405
	0.487	0.487	0.487	0.487
1=HH belongs to cooperative	13.000	13.000	13.000	13.000
	0.641	0.641	0.641	0.641
ln(HIV water fees)	-1.066	14.552	-12.559	8.638
	0.867	0.323	0.263	0.649
ln(HIV fertilizer loan, association)	1.068	5.781	12.872	-14.371
	0.884	0.326	0.023	0.076
ln(HIV fertilizer loan, input dealer)	-4.915	-7.106	13.190	-18.788
	0.589	0.420	0.102	0.185
ln(HIV fertilizer loan, ON)	-12.887	5.654	5.349	1.758
	0.217	0.481	0.457	0.886
ln(HIV cost of hired labor, transplanting)	-18.879	19.465	10.939	-3.464
	0.203	0.096	0.419	0.861
1=HH hired laborer, rainy season	-23.182	-23.182	-23.182	-23.182
	0.453	0.453	0.453	0.453
1=HH hired laborer(s), annual	23.121	23.121	23.121	23.121
	0.407	0.407	0.407	0.407
Average village rice sale price (FCFA/kg)	-3.838	2.084	-0.630	-0.791
	0.000	0.270	0.711	0.607
1=Village has good market access	0.655	0.655	0.655	0.655
	0.976	0.976	0.976	0.976
Cases	272	272	272	272
Correlated Random Effect terms included	Yes	Yes	Yes	Yes

Notes: 1) Tobit regression includes each explanatory variable as well as interaction between binary indicators of quarters 2, 3, and 4 and each explanatory variable (except for the year dummy). Each column shows the average partial effect of each explanatory variable in that quarter.

The negative price response from September to January may simply indicate that most households avoid selling any rice prior to February when their fertilizer loans and/or water fees begin to come due and when prices traditionally begin to rise. The positive price response in the February-March period is perhaps driven by the need to pay water fees in February.

Although we anticipated finding a more significant link between sales quantities and the price of rice when taking advantage of the seasonality of rice prices, we note that the years 2008/09 and 2009/10 did not exhibit the typical seasonality found in earlier years (Figure 4). That is, in 2008/09 and 2009/10, rice prices did not fall very much after the rainy season harvest in October/November, and then steadily climbed up until the following September; prices stayed high even after the rainy season harvest, didn't decline until April, and then began increasing again (as usual) up to September. Some of this unusual price movement in 2008/09 and 2009/10 may have been due to OPAM's interventions (or lack thereof) in both domestic and import markets (see Section 5.1.2).

7.2. Econometric Analysis of the Percentage of Household Rice Production That Is Sold

7.2.1. Introduction

To further investigate why households appear to be selling less of their rice production over time, we next run an OLS regression on the dependent variable 'household percentage of rice production that is sold (through June)' for each of our three survey years. We multiply this percentage by 100 to facilitate interpretation of the partial effects. An important caveat for this analysis is that since the only comparable sales variable across the three survey years are sales made through June, we are not able to measure the household percentage of rice production that is sold *annually*.

We use the same explanatory variables as those used above in the Tobit regressions of household rice sale quantities (see Table 24 for the descriptive statistics). One difference is that we use the natural log of rice and coarse grain quantities produced that year (and their squared terms) rather than levels, as the log transformation greatly improves the statistical significance of these variables. We run this regression using first the initial specification, and then the two additional specifications used in Section 7.1, which incorporate binary variables that are interacted with each of the explanatory variables. The first binary variable is equal to one for households in the lowest tercile of annual cereal production/AE, the second is equal to one for the second two years of the survey data. Table 28 presents the base model results using the initial specification (columns 1-3) and those with the interaction terms for the rice production/AE terciles (columns 4-6 for the low production tercile and columns 7-9 for the top two terciles). Table 29 presents the results of the model with year effects (columns 1-3 covering 2006/07, which represents a year of relatively normal prices, and columns 4-6 covering the 2008/09 and 2009/10 production years combined, when prices were unusually high).

The paragraphs following the tabular presentation of the modeling results provide an interpretation of those results for the following categories of effects: rice production/AE, input and credit costs, rice prices, and unobserved time factors.

Table 28. OLS/FE Regressions of the Percentage of Rice Production Sold: Base Model and Model with Household Cereal Production/AE Interaction Terms

	-------- Dependent Variable: 100 X % of HH rice production that is sold by June --------								
	All HHs			HHs in bottom tercile of cereal production/AE			HHs in middle & upper terciles of cereal production/AE		
Explanatory Variables	PE	SE	p-value	PE	SE	p-value	PE	SE	p-value
1=year 2008/09	-4.349	5.139	0.398	3.312	9.382	0.724	-7.939	6.654	0.233
1=year 2009/10	-9.922	4.374	0.024	-14.469	8.360	0.084	-8.443	5.727	0.140
1=HH in lowest tercile, cereal production				-0.886	10.703	0.934			
ln(Rice production, kg/AE)[a]	-8.749	4.438	0.049	-1.939	10.337	0.851	-11.408	6.868	0.097
ln(Coarse grain production, kg/AE)	0.275	1.392	0.844	0.820	2.389	0.732	0.487	1.557	0.754
Dependency ratio (kids & elderly /adults)	-0.393	5.472	0.943	-1.598	8.115	0.844	3.432	6.473	0.596
Head's education (years)	0.862	0.886	0.331	0.211	1.828	0.908	1.045	0.989	0.291
ln(Water fees)	7.812	3.780	0.039	14.020	6.276	0.025	5.823	4.277	0.173
ln(Fertilizer loan, association)	0.516	0.297	0.082	0.266	0.555	0.631	0.454	0.366	0.216
ln(Fertilizer loan, input dealer)	-0.367	0.337	0.277	-0.693	0.626	0.268	-0.394	0.413	0.340
ln(Fertilizer loan, ON)	0.045	0.419	0.915	-0.359	0.999	0.719	0.028	0.480	0.954
ln(Cost of hired labor for transplanting)	1.276	0.676	0.059	0.173	0.917	0.850	2.083	0.990	0.035
1=HH hired laborer, seasonal	1.090	4.396	0.804	-12.442	9.746	0.202	2.312	5.036	0.646
1=HH hired laborer(s), annual	7.181	5.316	0.178	0.597	15.502	0.969	7.009	5.730	0.221
HH average rice sale price (FCFA/kg)	0.006	0.076	0.931	-0.069	0.136	0.611	0.041	0.098	0.674
Household Fixed Effect included		Yes			Yes			Yes	
Cases		392			128			262	

Notes: A) A rice production/AE squared term is included in the regression using all households but not in the regression using tercile interaction terms.

Table 29. OLS/FE Regression of the Percentage of Rice Production Sold: Model with Year Interaction Term

	Dependent Variable: 100 X % of HH rice production that is sold by June					
	All HHs APEs in 2006/07			All HHs APEs in 2008/09 & 2009/10		
Explanatory Variables	PE	SE	p-value	PE	SE	p-value
1= year 2008/09 & 2009/10				1.989	10.112	0.844
ln(Rice production, kg/AE)[a]	-7.943	6.480	0.220	-4.924	4.627	0.287
ln(Coarse grain production, kg/AE)	-0.278	1.633	0.865	1.062	1.498	0.478
Dependency ratio (kids & elderly /adults)	-5.837	6.136	0.342	-0.940	6.066	0.877
Head's education (years)	1.788	1.072	0.095	0.377	1.022	0.712
ln(Water fees)	12.277	4.494	0.006	1.574	4.330	0.716
ln(Fertilizer loan, association)	0.587	0.524	0.263	0.565	0.349	0.105
ln(Fertilizer loan, input dealer)	0.174	0.522	0.738	-0.647	0.405	0.110
ln(Fertilizer loan, ON)	-0.405	1.237	0.743	0.084	0.448	0.851
ln(Cost of hired labor for transplanting)	0.895	0.996	0.368	1.825	0.832	0.028
1=HH hired laborer, seasonal	-2.153	6.366	0.735	2.202	5.466	0.687
1=HH hired laborer(s), annual	1.084	7.999	0.892	10.227	6.833	0.134
HH average rice sale price (FCFA/kg)	-0.192	0.212	0.367	0.102	0.074	0.168
Household Fixed Effect included		Yes			Yes	
Cases		128			264	

Notes: A) A rice production/AE squared term is included in the regression using all households but not in the regression using time-period interaction terms.

7.2.2. Effect of Rice Production/AE on Percent of Rice Production Sold

In the regression output (not shown here), the coefficient on the log of rice production/AE is positive, while its square is negative, indicating a concave response of the percentage off rice production sold to increases in rice production/AE. However, this response is only positive from 0 to 171 kg/AE of rice production, which represents only the lowest 10% of the distribution of household rice production over the three year period. Thus, for the majority of rice producers, the APE of rice production/AE is negative (Table 25). This implies that for most rice growers, the more rice that they produce, the lower the percentage of their rice production that they sell. However, there is an important difference in the APE of rice production by tercile of household cereal production/AE. The APE of rice production is insignificant for the lowest tercile, while that for the upper two terciles is significant and suggests that a 1% increase in rice production leads to a reduction of 11% in the percentage of rice production that is sold (Table 28).

7.2.3. Effect of Fertilizer Loans and Water Costs on Percent of Rice Production Sold

As with the sales quantity regressions, we find significant effects of various costs of rice production on the percentage of household rice production that is sold. For example, a 1% increase in a household's water fees increases the percentage of rice sold by 7.8 points (from 0 to 100), and a 1% increase in hired transplanting labor increases the percentage of rice sold by 1.2 points (Table 28). The size of fertilizer loans also affect the percentage of rice sold, as a 1% increase in producer association fertilizer loans increases the percentage of rice sold by

0.5%. The sign of the APEs for each of these costs of production are consist with the effects of these same variables on the quantity of rice sold, as reported in Table 25. For example, an increase in water fees leads to an increase in the quantity of rice sold/AE as well as a higher percentage of rice sold. However, while the APEs of various costs of production have a significant effect on the percentage of rice sold, these factors would not seem to fully explain the decline in the dependent variable over time. For example, the only cost of production that has a negative effect on the percentage of rice sold is loans from input dealers, and both the frequency of households acquiring fertilizer from an input dealer on loan and the mean loan value fell over time (Table 24).

7.2.4. Effect of Rice Prices on Percent of Rice Production Sold

The APEs of the price of rice are far from significant in the initial specification and the in the model with the cereal production tercile interactions (Table 28). However, the APE for the price of rice in 2008/09 and 2009/10 is not far from significant (p=0.16) and suggests that households responded to a 1% increase in the price of rice by increasing the percentage of their rice production that they sold by 0.1% (Table 29). Interestingly, the sign of the price effect in 2007/08 is negative (though this effect is insignificant), which may suggest a change in the general direction of price responsiveness of the share of production that is sold (Table 29).

7.2.5. Effect of Unobserved Factors over Time (Year Effects) on Percent of Rice Production Sold

The dummies for both 2008/09 and 2009/10 are negative, and the 2009/10 dummy is also significant. This latter result means that the average effect of unobserved factors resulted in a decline of 9.9 points in 2009/10 in the household percentage of rice production that is sold, relative to the base year 2007/08. This means that something other than our observable determinants such as household rice production quantities, rice prices, and household costs of rice production played an important role in the decline of the household percentage of rice production that is sold in 2009/10. While unobservable factors are by definition not known, there are several potential explanations for this shift in marketing behavior. The first might simply be a methodological shortcoming of our analysis due to our inability to observe sales made between August and October. That is, households that enjoy surplus rice stocks after repaying fertilizer loans and water fees may be holding on to their rice longer than in previous years to take advantage of the higher price environment. An alternative explanation might simply be that given the higher price environment, households' tolerance for food market price risk is lower thus they are choosing to hold on to more of their surplus grain.

8. CONCLUSIONS

This paper uses descriptive and econometric analysis of household survey data to inform the debate surrounding the effects of higher cereal prices and the GOM's *Initiative Riz* on household rice production and marketing in the *Office du Niger*. In this section, we briefly summarize the empirical findings from this analysis with respect to the research questions laid out at the beginning of the paper. These findings describe the situation for farmers in the Macina Sector of the *Office du Niger* and are based on a sample that was equally divided among farms located in the *casiers* (improved quality irrigation infrastructure) and the *bord de casiers* (lesser quality irrigation infrastructure).

When did cereal prices begin to rise in Macina markets, and to what extent did they increase?How did farmers respond to rising cereal prices and the Initiative Riz with respect to their area cultivated to rice and coarse grains? Relative to 2006/07, the average household sale price of rice in Macina was 25% higher in 2008/09 and 17% higher in 2009/10. However, Macina farmers responded to these higher prices with only minimal increases in their area cultivated to rice in 2008/09. For example, as compared with 2006/07, the mean (median) of household annual area cultivated to rice increased 15% (11%) in 2008/09, yet declined in 2009/10 to a level closer to that of 2006/07. Much of this one-year increase in cultivated rice area was due to a one-year increase in the percentage of households in the *bords de casiers* that grew dry season rice. A likely explanation for this minimal area response is that it is difficult for households to increase their access to irrigated land, and only a small portion of irrigated plots are appropriate for cultivation in both the rainy and dry seasons.

How did rising cereal prices and/or the Initiative Riz affect fertilizer use in Macina? The mean and median of total household fertilizer use in Macina actually fell in 2008 and 2009, relative to 2007, thus we cannot conclude that either the IR or the rising producer prices stimulated an increase in fertilizer use. While the subsidy enabled most Macina households to obtain fertilizer on credit at the same prices as they had paid in 2007, households without access to fertilizer credit through producer associations did pay higher prices when purchasing from input dealers. While lack of credit and higher prices limited purchases for some households, the major decline in use in 2008 was due to late delivery associated with delays in implementation of the IR program.

Although we cannot credit cereal price incentives or the IR with stimulating an increase in fertilizer use over 2006/07 levels, the impact of the fertilizer subsidy program needs to be understood in the context of rising international fertilizer prices. The real international prices of urea and DAP in 2008 were 200 to 300% higher than the average real prices of those fertilizers between 2001 and 2006 – an increase that was two to three times larger in percentage terms than the increase in the international rice price that same year (in 2008). With that context in mind, it appears that the main effect of the fertilizer subsidy program was to protect farmers from full transmission of the considerably higher international fertilizer prices. While the subsidy did not result in an increase in fertilizer use, it very likely prevented what would have been a much larger reduction in household fertilizer use, had all ON rice producers been forced to face the full increase in international fertilizer prices during this time period.

Did the Initiative Riz and higher expected cereal prices lead to higher yields and more aggregate rice production, as anticipated by the GOM? Compared with 2006/07, median and mean household rice production/AE fell slightly in 2008/09 and then fell dramatically in 2009/10. This appears to be due to a combination of relatively lower fertilizer use per hectare after 2006/07, late fertilizer applications, and an increase in both the frequency of water control problems as well as the magnitude of yield losses caused by such problems. However, there are important distinctions to note regarding the average rice production and yields over time of different kinds of rice producers. For example, if we rank Macina rice producers by terciles of a three-year average of their total household cereal production/AE, we find that those in the lowest tercile experienced 13% lower rice production and yields in 2008/09, as compared with 2006/07. By contrast, those in the middle and upper terciles of total household cereal production/AE actually enjoyed slightly higher rice production in 2008/09. In addition, while households in all terciles experienced large yield and production losses in 2009/10, the magnitude of the losses were much larger for those in the lowest tercile. Farms with the lowest average production/AE over the survey period appear to be less able than others to overcome production constraints.

Does econometric analysis of household rice yields in Macina help to explain the decline in rice production over time? Our econometric analysis of rainy season household rice yields in 2008 and 2009 found that an increase in both the frequency and magnitude of yield losses associated with poor water control largely explain the sharp decline in average rice yields between these two years. For example, the percentage of households reporting one or more problems with their rice production increased after 2006/07, especially those related to water control, and our yield analysis demonstrates that problems such as poor water control, late planting, or other problems can reduce household rice yields by 65 to 880 kg/ha, depending on the problem and the type of rice producer. In addition, mean (median) total fertilizer use appears to have declined by about 20% (10%) in 2008/09 relative to 2006/07, before increasing slightly in 2009/10. Based on nitrogen response estimates from yield regressions, we can estimate that the median reduction in fertilizer applied per hectare of 30 kg/ha from 2007 to 2009 could by itself explain a reduction in rice yields of 138 kg/ha (among farms that used urea).

The study also confirmed a yield gap between smaller and larger farms (defined in this case by irrigated area per AE). Contrary to what we might predict, average nitrogen and manure application rates are very similar for smaller and larger farms. However, while both smaller and larger farms reported production problems such as poor water control, late planting and other problems with relatively similar frequencies, it is clear that smaller farms face considerably larger yield losses when experiencing such events. Second, while both smaller and larger farms are equally likely to grow rice on a lower quality field (*hors casiers*), the *hors casiers* fields managed by smaller farms exhibit much lower yields/ha. For example, yields from *hors casiers* fields managed by smaller farms faced a yield deficit of 750 kg/ha (relative to yields from improved *casiers* fields), while *hors casiers* fields controlled by larger farms had yields comparable to their *casiers* fields. These results suggest that the smaller farms may be cultivating *hors casiers* fields of lesser quality (poorer soils or irrigation control) and/or that smaller farms are less able to efficiently manage their *hors casiers* fields due to labor and resource constraints.

Did survey households reduce the percentage of their rice production that they sold over time? The median household quantity of rice sold per adult equivalent (AE) fell from 265 kg/ha in 2006/07 to 215 kg/ha in 2008/09, and then to 166 kg/ha in 2009/10. Likewise, the median percentage of household rice production that was sold fell from 48% in 2006/07 to 39% in 2008/09, and then to 35% in 2009/10. Households in the lowest tercile of total cereal production per AE experienced rather large reductions in their rice production and yields in those latter two years. These production losses may well explain the decline in rice sales among these households. However, households in the middle and upper tercile did not face production losses in 2008/09 yet still reduced their sales quantities and the percentage of their rice production that was sold.

Our ability to draw firm conclusions from these cross-year comparisons is constrained to some extent because the survey only recorded sales through July of 2009 and 2010, respectively, so any sales after July are not taken into account. While information on rice sales by period from the 2006/07 survey suggest that 87% of household rice sales are made before July, we cannot be certain that this sales behavior has remained constant over time.

Does econometric analysis of household rice sales behavior explain why the quantity of rice sold and the percentage of rice production sold both declined over time in Macina? The principal observable factors affecting the household quantity of rice sold are household rice production that year and costs of rice production such as fertilizer loans and water fees. Surprisingly, the household's rice sale price does not have a significant effect on sale quantity. After doing some additional analysis of rice sales by quarter (to allow for more variation in the price of rice), we find limited and somewhat conflicting evidence of price responsiveness of rice sales. This lack of price responsiveness may be due to the fact that monthly prices in 2008/09 and 2009/10 did not exhibit the typical seasonality found in earlier years. That is, in contrast to earlier years, prices stayed high even in the months immediately after the rainy season harvest, didn't decline until April, and then began increasing again (as usual) through September.

Given the declines over time in average rice production/AE among households in the lowest tercile of cereal production, it is not surprising that their average quantity of rice sold also fell over time. Yet, given that households in the upper terciles did not face large production or yield losses in 2008/09 (though they did in 2009/10), and given that there do not appear to have been sufficient changes in other factors over time (such as the costs of production) that could explain the change in their rice marketing behavior, something different (and likely unobservable) would seem to explain this apparent shift in marketing behavior. One explanation is that the higher producer prices in an environment of relatively stable production costs (e.g., water fees and fertilizer) permitted farmers to pay off their production debts with a smaller quantity of rice, thus putting them in a position to hold on to their surplus rice longer than in previous years in anticipation of even higher prices. An alternative explanation might be that surplus rice producers are consuming more rice than before (i.e., including gifts to relatives) as a result of the income effect of higher rice prices. There is also the issue of what role the confusion about OPAM's rice marketing activities might have played in farmers' rice marketing decisions. OPAM was funded to purchase rice following the 2008/09 production season but ended up using those funds to import rice because they were unwilling to pay farmers the prevailing market price. Similar problems continued in subsequent seasons, leading farmers to hold stocks in expectation of significant OPAM market intervention, which failed to occur before 2011. While further research into this issue may be warranted, the extent to which farmers actual decision making processes can be extracted from the existing survey data is limited. Some combination of qualitative and quantitative data collection is probably most appropriate, but also difficult and costly to obtain on a broad scale.

There are a number of practical policy implications that flow from this study with respect to the government's goal of increasing marketed rice supply:

1) Because the study confirmed that increased fertilizer use can increase rice yields significantly, the GOM should be able increase marketable surpluses of rice by focusing its attention on improvements in fertilizer supply (particularly timeliness and reducing delivery costs), input credit, and better monitoring and evaluation of the costs and benefits of the input subsidy program for both farmers and private sector suppliers.
2) Efforts to increase fertilizer use are not likely to achieve significant increases in rice production or marketed supply unless they are accompanied by improvements in water control and other management practices to avoid the significant yield reductions reported in survey data. This implies a need to balance budgetary support for input subsidies and support for services that render those inputs more effective.
3) Although this paper did not address the contribution of other technical production issues (e.g., improved varieties, particularly for dry-season production; lower-cost approaches to fertilizer use; improved management practices to avoid soil acidification), continued benefits from fertilizer will be contingent on continued research and extension on these topics to ensure that fertilizer is being used as efficiently as possible and not having negative impacts on soil quality.
4) Roughly one third of ON farms are unable to provide for their own minimum cereal needs of 214 kg/capita after paying for production costs; this is not a sustainable situation and appears to be more of a problem for small farms than for large farms, suggesting that more attention needs to be given to policies concerning access to irrigated land for family farms and/or increasing opportunities for income diversification through off-farm employment that does not compete with farm demands for labor.
5) OPAMs role in rice marketing since the beginning of the IR has been unpredictable and not very helpful to rice producers; the GOM needs to reconsider its policy of OPAM intervention in rice markets, making it more transparent and predictable; reliable funding must be part of the picture or marketing is better left entirely to the private sector.
6) Although more research is needed to better understand farmers' production and marketing responsiveness to output prices, the survey results suggest that factors such as production costs and credit repayment scheduling (particularly fertilizer and water payments) may be more important influences on production levels and marketing behavior than output prices.
7) Mali is far behind many other African countries in its ability to systematically monitor and analyze the performance of its agricultural sector through the use of longitudinal data bases. Despite the many caveats mentioned about the panel data underlying the analyses presented in this paper, the data set is unique in its coverage of both production and marketing information for the same set of farms over the span of three years. There is a need for the GOM to invest in Mali's capacity to collect and analyze longitudinal data on the agricultural sector at a scale that is large enough to obtain representative results for at least the main production zones of the country; to date these types of investments have been made by donors and have not endured.

APPENDICES

Appendix 1. Household Fertilizer Applied to Rice, by Season, Macina, 2008/09, 2009/10

	2008/09	2009/10	2008/09	2009/10
Rainy season [1]	--- mean ---		--- median ---	
% HHs growing rice	93.9	94.6		
% Rice growers using fertilizer on rice	95.7	94.2		
Quantity fertilizer applied/ha of rice (kg/ha)	242.3	273.9	253.9	269.6
% HHs obtaining fertilizer on credit	79.9	87.0		
% of fertilizer obtained via credit	78.5	86.2		
Total value of fertilizer loan/ha [2]	75,191	78,004	75,000	76,262
Fertilizer price paid (FCFA/kg)	298	294	280	283
Cases of rice growers	134	131	134	131
Dry season [1]				
% HHs growing rice	68.0	44.2		
% Rice growers using fertilizer on rice	65.7	44.5		
Quantity fertilizer applied/ha of rice (kg/ha)	290.1	327.5	276.2	300.0
% HHs obtaining fertilizer on credit	70.7	35.5		
% of fertilizer obtained via credit	68.6	35.5		
Total value of fertilizer loan/ha [2]	92,077	120,189	84,000	103,929
Fertilizer price paid (FCFA/kg)	321	307	300	300
Cases of rice growers	92	62	92	62

Source: Authors' calculations based in IER-CIRAD-MSU household survey data.

Appendix 2. Median Household Cropping Patterns by Year, Season, and Location (*Casiers/Bord de Casiers*)

	--- HHs in Casiers ---			-- HHs in Bord de Casiers --			----- All HHs -----		
	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10
Rainy season	------------------------------- median -------------------------------								
% growing rice	95.8	93.0	94.4	88.2	94.7	94.7	91.8	93.9	94.6
% growing coarse grains	8.5	18.3	12.7	88.2	88.2	76.3	49.7	54.4	45.6
% growing other crops	2.8	7.0	7.0	3.9	23.7	11.8	3.4	15.6	9.5
rice area planted (ha), growers	3.50	3.86	3.19	2.70	2.91	2.58	3.00	3.00	3.00
CG area planted (ha), growers	1.50	0.30	1.00	3.50	3.00	3.00	3.00	2.50	3.00
OC area planted (ha), growers	0.23	0.35	0.12	2.04	1.50	0.25	0.23	1.00	0.25
% of CG in total area planted[1]	45.2	20.0	21.4	59.7	50.0	50.3	57.1	45.5	50.0
% of OC in total area planted	14.2	13.0	12.5	29.3	26.5	5.3	14.2	18.8	4.3
rice area planted (ha), all HH	3.09	3.55	3.00	2.25	2.65	2.50	2.86	3.00	3.00
CG area planted (ha), all HH	0.00	0.00	0.00	3.00	2.75	2.00	0.00	0.25	0.00
OC area planted (ha), all HH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dry season									
% growing rice	62.0	64.8	46.5	38.2	71.1	42.1	49.7	68.0	44.2
% growing other crops	88.7	69.0	95.8	90.8	69.7	89.5	89.8	69.4	92.5
rice area planted (ha), growers	1.00	1.00	1.00	1.00	0.80	0.50	1.00	1.00	1.00
OC area planted (ha), growers	0.18	0.25	0.22	0.25	0.28	0.25	0.24	0.25	0.25
% of OC in total area, growers	29.2	28.6	84.2	100.0	33.3	100.0	20.0	21.9	21.4
rice area planted (ha), all HH	0.50	0.50	0.00	0.00	0.50	0.00	0.00	0.50	0.00
OC area planted (ha), all HH	0.15	0.13	0.20	0.24	0.14	0.25	0.22	0.14	0.25
Cases	72	72	72	76	76	76	148	148	148

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.
Notes: All computations based on sample of panel households. CG = coarse grains; OC = other crops

This table contains the median values for Table 7 presented in the text.

Appendix 3. Median Household Rice Production Statistics by Year, Season, and Location (*Casiers/Bord du casier*)

	------ HHs in Casiers ------			-- HHs in Bord de Casiers --			----- All HHs -----		
	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10	2006/7	2008/9	2009/10
Rainy season [1]	---------------------------------- median ----------------------------------								
% HHs growing rice	95.8	93.0	94.4	88.2	94.7	94.7	91.8	93.9	94.6
Area planted to rice (ha)	3.50	3.86	3.19	2.70	2.91	2.58	3.00	3.00	3.00
Rice production (kg)	6,818	7,646	5,942	3,896	3,920	4,018	4,968	5,065	4,627
Rice production/AE (kg/AE)	722	642	479	403	424	434	562	532	469
Rice yield (kg paddy/ha)	3,188	3,500	2,895	2,755	2,393	2,250	3,034	3,000	2,547
Cases of rice growers	68	66	67	67	72	72	135	138	139
Dry season [1]									
% HHs growing rice	62.0	64.8	46.5	38.2	71.1	42.1	49.7	68.0	44.2
Area planted to rice (ha)	1.00	1.00	1.00	1.00	0.80	0.50	1.00	1.00	1.00
Rice production (kg)	1,583	1,802	1,656	1,826	1,364	1,200	1,705	1,705	1,461
Rice production/AE (kg/AE)	165	166	213	168	134	93	166	150	151
Rice yield (kg paddy/ha)	2,869	3,000	3,500	3,213	2,903	3,000	3,000	3,000	3,300
Cases of rice growers	44	46	33	29	54	32	73	100	65
Annual [1]									
% HHs growing rice	95.8	93.0	94.4	89.4	97.3	94.7	92.5	95.2	94.6
Area planted to rice (ha)	4.50	4.50	3.80	3.00	3.30	3.10	3.45	3.82	3.49
Rice production (kg)	8,718	9,091	6,331	4,968	4,505	4,651	6,088	6,045	5,292
Rice production/AE (kg/AE)	861	840	589	491	474	507	621	640	512
Rice yield (kg paddy/ha)	3,162	3,383	2,925	2,750	2,471	2,336	3,000	3,000	2,507
Cases of rice growers	68	66	67	68	74	72	136	140	139

Source: Authors' calculations based on IER-CIRAD-MSU household survey data.
Notes: 1) Rice area planted and production figures computed only for rice growers that season. All computations based on the sample of panel households.

This table presents the median values for data presented in Table 10 of the text.

Appendix 4. Rice and Coarse Grain Production, Sales, and Purchases by Location and Year.

Part I. Detailed Statistics

Household production characteristic	------ 2006/07------ Non-rice Selling HHs[4]	Rice-Selling HHs[4]	All HHs[1]	------ 2008/09 ------ Non-rice Selling HHs[4]	Rice-Selling HHs[4]	All HHs[1]	------ 2009/10 ------ Non-rice Selling HHs[4]	Rice-Selling HHs[4]	All HHs[1]
	---------- median ----------			---------- median ----------			---------- median ----------		
HHs in the casiers									
Rice yield, hiv (kg/ha)[2]	4,084	3,188	3,209	3,424	3,468	3,468	2,213	2,905	2,895
Rice yield, cs (kg/ha)[2]	2,500	2,925	2,869	3,000	3,000	3,000	.	3,500	3,500
Rice production/AE (kg/AE)	553	866	863	1,490	814	833	470	624	589
Rice retained/AE (kg/AE)[3]	498	283	301	1,341	453	456	423	304	306
Rice sold/AE (kg/AE)[4]	0	382	366	0	281	274	0	191	171
% of rice production sold	0	53	52	0	38	38	0	34	32
Coarse grain production (kg/AE)	0	0	0	130	0	0	0	0	0
Cereal production (kg/AE)	498	779	777	1,471	732	750	423	561	530
Cereals retained (kg/AE)	498	304	307	1,471	452	456	423	306	311
Coarse grain purchases (kg/AE)	47	52	50	0	48	43	79	64	64
Cereal purchases (kg/AE)	47	59	58	0	48	43	115	65	65
Net cereals available (kg/AE)[5]	569	341	354	1,471	486	496	538	394	399
Cases	3	65	68	2	64		2	65	67
HHs in bord de casiers									
Rice yield, hiv (kg/ha)[2]	1,800	2,939	2,761	1,192	2,463	2,393	750	2,383	2,250
Rice yield, cs (kg/ha)[2]	.	3,300	3,300	4,200	2,866	2,903	2,100	3,000	3,000
Rice production/AE (kg/AE)	177	562	492	136	490	474	63	572	507
Rice retained/AE (kg/AE)[3]	159	257	256	122	240	236	57	256	228
Rice sold/AE (kg/AE)[4]	0	203	181	0	177	158	0	188	166
% of rice production sold	0	42	36	0	41	40	0	38	35
Coarse grain production (kg/AE)	63	127	126	28	109	103	144	90	93
Cereal production (kg/AE)	295	700	690	185	579	562	230	631	617
Cereals retained (kg/AE)	295	469	450	185	363	357	230	392	361
Coarse grain purchases (kg/AE)	69	0	0	0	15	15	55	12	21
Cerea purchases (kg/AE)	101	4	9	40	17	17	81	15	21
Net cereals available (kg/AE)[5]	421	486	485	190	385	377	250	382	339
Cases	7	61	68	7	67	74	9	63	72

Source: Authors' calculations based in IER-CIRAD-MSU household survey data.

Notes: 1) Figures only computed among households which grew rice that year. 2) Rice yield is reported as kg of paddy per hectare; rice production as kg of grain. Rice yield in dry season only computed among subset of EAs which grew rice then. 3) Rice retained = rice production - rice sales. 4) Rice sold for 2006/07 only includes sales made at harvest and the beginning of the next rainy season; Rice sold for latter two years only includes sales through June. 5) Net cereals available = cereal production + cereal purchases - cereal sales.

Appendix 4. Rice and Coarse Grain Production, Sales, and Purchases by Location and Year.
Part II. Absolute and Percentage Changes in Household Yields, Production, and Sales

		----- 2008/09 -----		----- 2009/10 -----	
Household Production Characteristic	2006/07 median[1]	Absolute change between median in **2006/07** and 2008/09	% change between median in **2006/07** and 2008/09	Absolute change between median in **2006/07** and 2008/09	% change between median in **2006/07** and 2008/09
HHs in the casiers					
Rice yield, hiv (kg/ha)[2]	3,209	259	8.1%	-314	-9.8%
Rice production/AE (kg/AE)	863	-30	-3.5%	-274	-31.7%
Rice sold/AE (kg/AE)[3]	366	-93	-25.4%	-196	-53.5%
HHs in the bord de casiers					
Rice yield, hiv (kg/ha)[2]	2,761	-367	-13.3%	-511	-18.5%
Rice production/AE (kg/AE)	492	-18	-3.7%	15	3.1%
Rice sold/AE (kg/AE)[3]	181	-23	-12.7%	-15	-8.3%

Source: Authors' calculations based in IER-CIRAD-MSU household survey data.
Notes: 1) Figures in this table are based on medians from Appendix Table 4.1 2) Figures only computed among households which grew rice that year. 3) Rice sold for 2006/07 only includes sales made at harvest and the beginning of the next rainy season; Rice sold for latter two years only includes sales through June.

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