CHAPTER 3

MIGRATION, RURAL DEVELOPMENT, AND FOOD SECURITY IN WEST AFRICA

MIGRATION, RURAL DEVELOPMENT, AND FOOD SECURITY IN WEST AFRICA

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A. Summary Note*

This study examines the impact of return migration from Côte d'Ivoire (economic pole of West Africa) to Burkina Faso (enclaved Sahel country). The paper first gives the context for the migratory crisis in the region. Then, a methodology robust to the selection bias is used to examine the prospects for return migration and its effects on yields of cereal production. When studying food security and its stability in the Sahel, it is not realistic to keep the current production conditions constant. Among the pertinent questions in Sahel agriculture, the combined impact of the technological evolution and current demographic trends is a basic element. Technological innovation in cereal agriculture has the potential to eradicate the problems of food insecurity by improving yields. These technologies, if they prove to be of interest, could ultimately have carryover effects on all farms within the context of rapid demographic growth. While intense human flows have freely circulated between the countries of West Africa in the past, the Sahel countries are increasingly the destination of return migration, particularly between Côte d'Ivoire and Burkina Faso.

Formerly the pole of immigration in West Africa, Côte d'Ivoire is moving to a position of net re-export of labor over the period 1988–92 (with a declining migratory rate of +0.41 percent per year) vis-à-vis the network of countries studied by the REMUAO[13] survey (Burkina Faso, Ivory Coast, Guinea, Mali, Mauritania, Niger, Senegal and Nigeria for specific aspects of the questionnaires). This recent phenomenon is actually largely explained by the increasingly large return of Burkinabè migrants, causing an expansion of the rural population in that country. Despite this reality and its various consequences, the migration is among the least studied demographic phenomena in West Africa.

Here, we shall examine the effects of these migration returns on the productive efficiency of their original households in the Sahel. Concentrating on the households with migrants has the advantage of comparing their situation with those simulated without the contribution of migration, contrary to the usual comparison of migrant and nonmigrant local households. Indeed, in their study, Barham and Boucher (1998) observed that the incomes of individuals from households who did not experience migration are on average 40 percent systematically higher than those of nonmigrants coming from households with cases of migration. However, the simulated situation requires an estimate of the consequences of this potential return of "ex-migrants" in terms of the level of participation in local activities and the incomes of other members who usually remain in the Sahel. The net effects are consequently examined in two scenarios involving the "ex-migrants'" behavior toward technological agricultural innovation. In this exercise, the two scenarios envisaged are that the migrants simply prefer to join the group of "nonadopters" (scenario 1) or they adopt the local technology for managing the natural resources, that is, stone bunds[14] (scenario 2).

In a household model in the presence of high transaction costs (Dutilly-Diane et al. 2003), the households as food buyers try to bypass the high prices by increasing their production to ensure food self-sufficiency. The main instrument for increasing agricultural productivity in the Sahel is the introduction of stone bunds that permit water drainage and erosion control. In sum, the production and consumption

*Original summary was written in French.

[13]Network of Surveys on Migration and Urbanization in West Africa (NESMUWA).

[14]Embankments for rainwater harvesting and soil erosion control.

decisions here depend on the endogenous choice of stopping migration, adopting this technology of stone bunds, and the strategy for participating in the food market. Thus, the empirical approach is based on an estimate of a reduced form of the choices of return migration and technological adoption, and their combined effects on agricultural yields. In all, the migration concerns 46 percent of the households surveyed in 2002 in four departments in northeast Burkina Faso: Gorgadji, Gorom-Gorom, Dori, and Bani. From this survey, a panel of all adult members of the household was formed, distinguishing between households that did or did not use the stone bunds. The following results concern the two selection equations and the performance in agricultural yields.

1. *Consideration of the decision for return migration*. This decision positively depends on the availability of fields in the household and its average age, and the households in the region of Gorom-Gorom have relatively more incentive to return. Migrants would remain in Côte d'Ivoire if their household is self-sufficient in food and if the original household has higher human capital (literacy).
2. *The results of the equation for adoption of stone bunds* show that in the two scenarios, participation in the food market as a buyer has a significantly negative effect. This indicates that, contrary to those who are self-sufficient or sellers, access to the market as a buyer could cause diversification toward (more monetary) activities, which is confirmed by the negative effect of distance to markets. Indeed, the high purchase price of grains forces the buyers to move toward activities that bring them liquidity (raising animals, panning for gold, and the labor market). The age of the household negatively affects the propensity of the return migrant to adopt, while public education favors adoption. However, while it plays a positive role in the decision to adopt in scenario 2, the income risk seems to operate in the reverse direction in the scenario where the migrants are assumed not to adopt (scenario 1).
3. *Effect on productivity.* In the event of nonadoption by the return migrants (scenario 1), the "adopter" households significantly benefit from agriculture in the lowlands. However, the more formal rules there are for managing farmer/livestock relations, the lower the yields. Ethnic households with an agricultural tradition and a high level of masculinity also show greater yields. Being in the region of Oudalan (Gorom-Gorom and Gorgadji) in this same scenario 1 also favors yields as it does human capital. In the case of the enlarged group of "nonadopters," only the ethnic group and the type of soil seem, however, to influence the yields if nonadopters are joined by the returning migrants. In examining scenario 2, in which all the returning migrants join the "adopter" group, very similar, but generally less significant, results are obtained. On the other hand, the practice of letting fields go fallow benefits the yields of the "adopters." In general, however, there are better agricultural yields if the returning migrant adopts the good techniques for managing water and fighting erosion with the stone bunds, since the households that do not adopt them benefit from positive externalities of a more marked adoption phenomenon.

In the scenario of majority failure to adopt, serious consequences for the food security of the populations are probable. Consequently, the regional institutions should be interested in the basic question of inserting returning migrants in a rural setting. The West African region should favor a development strategy in the Sahel that promotes inexpensive, efficient technology like the stone bunds if it wants to prevent the migratory crisis from endangering food security and the environment.

MIGRATIONS, DÉVELOPPEMENT RURAL ET SÉCURITÉ ALIMENTAIRE EN AFRIQUE DE L'OUEST

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A. Résumé*

Cette étude examine l'impact de la migration de retour de la Côte d'Ivoire (pôle économique d'Afrique de l'Ouest) vers le Burkina Faso (pays enclavé sahélien). L'article met d'abord en évidence le contexte de crise migratoire dans la région. Ensuite une méthodologie robuste au phénomène de sélection est utilisée afin d'examiner la perspective de retour de migration et ses conséquences sur les rendements de la production céréalière agricole. Quand on étudie la sécurité alimentaire et sa durabilité dans le Sahel, il n'est pas réaliste de garder les conditions actuelles de production constantes. Parmi les questions pertinentes dans l'agriculture sahélienne, l'impact combiné de l'évolution technologique et des tendances démographiques actuelles est un élément essentiel. L'innovation technologique dans l'agriculture céréalière a le potentiel d'éradiquer les problèmes d'insécurité alimentaire par le biais de l'amélioration des rendements. Ces technologies, si elles se révèlent intéressantes, pourraient avoir des effets cumulatifs sur l'ensemble des agriculteurs dans un contexte de croissance démographique rapide. En effet, alors que d'intenses flux humains ont dans le passé librement circulé entre les pays d'Afrique de l'Ouest, les pays sahéliens sont de plus en plus la destination de migration de retour, notamment entre la Côte d'Ivoire et le Burkina Faso.

Jadis pôle principal d'immigration en Afrique de l'Ouest, la Côte d'Ivoire est en voie de passer à une position nette re-exportatrice de main-d'œuvre sur la période 1988-1992 (avec une croissance migratoire annuelle presque nulle) vis-à-vis du réseau de pays étudié par l'enquête REMUAO (Burkina Faso, Côte d'Ivoire, Guinée, Mali, Mauritanie, Niger, Sénégal et Nigeria pour certains aspects de l'étude). Ce phénomène récent est en fait largement expliqué par le retour de plus en plus nombreux des migrants burkinabè entraînant une expansion de la population rurale dans ce pays. Malgré cette réalité et ses conséquences diverses, la migration est parmi les phénomènes démographiques les moins étudiés en Afrique de l'Ouest.

Il s'agit d'examiner ici les effets de ces retours de migration sur l'efficacité productive de leurs ménages d'origine dans le Sahel. Se concentrer sur les ménages avec migrants a l'avantage de comparer leur situation observée à celles simulées, sans l'apport de la migration, contrairement à la comparaison habituelle des ménages migrants et non migrants locaux. En effet dans leur étude, Barham et Boucher (1998) ont observé que les revenus des personnes vivant dans des ménages ne connaissant pas la migration sont en moyenne 40 % systématiquement supérieurs à ceux de non migrants provenant de ménages avec des cas de migration.Cependant, la situation simulée exige l'estimation des conséquences de ce retour potentiel « d'ex-migrants » en terme de niveau de participation aux activités locales ainsi que les rendements des autres membres qui habituellement restent au Sahel. Les effets nets sont par conséquent examinés dans deux scénarios concernant le comportement des « ex-migrants » vis-à-vis de l'innovation technologique agricole. Dans cet exercice, les deux scénarios envisagés sont : les migrants préfèrent rejoindre le groupe des « non-adopteurs » de la technologie locale de gestion de ressources naturelles à savoir les cordons pierreux (scénario 1), ou ils adoptent cette technologie (scénario 2).

Dans un modèle de ménages en présence de coûts élevés des opérations commerciales, les ménages sahéliens en majorité acheteurs céréaliers cherchent à contourner les prix élevés en augmentant leur production afin d'assurer l'autosuffisance alimentaire. L'instrument principal pour augmenter la

* Résumé Original. Ce document existe également en version anglaise.

productivité agricole au Sahel est technologique, en l'occurrence l'introduction de cordons pierreux qui permettent des gains de productivité à travers le drainage d'eau et le contrôle de l'érosion. En somme, les décisions de production et consommation dépendent ici du choix endogène de cessation de migration, d'adoption de cette technologie de cordons pierreux ainsi que de la stratégie de participation au marché céréalier. Aussi, l'approche empirique est basée sur l'estimation d'une forme réduite du choix de retour de migration, de l'adoption technologique ainsi que leurs effets combinés sur les rendements agricoles**.** La migration concerne au total 46 % des ménages enquêtés en 2002 dans quatre départements du Nord-Est du Burkina Faso : Gorgadji, Gorom-Gorom, Dori, et Bani. Á partir de cette enquête, un groupe de tous les membres adultes du ménage est constitué tout en distinguant les ménages qui pratiquent ou non les cordons pierreux. Les résultats suivants concernent les deux équations de sélection (décisions de la migration de retour et décision d'adoption des cordons pierreux) et les performances en rendements agricoles.

(1) *L'estimation de la décision de retour de migration.* Cette décision dépend positivement de la disponibilité de champs dans le ménage, son âge moyen et les ménages de la région de Gorom-Gorom ont relativement plus d'incitation au retour. Par ailleurs, les migrants resteraient en Côte d'Ivoire si leur ménage est autosuffisant en nourriture et si le ménage d'origine a un capital humain plus élevé (alphabétisation).

(2) *Les résultats de l'équation d'adoption de cordon pierreux* montrent que dans les deux scénarios, la participation au marché céréalier comme acheteur a un effet significativement négatif. Cela indique que contrairement aux autosuffisants ou vendeurs, l'accès au marché comme acheteur pourrait susciter une diversification vers des activités (plus monétaires), ce qui est confirmé par l'effet négatif de la distance aux marchés. En effet, le prix élevé d'achat des céréales force les acheteurs à s'orienter vers des activités leur rapportant de l'argent (élevage, orpaillage, et marché de la main d'œuvre). L'âge du ménage affecte négativement la propension du migrant de retour à adopter alors que l'éducation publique favorise l'adoption. Cependant, alors qu'il joue un rôle positif dans la décision d'adoption dans le deuxième scénario, le risque sur le revenu semble opérer dans le sens inverse dans le premier scénario où les migrants sont supposés ne pas adopter.

(3) *Effet sur la productivité*. En cas de non adoption par les migrants de retour (scénario 1), les ménages qui constituent le groupe des « adopteurs » bénéficient significativement de la culture des bas-fonds. Cependant, plus il y a de règles formelles de gestion des relations agriculteurs/éleveurs, moindres sont les rendements. Les ménages d'ethnie de tradition agricole et à fort taux de masculinité montrent aussi de plus forts rendements. Être de la région de l'Oudalan (Gorom-Gorom et Gorgadji) , sous ce même scénario 1, favorise également les rendements comme le fait le capital humain Dans ce cadre d'un groupe élargi de « non-adopteurs », seuls le groupe ethnique et le type de sol semblent cependant influencer les rendements s'ils sont rejoints par les migrants de retour. En examinant le scénario 2 dans lequel tous les migrants de retour joignent le groupe « adopteur », on obtient des résultats très similaires mais généralement moins significatifs. Par contre, la pratique de la jachère bénéficie aux rendements des « adopteurs ». En général cependant, les résultats concluent à de meilleurs rendements agricoles si le migrant de retour adopte les bonnes techniques de gestion d'eau et de lutte anti-érosion que sont les cordons pierreux, puisque les ménages qui n'adoptent pas bénéficient alors des externalités positives d'un phénomène plus marqué d'adoption.

Dans le scénario d'une défaillance majoritaire à l'adoption, de graves conséquences sur la sécurité alimentaire des populations sont probables. Par conséquent, les institutions régionales devraient s'intéresser à la question essentielle d'insertion des migrants de retour en milieu rural. La région d'Afrique de l'Ouest devrait favoriser dans le Sahel une stratégie de développement en encourageant une technologie peu coûteuse et efficace, comme les cordons pierreux si elle veut éviter que la crise migratoire mette en danger la sécurité alimentaire et l'environnement.

MIGRATION, RURAL DEVELOPMENT AND FOOD SECURITY IN WEST AFRICA

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C. Background Paper

Introduction

While labor migration for wage work has long been undertaken in West Africa, this study examines an increasingly important empirical phenomenon: the decision made by many migrants to return to their home villages. This phenomenon is referred to as return migration. The current work assesses the impact of return migration on rural development and food security in West Africa, with an emphasis on a case study of Burkina Faso and Côte d'Ivoire, the most sensitive migration story in the region. Perceived by the New Economics of Migration as a risk management mechanism, the sending of a household member to migrate is an insurance mechanism that enables the household to smooth its consumption path. In bypassing the credit and insurance markets (with their bias against small farmers) migration facilitates the transformation of modes of production. It succeeds in doing this via its role in the accumulation of investment capital, usually generating significant flows of remittances, and by diversifying income sources, thereby controlling the level of risk (Stark 1991). What happens to such a household when the migration strategy has to be abandoned? To answer this question, this paper analyzes the impact of Sahelian population dynamics and the adoption of improved agricultural techniques in terms of yields and food security.[15]

The analysis of food security has three dimensions, availability, accessibility, and stability, in which availability is related to domestic production, import capacity, food aid, and stocks. The current paper intentionally focuses solely on yield outcomes in cereal crops (millet and sorghum) because these cereals are at the heart of most policy strategies on food security by governments, multilateral world food organizations (Food and Agriculture Organization of the United Nations [FAO], World Food Programme [WFP], International Fund for Agricultural Development [IFAD]), international research centers (International Food Policy Research Institute [IFPRI]), and nongovernmental organizations (NGOs). In most of the developing world, the expansion of crop area will be severely limited; therefore, yield increases will have to account for most of the increases in production. Research on policies to boost smallholder productivity in developing countries remains critical for food supplies, trade balances, and income among rural households (Rosegrant et al. 2001).

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[15]Although the world has made remarkable progress in increasing food production over the past three decades, during the 1990s the number of food-insecure people of the developing world increased by more than 50 million if China is excluded (IFPRI 2003).

When studying future food security and sustainability in the Sahel, current conditions cannot realistically be held constant. Among the relevant issues for Sahelian agriculture is the combined impact of both technological innovation and the current regional migration crisis. Technological adoption in cereal crops has the potential to alleviate current and future problems of food insecurity by raising current levels of yield. Also, technologies that are beneficial may trickle down to all farmers; and if technologies are not yet beneficial, they will become so, as continuous population growth will ultimately necessitate increases in yield (Reynolds, Rajaram, and McNab 1996; Reynolds, Rajaram, and Sayre 1999). The next section briefly reviews migration trends and patterns in West Africa. The third section focuses on the potential consequences of the recent migratory crisis in Côte d'Ivoire and assesses the impacts of return migration and technology adoption on agricultural productivity (yields). The fourth section presents the econometric approach in detail. In the fifth section, the empirical results come together with a description of the survey data set. The concluding section outlines the types of policies and strategies that could enhance the positive impacts and minimize the negative impacts of return migration on rural development. Finally, actions are suggested for facing food and environmental sustainability issues in West Africa.

Migration Patterns in West Africa

The different regional treaties in West Africa tackled the important issue of labor mobility and included provisions guaranteeing the free movement of the union's citizens; the treaties' authors were convinced that optimal allocation of labor would favor regional growth.

As a consequence of the integration policy (Table 1), West Africa is one of the leading regions for international labor migration (Robin 1996; Bocquier 1999). Thousands of migratory jobs have been created in the region, and there appears to be a real interdependence among national labor markets, with a strong tendency toward labor income convergence through migration that is faster than the comparable outcome that would have come from trade and capital flow channels (Coussy 1994). However, the migrants are subject to numerous administrative annoyances and police harassment, while the national policies in the receiving countries remain very sensitive to economic fluctuations in their labor market.

Table 1 — Regional treaties in West Africa and free movement of people

CEAO (1973)	ECOWAS (1975)	WAEMU (1994)
• Free movement of people and capital (Art. 39). • Free entrepreneurship (Art. 4).	• Member States agreed on abolishing barriers to free movement of people, services, and capital. • Exemption • from visa formalities and residential permits. • Entitlement to residence and establishment within the union. • The revised treaty "Cotonou 1993" reinforced the above provisions.	• The citizens of a union member state are entitled to the right to reside and move inside the whole union territory.

Note: CEAO is the Economic Community of West Africa, ECOWAS is the Economic Community of West African States (CEDEAO in French), and WAEMU is the West African Economic and Monetary Union (UEMOA in French).

Despite the striking importance of migration and its socioeconomic and environmental implications, migration is the least studied demographic phenomenon in West Africa. The available statistics are not up to date and hardly allow one to study the evolution of the phenomenon. The Network

of Surveys on Migration and Urbanization in West Africa (REMUAO 1993), the most recent source of regional data (for Burkina Faso, Côte d'Ivoire, Guinea, Mali, Mauritania, Niger, Nigeria, and Senegal), confirms the intensity of migration in West Africa as well as the diverse migratory situations in each country. During the period 1988–92, almost 1.8 million migrations occurred inside the network.[16] The most important flows are between Côte d'Ivoire and Burkina Faso, with 920,000 migrations—half of the total flows. These two countries represent interesting case studies in terms of capturing the importance of the migration phenomenon in West Africa. Côte d'Ivoire has the most significant community of foreign inhabitants coming from other countries in the network. In 1998, the foreign population in Côte d' Ivoire represented more than a quarter of the total population (Table 2).

Table 2 — Percentage of foreign population in Ivorian total population

	1975	1988	1993	1998
Total Ivorian population	6,755,000	11,003,850	13,036,540	15,159,110
Foreign population in Côte d'Ivoire	21.8%	27.6%	25.4%	26.4%
Foreign population in all of West Africa	21.1%	27.3%	25.3%[a]	25.6%

Sources: Institut National de la Statistique 1998, 2001; REMUAO 1993; World Bank 2003.
[a] Approximation based on REMUAO 1993 data.

However, the picture is under rapid and striking evolution. Burkina Faso's net migration rate[17] changed slightly from −0.7 percent to −0.2 percent per year between 1969–73 and 1988–92, which denotes a higher flow of return migration. Côte d'Ivoire, the active receiving country, has a null net migration rate for the period 1988–92. Although remaining a polar country of international immigration in West Africa, Côte d'Ivoire is no longer a net beneficiary of labor migration (with a migratory rate of +0.41 percent per year vis-à-vis the rest of the network) as a result of increasing return migration (REMUAO 1993). This declining role is completely explained by its labor exchanges with Burkina Faso, which now sees increasing flows of return migrants[18] and fewer departures to Côte d'Ivoire (Appendix Figure A1). Another characteristic common to the two countries is that, in contrast to the other countries in the network, Côte d'Ivoire and Burkina Faso are the only countries where rural areas are expanding[19] as a consequence of return migration. This important evolution of migration in West Africa is the main focus of the paper, along with an attempt to outline the impact of these changes on food security and rural development in Burkina Faso, a Sahelian country.

[2] Comparatively, the migration balance in favor of Europe is evaluated at only +15,600 yearly in the same period (1988–92). This count indicates that a European destination is negligible compared with intraregional flows (9 percent of all migrations in the network).

[17] Population growth is affected by two factors: migration rate and natural population growth rate due to fertility and mortality.

[18] In the wake of structural adjustment and administrative harassment (residential permits) in the last decades, 76 percent of the sample interviewed in Côte d'Ivoire planned to return to Burkina Faso (author survey).

[19] For example, Senegal formerly qualified as an emigration country, but it now has less migration within the network, compared with internal rural-urban flows (Traoré and Bocquier 1995). Other countries, like Ghana and Nigeria, have evolved from receiving to sending countries.

The Return Migration Perspective and Natural Resources Management: Effects on Household Productive Efficiency

An important problem in international migration literature consists of migrants' expected earnings and the impact of an income gap on the migration decision (Todaro 1969). Foreign and domestic labor markets are considered alternatively as the reference when comparing migrant and nonmigrant households. In the current work, I consider the phenomenon of migrants returning home by focusing on the potentially counterfactual no-migration scenario. Therefore, I examine the net effects of return migration only on the migrant households' crop yields in the Sahel, instead of comparing this target group to nonmigrant households who may be heavily self-selected. As indicated by Barham and Boucher (1998), observed average incomes of individuals from households without migrants are 40 percent higher than incomes of nonmigrants from migrant households, suggesting that the two groups of households are very different.[20] However, the counterfactual scenario demands that I also compute the consequence of this "potential" return of erstwhile migrants on the basis of the decision to participate in local activities, namely, the adoption of the use of stone bunds (embankments for rainwater harvesting and soil erosion control), and on the basis of the performance of the household members who are currently at home.

The net effects of return migration on yields is therefore examined in combination with the consequences of the adoption of local technological innovation in agriculture. Technological change in crop production is understood in this study to be the construction of contour stone bunds for rainwater harvesting and soil erosion control (Dutilly-Diane, Sadoulet, and de Janvry 2003). This traditional and cost-effective technology enhances grain (millet and sorghum) yields; the Mossi introduced it in Burkina Faso in the early 20th century and interest in it was regained in the 1970s and 1980s in response to droughts. Impacts on yields have been measured as 40–100 percent depending on the region, the rainfall in the year of the study, and the spacing of stone bunds. The choice of which field is protected by stone bunds is endogenous: it is partly the decision of the field owner himself (the average willingness of individuals in the household to adopt stone bunds), partly the result of the political process in allocating project benefits, and partly related to the physical characteristics of the field and its location in the village. In addition, stone bunds may create strong externalities, since collection of water run-off and protection from soil erosion go beyond the field that the stone bunds actually surround. Because the presence of stone bunds on any field is an endogenous decision at the household and community levels, I am able to model this decision process.

In the Sahelian context of high transaction costs,[21] Dutilly-Diane, Sadoulet, and de Janvry (2003) have established the roles of technological change in agriculture (stone bunds) and of cooperation in natural resources management (NRM) for crop yields and market participation decisions. In so doing, they have modeled the complex linkages in the economy of Sahelian households as buyer or self-sufficient households. These investigators have also shown how, depending on the market participation regime, technological change affects land allocated to crops. In addition, they have analyzed the way in which technological change and cooperation affect the total income of households and the income strategies that households pursue. It is therefore an interesting issue to analyze the propensity of households to participate in local NRM from the perspective of return migration or the consequences of

[20] There are also a number of studies that examine the relative productive efficiency of the households of remittance recipients, assuming information asymmetry between the migrant and his family in the source country (Azam and Gubert 2002; de la Briere et al. 2002).

[21] Many markets fail because the costs of using the market for a transaction are too high relative to the benefits that the transaction yields. Transaction costs include not only transportation costs, but also the consequences of the opportunistic behavior that they allow (Sadoulet and de Janvry 1995).

higher pressure on natural resources in the Sahel.[22] An econometric challenge is to incorporate the indirect effects of return migration on the other activities of receiving households (such as livestock farming income for a credit-constrained household or diversification of off-farm activities). De Janvry, Fafchamps, and Sadoulet (1991) show that when food markets fail, the theory of household behavior predicts that technological change in food production can be effective in promoting the cash crop economy of households. However, the benefits from this cross-activity effect also depend on the nature of households' heterogeneity in a food market integration strategy (binary variables for buyer or self-sufficient households, migrants/nonmigrants), stressing the importance of considering heterogeneity in predicting differentiated effects across households of a given policy intervention. With a small variability in household participation in the food market (98 percent are buyers), it is difficult to include and estimate a selection rule for market participation. In the current study, I use panel data techniques and assume that controlling for household heterogeneity accounts for their market participation strategies[23] as well.

Econometric Model with Double Selection

The challenge of the counterfactual approach is the econometric methodology. Although our goal is to estimate the impact of return migration on crop yields, I must obviously handle the potential bias due to selectivity of migrant/nonmigrant individuals of the sample households. A simple Ordinary Least Squares (OLS) approach becomes problematic if migrant and nonmigrant individuals differ systematically in their productive capabilities. To control for these important household and individual selection problems, Tunali (1985) and Barham and Boucher (1998) propose estimating individual performance equations by using a Heckman double-selection model. Following their steps, I consider two endogenous selection rules concerning, respectively, the decision of some members to return from migration in Côte d'Ivoire and then whether to participate or not in local resource management, in particular the simple practice of using contour stone bunds. Because migrants' home productivities are unobservable and because migrants may represent a nonrandomly chosen subset of the overall sample, estimating the conditional mean of migrants' performance first requires one to take into account that selection bias. The second selection criterion arises from the fact that the decision to participate in local stone bund activities may be selective among the group of all croppers. Although it allows the nonobserved migrant home yield effects to be imputed, the Heckman procedure also enables one to account for the indirect effects on the input allocation and product market, through the selection function of participation in stone bunds. The econometric procedure controls for the fact that individuals may possess unobserved characteristics that are generally positively related to the yields, resulting in a sample selection bias. In the context of selection bias, results from a standard OLS are simply biased. The regression model that includes the preceding selection issue is written as a simultaneous system that includes two selection rules:

agricultural yields if individual stays, $W_i = \beta' X_i + \varepsilon_i$, (1)

net benefit of returning home or sample selection mechanism among migrants group, $V_i^* = \gamma' Z_i + u_i$, and (2)

[22] Unlike the work of Barham and Boucher (1998), who studied the consequences of return migration in terms of the participation of those who stay in the local labor force, our survey (CAPRi2) showed that there is almost no local labor market in the Sahel and that the household allocates its total labor endowment to food crops and livestock production.

[23] Unlike livestock and nonfood consumption, households are diverse in their food position, and it is the high transaction costs that influence household market participation as seller, buyer, or self-sufficient. I also include in the model a dummy for each household category, and I also tried the assets position indicator of households, without significant effects, however.

local NRM participation selection rule (adoption of contour stone bund techniques),

$$Y_i^* = \theta' F_i + e_i, \tag{3}$$

where X_i, Z_i, and F_i are vectors of explanatory variables and β, γ, and θ are unknown coefficients.

The selection outcome variables V_i^* and Y_i^* are not observed and represent the propensity to return and the individual propensity to participate in stone bund activities at home, respectively. As a consequence, the variance of the unobserved error terms in the selection equations cannot be estimated and are set to one, whereas the means are set to zero. Only the correlations among error terms are unknown and will be estimated together with all other parameters by using a two-step double Heckman procedure, after transforming the model in bivariate normal distribution models. Even though the two selection variables are not observed, their sign, that is, whether or not an individual is selected, is known and enables one to construct two binary probit variables (P_V and P_Y) that are the observed outcomes of the selection rules. This leads finally to the Heckman specification of the yields equation under the return migration problem:

$$E(W_i / X_i, \text{ sample selection rules } P_V \text{ and } P_Y) = \beta' X_i + \sigma E(\varepsilon_i / X_i, P_V, P_Y) \tag{4}$$

Under a multivariate normal structure, an expression for the conditional expectation of the disturbance ε_i is as follows:

$$E(\varepsilon_i / X_i, P_V, P_Y) = p_{VW}\lambda_V + p_{YW}\lambda_Y, \tag{5}$$

where the p and the λ are the correlation of the errors terms and the inverse Mills ratios, respectively. Therefore, the overall conditional expectation of yields under return migration becomes

$$E(W_i / X_i, \text{ sample selection rules } P_V \text{ and } P_Y) = \beta' X_i + k_V\lambda_V + k_V\lambda_V . \tag{6}$$

In summary, the Heckman's two-step estimation procedure applies to each of the selected groups that are the migrants of the sample (living in Côte d'Ivoire) and all of the individuals who are at home in the sample of migrant households at the second selection stage (Burkina Faso), respectively. For observations in the first group, the probit equation (2) is estimated to obtain estimates of γ' and compute the inverse Mills ratio. At a second step, the previous inverse Mills ratio is included in the adoption equation (3) to produce its estimated coefficient and that of θ'. Finally, because the decision to adopt stone bunds, which will affect yields, may also be affected by the migrants' decision to return, the Mills ratio of the second step is computed and included in the model of yields that can be studied to predict performance under each scenario concerning the returnees' adoption behavior while correcting also for the two selection biases. However, the coefficients estimated in the first two steps measure how the log-odds in favor of returning home and adopting stone bunds, respectively, change as the independent variables change by a unit. For interpretation, marginal effects need then be computed (Long and Freese 2001). In the following section, I will first estimate a probit for return migration participation. After generating the inverse Mills ratio (IMR) term, I will include this term in a second probit equation explaining technology adoption. The appropriate IMR term from this equation would then be included in the final yield equations.

Estimation Results

Description of the data and variables used

Burkina Faso is a Sahelian country where agriculture and livestock farming are the main contributors to the gross domestic product and therefore play a fundamental role in the development strategy of the economy. However, for several decades now, drought and rainfall instability have degraded the natural resources in the region, rendering farming uncertain. Our survey concerns the two northeastern provinces of Seno and Oudalan, which are indeed the most affected zones. This region is characterized by a Soudano-Sahelian climate with an average annual rainfall estimated at 350–600 millimeters, and it is therefore devoted mainly to livestock farming (Drabo et al. 2001). Conducted between July and October 2002 in cooperation with the International Livestock Research Institute (ILRI) and the German Technical Cooperation (GTZ) (Project CAPRi), [24] the household survey was part of three sets of questionnaires at different levels: the village, the institutional, and the household level. The household questionnaire was addressed to 250 rural farmers primarily to assess the migration phenomenon, as perceived by nonmigrant households and sending households, at home. The questionnaire was organized around four main topics:

1. household characteristics;
2. household activities and their linkages to the migration phenomenon (migrants and remittances);
3. collective actions and participation in natural resource management; and
4. risk management, solidarity, and mutual trust in the village.

The sampling frame was the 2000 survey (CAPRi 1) units, which were designed in a multistage sampling mode in which primary sampling units were the two provinces, departments were the second clusters, villages were at the third stage, and finally 401 households were selected. On the basis of migration information identified in CAPRi 1, two strata were constituted; the number of households sampled was proportional to the group size of migrant and nonmigrant households in each of the 48 villages of the 2000 survey.[25] I aimed at maintaining the same proportions for the group of migrant households and the group of nonmigrant households, using a constant sampling fraction. Then 250 households were randomly selected from the total population of 401 households.[26]

Using the household- and village-level data of the 2002 survey, I constituted for the current empirical work a panel of only 115 migrant households, while distinguishing households that do or do not use stone bunds. The two dimensions are migrant and nonmigrant members and the household units.[27] The total number of individual observations is 899, including 140 migrants living in Côte d'Ivoire. The head of household answered the household questionnaire and the related migration questions under the assumption of the New Economics of Migration theory that migration is also a household-level strategy.

[24] Collective Action and Property Rights (CAPRi) is a system-wide program and one of several intercenter initiatives of the Consultative Group on International Agricultural Research (CGIAR). The first round of the survey was conducted in 2000.

[25] A migrant household is defined as one in which at least one person over 12 years old who was previously a member of the household—or was simply a relative (in which case he/she should have kept contact with the household)—left to live or work either in Burkina Faso or abroad, the focus here being Côte d'Ivoire.

[26] The 48 villages sampled in 2000 were composed of 91 households on average, with 9 members per household, among whom 3.5 were children younger than 12 years old.

[27] Panel data need not be restricted to two dimensions, one of which is time (Nerlove 2002, see preface; Sevestre 2002, 4).

Following the household model (under large transaction costs on food markets) derived in Dutilly-Diane, Sadoulet, and de Janvry (2003) for the same households,[28] the estimations of each of our three equations may contain explanatory variables classified in the following categories: prices and transactions costs (regional effects and distance to the nearest local town); shifters in consumption (number of dependents, exogenous transfers); shifters in crop production (yield, household characteristics, land availability); shifters in livestock and crop production (household characteristics, quality of cooperation in the management of common property pastures, land availability); shifters in production and consumption (family size at home, human capital); and regional dummies. The risk variables and other family characteristics are also included to reflect the possibility that the migration decisions may depend on an individual's status in the household or known characteristics of other household members. Crop yields used as the indicator of productivity in the case of food production are evaluated as production (including home autoconsumption) divided by total land or land allocated to the specified crop. The dependent variable is therefore average yield (millet and sorghum) or yield for the main crop (millet). It is important to keep in mind that the determinants of crop yields are manifold, including biophysical and socioeconomic constraints, as well as interactions between them. The assumption here is that soil quality29 controls for these important biophysical factors such as nutrients, water, pests, diseases, weed infestation, lodging, and other stresses.

Table 3 presents the results of mean comparison for the two observed groups of nonadopters and adopters of contour stone bunds. Appendix Table A1 in the appendix presents the related descriptive statistics.

[28] The authors used data from the first round of the same survey conducted in 2000.

[29] The survey asks farmers about the soil texture (proportion of sand, clay, and silt given by local classification of soils as Seeno, Ceekol, Bolaare); however, soil properties also include nutrient balances such as nitrogen, phosphorus, potassium, acidity, organic matter, and moisture levels. It should be noted that part of the nutrients are added by farmers through the use of green manure and fertilizer, information that is available in our survey.

Table 3 — Two-sample *t*-test with unequal variances[a]

Variable	*t*-statistic	*P*-value
Transaction costs	4.30	0.00
Distance to regional capital		0.00
Shifters to consumption		
Dummy, nonmember remitted money and/or in-kind	1.80	0.07
Shifters in crop production		
Meanyield: overall mean yield (millet and sorghum)	3.41	0.00
Meantail: mean area cultivated by household	2.10	0.04
Head of household is from cropper ethnic group	–15.19	0.00
Number of ethnic groups per village	–6.86	0.00
Shifters in crop and livestock production		
Total number of formal rules of natural resource management organizations	0.94	0.34
Total number of plots per household	–2.12	0.03
Mean age	4.25	0.00
Household member's age	–0.08	0.93
Age of head of household	–3.83	0.00
Number of members who completed alphabetization	–3.87	0.00
Number of years of schooling, all types	–1.48	0.14
Percentage of members attending public school in 2000	–4.91	0.00
Shifters in production and consumption		
Member's sex	4.07	0.00
% of men among adults	7.28	0.00
Regional dummies		
Region = gorom	3.84	0.00
Regional dummy = Gorom + Gorgadji	4.54	0.00
Market participation, soil quality, and risk variables		
Dummy for food buyer	4.95	0.00
Total number of Ceekol	–0.05	0.96
Total number of Seeno	–1.20	0.23
Total number of Bolaare	–4.57	0.00
Total number of contour stone bund	–16.00	0.00
Percentage of soil of quality Bolaare	–12.37	0.00
Existence of field under fallow	–0.26	0.79
Variance: crops income in 2000	11.84	0.00
Variance: migration income in 2000	4.34	0.00
Variance: local off-farm income in 2000	–4.51	0.00

[a] Individual-level observations. Ho: mean (no adoption) – mean (yes) = diff = 0.

Empirical results

Finally, the estimations are presented in three steps:

1. Panel data regressions of the two selection rules are used to produce the likelihood functions for the probit. This is a straightforward extension of the Heckman (1979) two-step procedure in which I make the underlying assumption that the unobservables that determine the return migration decision from Côte d'Ivoire are independent of the unobservables that determine stone bund adoption once at home (Amemiya 1985; Brian, Main, and Barry 1992; Maddala 1983). The return migration sample is in effect constituted only of the 140 migrants in the Ivorian labor market, and the return dummy takes the value one for those who plan to return home. From this group are considered returnees, individuals who show a predicted probability above 65 percent.[30] Once at home, two scenarios are considered in which the returnee will adopt the technology (optimistic scenario 2) or will not adopt (pessimistic scenario 1); consequently, the total sample of adopters and nonadopters is constituted to estimate the adoption probit corresponding to the scenario. Scenario 1 assumes that return migrants join the individuals who are nonadopters, whereas the second scenario simply assumes the reverse. Estimates of the yield effects for all households taken together would mask the important differences because of the heterogeneous behavior of their members toward technology and migration.
2. The estimated hazard functions are used to derive the selection terms, and at the final step their combined effects are added to the productivity equation (average yield and millet specific yield). The latter is estimated using a panel data estimation to get the counterfactual performance under each of the two specific scenarios about the return migrant's technology adoption.
3. The outcomes of the different scenarios are compared and a graphical summary of the productive performance of households is presented, together with its food security implications.

Return Migration Choices

Consider the case of estimating the effect on individual performance of becoming a nonmigrant. Simply including in the yield equation a dummy variable to pick up this effect by using a pooled sample of migrant and nonmigrant is inappropriate because migrant individuals may self-select and migration may not be random. Indeed, the same applies when one considers individual selection into stone bund adoption. In the case of the double-selection model, two exclusion or identifying restrictions would then be needed (one for the return migration probit, one for the natural resource management probit). Although it is well known that for instrumental variable estimation, one requires a variable that is correlated with the endogenous variable, uncorrelated with the error term, and not affected by the outcome of interest conditional on the included regressors, identification in sample selection issues is often not as well grounded. Because the IMR is a nonlinear function of the variables included in the first-stage probit model, then the second-stage equation is considered identified because of this nonlinearity, even if there is no excluded variable. Another issue here is that the fixed-effects probit model suffers from the incidental parameter problem (Lancaster 2000). This problem justifies the preference for the random-effects procedure presented in Table 4, which also allows for correction of the probit for clustering.[31]

[30] The degree of positive outcome of return migration in the sample.

[31] Because I use a repeated cross-section of individual-level data and because individuals are clustered in particular households, I need to correct the standard errors for clustering at the household level.

Table 4 — Regression of return migration decision

	Return prospect of migrants
Meanyield: total mean yield for both crops (millet and sorghum)	–0.011 (–2.38)***
Total number of plots per household	3.857 (2.44)***
Number of members who completed alphabetization	–1.146 (–1.75)*
Mean age	1.565 (2.36)***
Region = Gorom	6.014 (2.52)***
Constant	–4.368 (–1.78)*
Number of observations	138
Number of group (vfolio mfolio)	100

Notes: *z* statistics are shown in parentheses.
* Significant at 10 percent; *** significant at 1 percent.

Table 4 analyzes the return prospects of the 140 migrants in Côte d'Ivoire, among whom 66 percent have planned to stop the migration project. A survey of another 263 households conducted in Côte d'Ivoire during the same period indicated that 94 percent of households suffer residential permit difficulties and harassment by local authorities, which makes their stay in Côte d'Ivoire not beneficial. Thirty-five percent of the sample added problems of cohabitation (tensions among communities about recognition of migrants' property rights and risk of their land withdrawal). After facing this difficult situation, 76 percent of the sample planned to return to Burkina Faso, even though only 35 percent specified their exact expected return year. Results in Table 4 indicate that the decision to return positively depends on the household's assets in plots and its average age, and that the households from the Gorom[32] region have more incentives to return home.

On the other hand, migrants would stay in Côte d'Ivoire if their household at home were moving toward food self-sufficiency, as indicated by the yield variable, as well as if the household of origin has higher human capital (alphabetization). Appendix Table A2 in the appendix calculates the average marginal effects as changes in the probability of returning home. The Mills ratio coming from this first-stage equation is then included to correct for selection effects in the technology adoption model.

Natural resource management technology adoption

Two scenarios are assumed on realization of the return of the migrants. In the second scenario (regression 1, Table 5), the individual who returns is supposed to adopt the technology. Because self-sufficiency is an important objective for Sahelian farmers under high transaction costs in the food market, policies to increase productivity in food crops would have a good chance of being adopted if the constraints due to imperfect and missing markets and risk are not too binding. Farm households may also communicate innovations.[33] In the literature, these positive externalities take place among neighbors, and farm

[32]The field survey in Burkina Faso concerned four departments: Bani with 58 households interviewed, Dori-Ouest (Western Dori) with 53 households, Gorgadji with 37 households, and Gorom-Gorom with 102 households.

[33]The fact that the choice of the stone bund technique is partly related to the physical characteristics of the field and its location in the village may reinforce this community effect.

households adopt a technology when the neighbors have adopted the technology successfully, with the diffusion increasing when a high fraction of the neighbors have successfully adopted. However, I test an opposite pessimistic scenario (1), in which the returning migrant may not be interested in the technology. This is a possibility in a region where households are constituted by autonomous subhouseholds. More than 17 percent of the migrant households have several subhouseholds, and in 59 percent of cases they have their own harvest lofts. Moreover, the choice of the field to be the beneficiary of stone bunds is not the sole decision of the field owner but may also involve political authorities and the village as a whole.

Table 5 — Regression of stone bund adoption

	(1) Scenario 2: Return migrant adopted	**(2) Scenario 1: Return migrant refused innovation**
	Adoption of stone bunds	Adoption of stone bunds
Mills ratio for return migration	0.164	0.523
	(0.91)	(2.12)**
Dummy for food buyer	–14.849	–1.708
	(–43.23)***	(–2.25)**
Variance: local off-farm income in 2000	2.71e-11	
	(1.88)*	
Distance to regional capital	–0.020	–0.128
	(–2.12)**	(–5.69)***
Dummy, nonmember remitted money and/or in-kind	–1.206 (–2.05)**	1.327 (1.83)*
Household member's age	–0.014	0.012
	(–2.82)**	(1.50)
Percentage of members attending public school in 2000	3.172 (1.64)*	
Member's sex	1.824	–2.376
	(7.96)***	(–4.45)***
Variance: local off-farm income in 2002		–1.27e–10
		(–3.96)***
Number of members who completed alphabetization		–0.365 (–2.55)**
Number of men and women above 12 years old		0.384 (5.66)***
Constant		0.354
		(0.37)
Observations	772	772
Number of household panels	111	111

Notes: *z* statistics are shown in parentheses.
* Significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

The model specification of contour stone bund adoption incorporates the impact of market participation and its potential endogeneity[34] via its yield effects. Stone bund adoption is assumed to increase yields, which indeed reduces food market participation toward self-sufficiency. I shall then instrument the participation dummy. The results are presented in Table 5 together with the Nakamura and Nakamura test of endogeneity (Appendix Table A3). Unfortunately, the statistical test could not reject the orthogonality assumption and, as explained earlier, there may be two explanations: the poor diversity in the market participation regime (actually more than 98 percent of the sample are food buyers) or simply the weakness of the available instruments. The results in Table 5 (and the marginal effects in Appendix Tables A4 and A5) of stone bund adoption show that in both scenarios, participation in the food market as a buyer has a significant negative impact on a household's adoption of stone bund techniques. This means that in opposition to self-sufficiency or the seller regime, access to the market as a buyer may bring households to diversify their activities, which is confirmed by the negative effect of distance to regional markets. The high market price facing the buyer forced him to look for cash in activities such as livestock farming or off-farm activities. The household's age negatively affects the propensity of the returnee to adopt, whereas human capital in the form of public schooling favors adoption. However, although lagged income risk (captured through its variance) plays a positive role in the adoption decision under scenario 2, its current value seems ineffective in the case in which migrants are assumed to not adopt (scenario 1).

Because former studies measured the positive impact of the traditional contour stone bunds on yields between 40 and 100 percent, it is interesting now to study the yield outcomes of different types of technology adoption behavior once return migration has been controlled for.

Estimation of the productivity equation

In this section, the dependent variable is either the average yield for millet and sorghum or the millet yield only. The yield outcome is observed for two restricted, nonrandom samples of households who adopt contour stone bunds or not and call for estimating a yield equation conditioned on technology adoption and return migration. Therefore, for each scenario and for average and millet productivity, respectively, Tables 6 and 7 present the regression results, broken down to the two categories of households—those who adopt food production technology or those who do not. Focusing on the food sector, it is clear that household substitution strategies (crop, livestock, nonfarm activities, and migration) between income sources in a context of return migration cannot be fully identified.

[34] Endogeneity refers also to the fact that market participation is potentially a choice variable, correlated with unobservables relegated to the error term. But this cannot be modeled here because only 1.74 percent are not food buyers and are self-sufficient, whereas only 6 percent sell food.

Table 6 — Regression of food productivity: scenario 1, nonadoption by return migrant considering both adoption groups

	(1) Scenario of adopters group, without all return migrants	(2) Regression (1) for millet only	(3) Scenario of nonadopters group, joined by all return migrants	(4) Regression (3) for millet only
	Meanrend: mean yield for millet and sorghum	Mean value of yield for millet	Meanrend: mean yield for millet and sorghum	Mean value of yield for millet
Total number of soil with quality = Ceekol (shallow)[a]	258.873 (5.02)***	202.142 (4.05)***	13.193 (0.48)	–37.763 (0.37)
Head of household=cropper ethnic group	216.987 (3.37)***	242.040 (4.06)***	25.645 (0.78)	279.533 (2.22)**
Total number of formal rules of natural resource management organizations	–106.325 (–3.73)***	–187.029 (–6.56)***	4.415 (0.23)	32.954 (0.47)
% of men among adults	730.450 (2.78)**	630.373 (2.59)**	136.486 (0.93)	298.699 (0.57)
Existence of field under fallow	9.080 (0.18)	–60.073 (–1.32)	50.171 (1.54)	46.593 (0.39)
Regional dummy = Gorom + Gorgadji	232.772 (3.71)***	415.946 (6.46)***	–62.346 (1.62)	128.340 (0.92)
Mills ratio for technology adoption	–14.422 (–1.30)	–4.043 (–0.39)		
Number of years of schooling, all types		9.120 (4.71)***		–3.878 (1.21)
% of soil of quality Bolaare (clay soil)			187.872 (2.18)**	676.206 (2.07)**
Mills ratio for nonadopters in scenario 1			–9.455 (0.17)	44.518 (0.22)
Constant	89.722 (0.49)	259.902 (1.51)	228.215 (2.11)**	163.520 (0.43)
% of soil of quality Ceekol + Kollade			318.120 (2.01)**	
Number of observations	166	145	606	593
Number of households panels	24	23	108	105
R-squared	0.73	0.85	0.19	0.11

Notes: *z* statistics are shown in parentheses.
** significant at 5 percent; *** significant at 1 percent.
[a]Farmers were asked to classify their plots (up to nine per household and not under fallow at the survey time) among four types of soil: Ceekol (shallow soil), Seeno (sandy soil particularly appropriate for millet), Kollade (poor degraded soil), and Bolaare (clay soil, best for livestock farming).

Table 7 — Regression of food productivity: Scenario 2, adoption by return migrant considering both adoption groups

	(1) Scenario of adopters group, joined by all return migrants	(2) Scenario of adopters group, joined by all return migrants (millet only)	(3) Scenario of nonadopters group when all return migrants adopt	(4) Scenario of nonadopters group when all return migrants adopt (millet only)
	Meanyield: mean yield for millet and sorghum	Mean value of yield for millet	Meanyield: mean yield for millet and sorghum	Mean value of yield for millet
Total number of soil with quality = Ceekol (shallow)	107.643 (2.06)**	34.696 (0.48)	43.948 (0.72)	–43.073 (–0.41)
Head of household = cropper ethnic group	72.926 (1.04)	132.297 (1.37)	105.795 (1.33)	249.692 (1.79)*
Total number of formal rules of natural resource management organizations	–103.270 (–2.52)**	–130.926 (–2.30)**	93.975 (1.95)*	106.466 (1.29)
% of men among adults	477.978 (1.41)	804.674 (1.72)*	614.691 (1.48)	684.092 (1.00)
Existence of field under fallow	166.461 (2.32)**	191.220 (1.96)*	–47.301 (0.55)	–53.735 (–0.36)
Regional dummy = gorom + gorgadji	128.606 (1.63)	214.789 (2.01)**	–36.068 (–0.38)	126.083 (0.77)
Mills ratio for technology adoption	–190.738 (–2.69)***	–259.738 (–2.65)***		
Number of years of schooling, all types		–1.029 (–0.74)		–5.337 (–1.05)
% of soil of quality Bolaare (clay soil)			573.498 (2.70)***	749.035 (2.08)**
Mills ratio for nonadopters in stbund			–121.161 (–1.24)	–164.818 (–0.99)
Constant	701.864 (3.06)***	748.085 (2.41)**	–244.560 (–0.80)	–357.353 (–0.71)
% of soil of quality Ceekol + Kollade			847.630 (2.38)**	
Number of observations	292	266	480	472
Number of panels	94	90	87	85
R-squared	0.19	0.16	0.24	0.15

Notes: *z* statistics are shown in parentheses.
* Significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Under nonadoption by return migrants, the households who adopted stone bunds benefit significantly from cultivating shallow soil. However, more formal rules (the number of rules that regulate the relationship between agriculture and livestock breeding) have a negative effect on their productivity. Cropper households and households with a high proportion of men also show higher yields in general. Being a household from the regions Oudalan or Gorgadji under this scenario favors yields, as well as schooling capital of households. In the case of nonadopters, only ethnic group and soil type seem to positively influence yields if return migrants crowd in this group. The poor results that come with nonadoption by newcomers seem to be linked to a relative advantage of adopting in a context where others do not, thereby indicating a decreasing return to scale. However, as we shall soon see in the graphical summary, adoption has generalized positive externalities for the whole community. Putting these two results side by side justifies a political intervention that may induce the social optimum.

Considering scenario 2, in which all of the return migrants join the adopters (Table 7), we have very similar but generally less significant results. In addition, the practice of fallow benefits the yields of the adoption group.

On the basis of the overall fit of the estimation outputs for the case of millet and sorghum yield, I summarize the results in Figure 1. It can be seen that, in general, the average predicted yields are lower under scenario 1, in which migrants do not adopt the technology when they return home (with yield performance under 500 kilograms per hectare), whereas the predictions are clearly above 500 kilograms per hectare in the second scenario. Another fact is that the group of households that adopts stone bunds shows significantly higher yields. However, it can be observed that households who do not adopt benefit from the positive externalities of higher adoption (higher average yields for each group under scenario 2, that is, graph 2) of the stone bund technology. As indicated by Dutilly-Diane, Sadoulet, and de Janvry (2003), stone bunds create strong externalities because collection of water run-offs and protection from soil erosion go beyond the field that the stone bunds actually surround.

Conclusion

This paper tackles a currently important regional issue in West Africa, the migration crisis, and tries to infer its effects on local food security and natural resource management. First, I show that if return migrants do not care about environmentally friendly innovation such as the traditional contour stone bunds (plot 2 in graph 1 of Figure 1 or results 3 and 4 of Table 6), consequences on food yields could be severe and therefore food security could be endangered in Burkina Faso and in the Sahel in general. Second, because, on the one hand, graph 2 in Figure 1 shows that adoption is good for adopters' yields but benefits also trickle down to the whole community, and on the other hand, in Table 6, results seem better when farmers adopt in a context of nonadoption in general (recall that return migrants refuse adoption in scenario 1), the conclusion is that we need political intervention at the macro level to induce a social optimum. Therefore, regional institutions should consider serious actions to favor the integration of return migrants. This study supports the development strategy in the Sahel that promotes efficient and cost-effective traditional agricultural technologies.

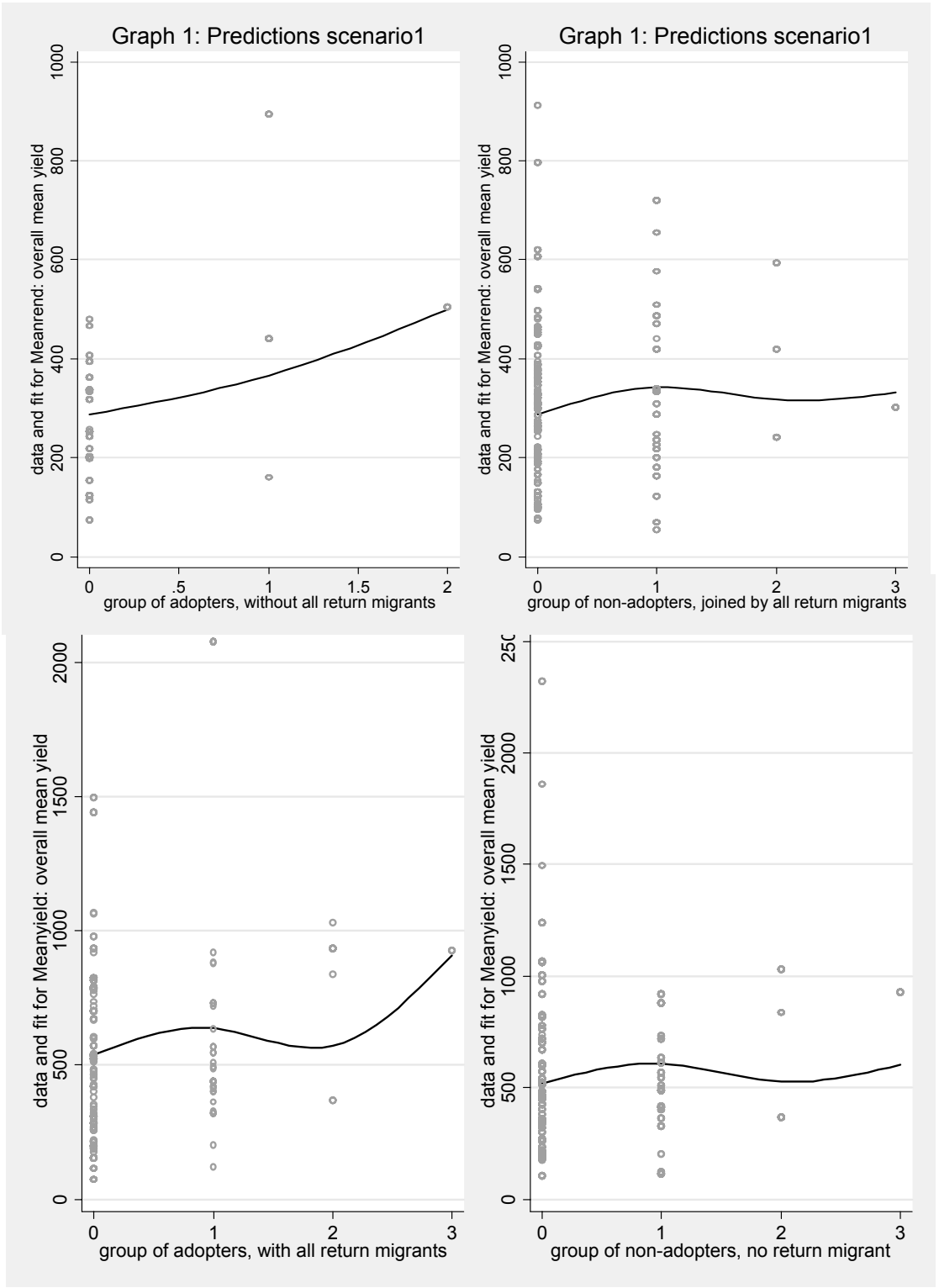
Given that the data were collected a few weeks before the start of the current political crisis in Côte d'Ivoire, the migration challenge is rather an urgent matter, as recent forced return migration in all of the landlocked countries may worsen the food and environmental situation. Dore, Benoit, and Engmann (2003) noted that in the aftermath of the 1999 coup d'état, 12,000 migrant agricultural workers were forced to leave the western and southern part of Côte d'Ivoire because of ethnic clashes, and several recent sources[35] reported that up to 350,000 Burkinabe immigrants to Côte d'Ivoire have fled home since

[35] According to the United Nations, nearly 350,000 Burkinabe immigrants left Côte d'Ivoire (November 2003, Africa.com, afrik.com); earlier figures registered 186,505 Burkinabe (March 2003, afrikeco.com) and 30,000 Burkinabe (December 2002, Newspaper Humanité [France]).

the start of the September 2002 conflict, which led to a wave of persecution of West African immigrants in Côte d'Ivoire.

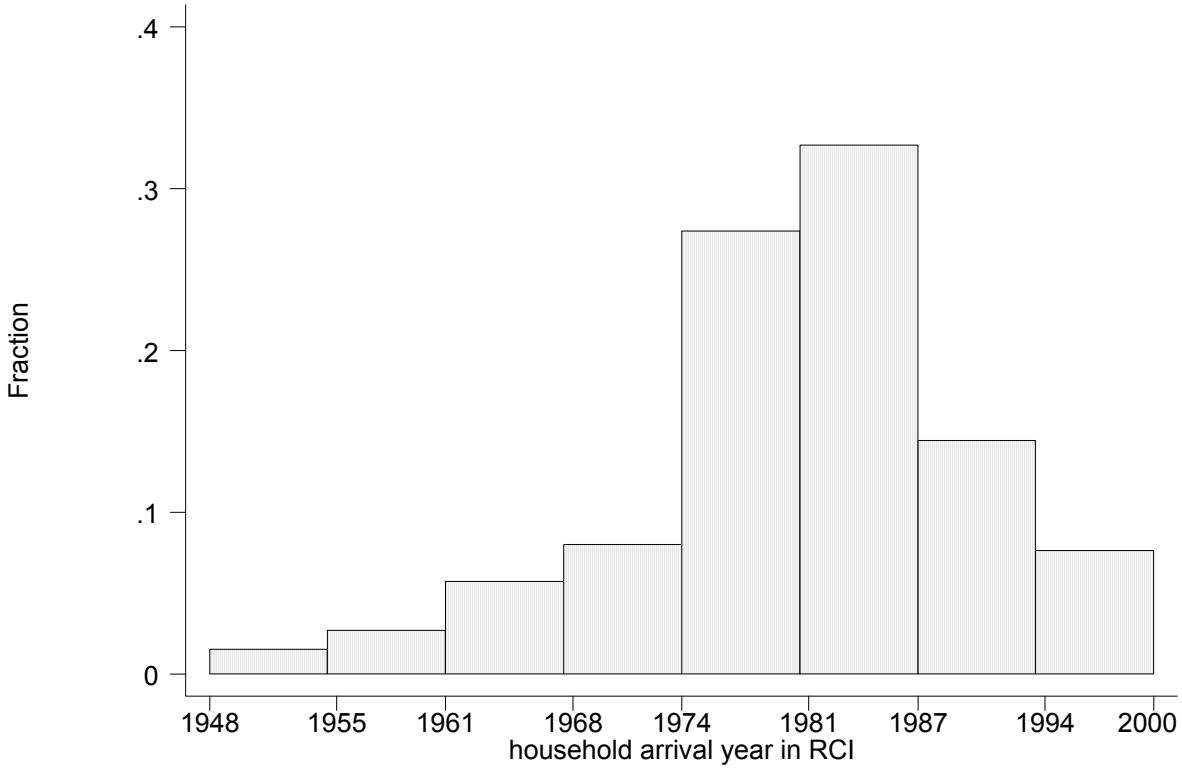
One way to address such a politically important issue is certainly to widen the scope of our research. First, because return migrants have specific skills and typically are entrepreneurial, we need a survey that focuses on the returnees' strategies at home. Second, food insecurity is often a problem faced by the poorest of the poor, who may be disadvantaged in both biophysical and human resources. These vulnerable households need special attention that can be captured within more general modeling such as the Multi-Agent Systems that allow modeling of the entire diversity of biophysical conditions as well as the entire diversity of households. As a policy decision support tool for food security and sustainability, such a research project calls for an interdisciplinary team that involves all scientists concerned with the debate on food production (economists, crop physiologists, agronomists, crop pathologists, crop geneticists).

Figure 1 — Predicted mean yield under both scenarios



Appendix: Supplemental Tables and Figures

Appendix Figure A1 — Recent trends in migration from Burkina Faso to Côte d'Ivoire, fraction of total sample



Source: Author survey in Côte d'Ivoire (summer 2002).
Note: RCI indicates Côte d'Ivoire.

Appendix Table A1 — Potential variables in the Heckman two-step model

Variable	Number of observations	Percent missing	Mean	Standard deviation
Transaction costs				
Distance to regional capital	190	2.56	30.26	19.46
	703	**0.14**	**37.05**	**18.63**
Shifters in consumption				
Dummy, nonmember remitted money and/or in-kind	195	0.00	0.09	0.29
	704	**0.00**	**0.14**	**0.34**
Shifters in crop production				
Head of household = cropper ethnic group	190	2.56	88.95	
	703	**0.14**	**44.10**	
Number of ethnic groups per village	190	2.56	4.18	1.71
	703	**0.14**	**3.21**	**1.84**
Meanyield: total mean yield for all crops and plots by household	195	0.00	643.91	424.21
	700	**0.57**	**1,294.60**	**4,986.18**
Mean value of yield for mil by household	175	10.26	742.48	481.82
	688	**2.27**	**662.94**	**460.57**
Shifters in crop and livestock production				
Total number of formal rules of natural resource management organizations	190	2.56	4.00	0.92
	703	**0.14**	**4.07**	**0.86**
Total number of plots per household				
Household member age	184	5.64	33.35	18.65
	649	**7.81**	**33.22**	**16.38**
Age of head of household	190	2.56	55.23	13.83
	703	**0.14**	**50.83**	**14.75**
Number of members who attended alphabetization	194	0.51	1.06	1.43
	704	**0.00**	**0.57**	**1.89**
Number of years of schooling, all types	183	6.15	12.52	29.38
	651	**7.53**	**8.97**	**25.52**
Percentage of 2000 members who attended public school	195	0.00	0.08	0.12
	704	**0.00**	**0.03**	**0.07**
Shifters in production and consumption				
Member's sex	176	9.74	37.50	
	645	**8.38**	**54.42**	
% of men among adults	195	0.00	0.43	0.10
	704	**0.00**	**0.49**	**0.09**
Regional dummies				

Variable	Number of observations	Percent missing	Mean	Standard deviation
Region=gorom	195	0.00	42.56	
	704	**0.00**	**57.95**	
Regional dummy = gorom + gorgadji	195	0.00	51.79	
	704	**0.00**	**69.89**	
Market participation, soil quality and risk variables				
Total number of Ceekol	42	78.46	1.24	0.43
	222	**68.47**	**1.23**	**0.55**
Total number of Seeno	168	13.85	2.16	1.77
	577	**18.04**	**1.99**	**0.98**
Total number of Bolaare	31	84.10	1.65	0.49
	152	**78.41**	**1.22**	**0.41**
% soil of quality Bolaare	31	84.10	0.61	0.08
	152	**78.41**	**0.39**	**0.12**
Existence of field under fallow	195	0.00	32.82	
	704	**0.00**	**31.82**	
Dummy for food buyer	195	0.00	88.21	
	704	**0.00**	**99.72**	
Total number of plots per household	195	0.00	3.17	2.12
	704	**0.00**	**2.83**	**1.39**
Variance: crops income in 2000	195	0.00	4.73e+09	6.53e+09
	704	**0.00**	**1.98e+10**	**3.15e+10**
Variance: migration income in 2000	195	0.00	1.08e+10	2.43e+10
	704	**0.00**	**2.18e+10**	**4.83e+10**
Variance: local off-farm income in 2000	195	0.00	8.58e+09	1.85e+10
	704	**0.00**	**2.43e+09**	**8.06e+09**

Note: The first row records results concerning adopters, the second row (in bold) records results concerning nonadopters of stone bund techniques.

Appendix Table A2 — Test of endogeneity in market participation variable

	(1) Test regression	(2) First stage, auxiliary regression
	Adoption of stone bunds	Dummy for food buyer
Mills ratio for return migration	0.241	0.006
	(1.47)	(0.49)
Dummy for food buyer	–12.220	
	(12.96)***	
Variance: local off-farm income in 2000	0.000	–0.000
	(1.86)*	(–3.41)**
Distance to regional capital	–0.012	–0.002
	(1.52)	(–2.20)*
Dummy, nonmember remitted money and/or in-kind	–1.624	0.015
	(3.10)***	(0.42)
Household member age	–0.015	0.000
	(2.98)***	(0.11)
Percentage of 2000 members attending public school	2.996	0.153
	(1.44)	(0.95)
Member's sex	1.559	0.123
	(2.99)***	(0.90)
% of men among adults	–6.589	–0.060
	(3.57)***	(0.36)
Predicted combined residual	**–2.459**	
	(0.61)	
Variance: crops income in 2000		0.000
		(0.79)
Variance: migration income in 2000		–0.000
		(1.08)
Regional dummy = gorom + gorgadji		0.014
		(0.45)
Number of ethnic group per village		–0.012
		(1.39)
Meantail: total mean plot size for all crops		0.011
		(0.86)
Constant		1.017
		(8.90)**
Number of observations	772	777
Number of group(vfolio mfolio)	111	111

Notes: R-squared = 0.16. *z* statistics are shown in parentheses.
* Significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.
Test of excluded instruments: varRag00 varrevMig00 oudalan eth_nb02 Meantail=0: Prob > chi2: 0.54.

Appendix Table A3 — Marginal effects on Prob (willing to return) after xtprobit

Return prospect of migrants	Marginal effects	*z* statistics
Meanyield: total mean yield for both crops (millet and sorghum)	–0.0001751	–3.66***
Total number of plots per household	0.06257	3.66***
Number of members who completed alphabetization	–0.0181734	–1.92*
Mean age	0.0260563	3.59***
Region = gorom	0.1007442	3.73***

Note: * Significant at 10 percent; *** significant at 1 percent.

Appendix Table A4 — Marginal effects on Prob
Scenario 2, return migrant adopted (Table 5 column 1)

Adoption of stone bunds	Marginal effects	*z* statistics
Mills ratio for return migration	0.0007	0.83
Dummy for food buyer	–0.469	–6.98***
Variance: local off-farm income in 2000	2.18e-15	278.04***
Distance to regional capital	–0.0001	–2.78***
Dummy, nonmember remitted money and/or in-kind	–0.005	–2.02**
Household member's age	–0.00007	–2.86***
Percentage of 2000 members attending public school	0.0153	1.67*
Member's sex	0.638	11.39***

Note: * Significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Appendix Table A5 — Marginal effects on Prob
Scenario 1, return migrant refused innovation (Table 5 column 2)

Adoption of stone bunds	Marginal effects	*z* statistics
Mills ratio for return migration	0.031	2.24**
Dummy for food buyer	–0.101	–2.82***
Variance: local off-farm income in 2002	–4.66e-15	–10.17***
Distance to regional capital	–0.007	–11.02***
Dummy, nonmember remitted money and/or in-kind	0.076	1.82*
Household member's age	0.001	1.41
Number of members who completed alphabetization	–0.019	–2.40**
Member's sex	–0.130	–5.18***

Note: * Significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

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