PN-ACC-734

Staff Paper

Determinants of Farm Productivity and Supply Response in Burkina Faso

by Kimseyinga Savadogo, Thomas Reardon, and Kyosti Pietola

Staff Paper No 94-79 November 94

Department of Agricultural Economics
MICHIGAN STATE UNIVERSITY
East Lansing, Michigan

MSU is an Affirmative Action/Equal Opportunity Institution

Michigan State University (MSU)
Department of Agricultural Economics

Draft for Review
November 1994

DETERMINANTS OF FARM PRODUCTIVITY AND SUPPLY RESPONSE IN BURKINA FASO

EXECUTIVE SUMMARY

Kimseyinga Savadogo, Thomas Reardon, Kyosti Pietola

INTRODUCTION

The physical, policy, and economic context in the West African semi-arid tropics (the WASAT) has changed radically from the 1960s-1970s (when the bulk of farm management studies were done) to the 1980s-1990s there has been rapid population growth, soil and natural resource degradation, declining rainfall, growing land constraints, structural adjustment programs, increased market involvement by farmers, diversification of farm household incomes into nonfarm activities, and mixed success of technology development

Moreover, there has been recent concern for stagnation of coarse grain and cash crop agriculture in the WASAT based on perceptions of low or declining agricultural productivity

The above changes and concerns point to the need to update our understanding of farm productivity in Africa. To this end, and to support Development Fund for Africa objectives, AID/AFR/SD/PSGE/FSP has funded the present study in Burkina Faso, conducted by researchers from University of Ouagadougou and Michigan State University under its Michigan State University's Food Security II Cooperative Agreement with AID The overall study of farm productivity also includes case studies in Rwanda, Senegal, and Zimbabwe

Our objectives were to

- "dig below" aggregate trends to uncover farm-level patterns in and determinants of
  - agricultural productivity,
  - crop supply response,
  - farm input demand,
- examine how these determinants may vary by crop, agroecological zone, farm type, technology, and institutional/policy setting
- examine implications for strategy, policy, and programs to promote and sustain increases in agricultural productivity

DATA AND METHODS

The study used detailed farm household data from an ICRISAT survey covering both farm and nonfarm activities of 150 households over four years (1981-1985) Having several years of survey data allows us to explore the effects of changes in prices and rainfall on productivity, supply, and input use, such variation is important in the semi-arid tropics, and data sets rarely cover more than one year and thus allow exploration of these effects

The sample was distributed over three zones, the northwest, middle, and southwest, corresponding to the Sahelian, Sudanian, and Guinean agroclimatic zones

The approach was as follows

- We examined patterns in average land and labor products (over crops, animal traction versus manual farm types, zones, and years) Total factor productivity indices were calculated

- We explored determinants of crop productivity differences by computing marginal factor productivities over crops, farm types, and zones These figures were derived from production function coefficients

- We analyzed determinants of crop supply response and input demand using a profit function approach, using the same breakdown by crops, farm types, and zones

The factors examined were primarily physical production inputs -- variable inputs such as fertilizer and manure, and capital inputs such as animal traction equipment, as well as conditioning variables such as agroclimatic zone, household characteristics (e g , nonfarm income earned), supporting institutions and services (input supply infrastructure)

The study focuses on farm-level productivity Outside of our scope is the issue of how changes in farm-level productivity (and changes in policy to effect them) affect the rest of the economy

CHARACTERISTICS OF BURKINABE AGRICULTURE AND AGGREGATE TRENDS

- Burkina agriculture is smallholder and rainfed, with a low average marketed surplus rate (around 10 percent), and important sales of cotton and livestock About half of rural incomes are now earned in nonfarm activities mainly connected upstream or downstream to agriculture, and in migration

- Grain imports are about a quarter of cereal consumption

- Cotton and livestock constitute about 60 percent of exports (they pay for the grain imports)

- Growth in average land product (output per hectare) and average labor product (output per agricultural worker) was slow in Burkina Faso for most crops In general, average land product grew more quickly than average labor product, indicating increasing population density per square kilometer

- Output of millet and sorghum (the main food crops) grew slowly, behind population growth, and average land product grew only around 1 percent yearly

- Maize has bright production prospects but is still a minor part of food output, and its average land productivity is growing moderately, around 2 percent yearly

- Output of cotton, the main cash crop, grew rapidly in the 1980s, as did its average land product, output growth has tapered off in the 1990s Area under cotton grew from 66,601 ha in 1973 to 74,948 ha in 1980 to 185,750 in 1991 to 176,900 ha in 1992, and average land productivity grew 3 8 percent yearly over 1961-1991

- Pressure on arable land is already high in the unfavorable agroclimate zones (Sahelian and Sudanian zones) where two-thirds of the rural population lives, and moderate for now in the favorable agroclimate zone in the south (Guinean zone) But a World Bank study (Lallement 1990) shows that population is migrating quickly and pressure on land mounting in the south

- Hence a major issue in Burkinabe agriculture is the need to move from "extensive" to "intensive" systems that involve much-increased land productivity

. Through **sustainable intensification** as the "carrying capacity" of arable land is being undermined quickly by soil degradation and erosion of soil, soil conservation and water

retention investments are needed (see e g Matlon and Adesina 1992, and Sanders et al 1994)

MAJOR FINDINGS

DISAGGREGATED PRODUCTIVITY PATTERNS

- Among the coarse grains, maize has the highest average land productivity, followed by sorghum then millet The same pattern holds for labor productivity

- The Guinean zone has from moderately to much higher (1 5-3 times) average land products than the other zones for all crops -- yet in good years millet yields, and to a lesser extent sorghum yields, can be similar across zones

- Sorghum, maize, and cotton land and labor productivity are correlated with agroclimate (increase as go south), but the relationship is weaker for millet, especially in labor productivity, as it is relatively easy in the north to add land and thus protect labor yield (hence output per consumer)

- Animal traction (AT) confers an advantage in land productivity in the case of maize and cotton in the Guinean zone, and a labor productivity advantage in cotton in the Guinean zone Cotton average land products on animal traction farms were 1 5 times those on manual farms

- In general AT helps productivity in the case of crops that are relatively labor intensive

- Land and labor yields fluctuate the most over years in the north, where rainfall fluctuates most For example, average land products changed sixfold between the good year of 1983 and the drought year of 1984 In general, maize land and labor productivity fluctuates more than that for the other crops because of its sensitivity to soil moisture This result points to the notorious riskiness of agriculture in many areas, and to the sensitivity to beginning and ending points of longitudinal productivity analysis in WASAT

- Labor yields tend to fluctuate more than land yields in the Sudanian and Guinean zones, partly because there appear to be land constraints (quality and quantity of land suitable to each type of crop), while this is not the case in the Sahelian zone where farmers can use more land (albeit of low quality) to augment labor

- In the traction group, for both zones, the marginal value products of labor exceed the observed wage rates, suggesting a relative labor shortage

- The marginal value products of labor for traction households exceed those for manual households, suggesting that animal traction makes labor more productive

- In the traction group of the Guinean zone, the marginal value products of labor are almost equalized across crops, suggesting economic rationality in labor allocation This is not the case for manual farmers

- In both zones, the average labor product is above the marginal labor product, again suggesting a labor constraint

DETERMINANTS OF PRODUCTIVITY. GENERAL FINDINGS

- Our results reemphasized the importance of traditionally identified factors that determine productivity in farm management studies in the WASAT

  - fertilizer
  - manure
  - animal traction

  as well as land and labor But actual

productivity effects varied substantially by location and farm household type Other country case studies also showed importance of access to improved seed (MSU studies of returns to agricultural research (Oehmke and Crawford, 1993) have also showed the pivotal role of effective seed distribution)

• Our study identified constraints on availability of fertilizer, equipment, operating capital, and good quality land The study also showed unequal access to these inputs, and hence an unequal distribution of benefits from improved input use, partly because of unequal access to cash income (especially from nonfarm activities) and to credit

• Our study highlighted several determinants of productivity that have not traditionally been emphasized in Africa, that we believe are linked to the changes in the economic and physical context over the last few decades (discussed above),

- nonfarm income generation often plays a key role in facilitating acquisition and use of productivity-enhancing inputs

- market infrastructure, important to acquisition of inputs that drive productivity change

Other country case studies, whose results we feel are important for the Burkina case, but which our data did not allow us to confirm for Burkina Faso, highlighted the role of natural resource conservation in improving farm-level productivity Conversely, improving farm productivity helps conserve resources

IMPACTS OF INPUT USE ON PRODUCTIVITY – AND PATTERNS AND DETERMINANTS OF INPUT USE

Fertilizer

• We found fertilizer to have a positive impact on land productivity, but noise in the data appears to be the cause of its statistical insignificance

• Fertilizer use in Sub-Saharan Africa is low compared to world standards (9 kgs/ha in 1985 versus 58 5 in all LDCs)

• Fertilizer use in Burkina (i) virtually no fertilizer was used in the Sahelian zone, (ii) an average of 11 kgs/ha in the Sudanian zone, and (iii) 39 kgs/ha in the Guinean zone

Availability and affordability are key issues in the use of fertilizer, in particular in the non-cotton areas Unfortunately, this is also where land is degraded and needs fertilization

• Use varies alot over crops In the Guinean zone, use on cotton was 109 kgs/ha, followed by 46 kgs/ha on maize, and less than 5 kgs/ha on millet/sorghum.

• Fertilizer use is positively related to nonfarm income and accessibility as indicated by the proximity to a road in the Sudanian zone – but not in the Guinean zone where the presence of SOFITEX (the cotton parastatal) makes fertilizer available to farmers regardless of village location and household cash sources

• The elimination of credit and fertilizer subsidies and a switch from government to private sector distribution (reducing the area served), often associated with structural adjustment programs, have had a negative impact on fertilizer use, at least during the period of gradual removal of the subsidy, 1983-1987 Use has picked up again thereafter due apparently to intensification strategies on waning land of sufficient quality

Hence, greatest fertilizer use (well above the African average) was in higher rainfall areas and on cash crops, where distribution, credit, and marketing/credit recovery were handled by a parastatal, or where households had more nonfarm income

Manure

- Soils in Burkina Faso are known for their low organic matter content Soil amendment with manure and compost is needed to slow soil acidification

- We found

  - Manure increases land productivity of cotton and maize

  - Use of manure increases the output of maize, for both AT and manual farmers, in the Guinean zone

  - Cotton benefits from residual effects due to the rotation with maize

- Manure use Overall only 150 kgs/ha are used in the Sahelian zone, then 411 in the Sudanian, and 995 in the Guinean zone

In the Guinean zone, maize gets most manure (7384 kgs/ha) then cotton (1314) then sorghum (427) then millet (155)

Animal traction

- In Africa, the main effect of AT shown to date has been to reduce field labor inputs and aid area expansion (especially on light soils), rather than to increase yields

- We found AT have the following effects (relative to use of manual technology)

  - AT strongly improved <u>land</u> and labor productivity on cotton, and on labor productivity in millet, in the Guinean zone

  - AT farms had greater supply responsiveness to price and nonprice incentives

  - AT farms were more efficient in resource allocation

  - AT farms used much more manure

  - AT farms grew much more cotton

  - AT farms were much bigger

  - AT farms used only slightly less labor per hectare (overall)

- AT use The portion of households in the study zones that used AT in the study period was 9 percent in the Sahelian, 14 percent in the Sudanian, and 19 percent in the Guinean zone

- Nonfarm income and farm size were important determinants of adoption of AT Nonfarm income (controlling for farm size) was particularly important in the Guinean zone, as credit was not generally available for it so the household's own liquidity sources -- mainly nonfarm income -- was crucial to that investment

Land and labor

- An increase in total farm land size has positive effects for all crops, with the bigger effect accruing to millet which is the main beneficiary of land expansion

- Wage increase decreases overall labor demand -- as off-farm opportunities increase, we expect that this will bid up farm wages, but with a land constraint, there will be a need for agrarian capital formation, mainly in form of AT investment

Nonfarm income

- Nonfarm income can increase purchased input use or capital investments (thereby increasing productivity) where credit is unavailable or costly to use, or where other sources of cash income for loan repayment are lacking

- Nonfarm activities smooth household income and help to reduce risk by diversifying the sources of household income

- Within a given agroecological zone, the poor have less access to nonfarm income opportunities -- nonfarm income tends to make up a smaller share of total income for poor than for rich households, poor households are less able than rich households to participate in high-return nonfarm activities

- There is generally a positive relationship between nonfarm income and improved input use (fertilizer in the Sudanian zone (where SOFITEX is not present to make it available to households regardless of their own-liquidity sources, and animal traction in the Guinean zone)

- The combination of the above two points is worrisome because unequal access to nonfarm income translates into unequal access to farm inputs in the face of limited credit access

DETERMINANTS OF OUTPUT SUPPLY AND CROP MIX

Prices

- The panel data allowed the isolation of the effects of prices on supply response The effects of prices are reinforced by those of non-price factors

- We found in general that

  - Aggregate output responds positively to increases in the price of commercialized crops (cotton and maize) among AT households in the zone with the most favorable agroclimate, the Guinean zone -- thus averting the fear that price increases only lead to crop mix shifts

  - In response to policies increasing price to the farmer, cotton in the Guinean zone responded strongly to own price over the period of analysis A 10 percent increase in price led to the increase of supply by 256 kg for AT and 158 kg for manual farmers, from the mean

  - Millet and sorghum respond positively to own price changes, in the Guinean zone, with the response of millet larger, reflecting a land and/or an outlet constraint to expanding sorghum production

- For the AT group, in the Guinean zone, we found

  - There is a complementarity, not a substitution in price between cotton and maize, reflecting cultural practices which rotate cotton and maize

  - Cotton is a substitute in price for the traditional cereals, millet and sorghum

  - For the manual group, in the Guinean zone, all cereal crops are in competition with cotton, reflecting a lower flexibility than AT households to reallocate resources to raise outputs simultaneously

  - The effects of prices are more limited in the less favorable Sudano-Sahelian zone, where only sorghum responds positively to own price, for the traction group

Fertilizer

- An increase in the amount of fertilizer used by the households is associated with an increase in the output of cotton, in the Guinean zone, for both AT and manual farms

- Fertilizer has a positive effect on the output of maize for the traction households

Animal traction

- Greater supply responsiveness to price

Markets

- Well-functioning input and output markets facilitate the acquisition and use of productivity-increasing inputs by making inputs and market outlets available, and by reducing transactions

costs and risks (e g , from imperfect information, or price volatility due to a thin market) Vertical integration and coordination functions (input supply, credit, output marketing) were assured effectively by a parastatal for cotton (This result coincides with Lele et al 1989

RELATION OF OUTPUT SUPPLY AND PRODUCTIVITY

- Incentive policies that increase cotton and maize production increase the output of crops that have higher land productivity -- and thus are appropriate where land constraints are growing such as in the Guinean zone

MODELING/THEORETICAL

- Modeling productivity and supply response in the context of an endogenous selectivity approach was shown to be appropriate in capturing the differences between traction and non-traction households and providing better parameter estimates than the use of an exogenous partition based on the usual dummy variables approach

- It is important for farm productivity analyses to incorporate directly or indirectly intersectoral effects (effects of nonfarm income) on investment and in turn on productivity

STRATEGIC, POLICY, AND PROGRAM IMPLICATIONS

1 Sustainable intensification of farm production through use of improved inputs that raise and sustain increases in land productivity is a major food security issue in Burkina Faso, given growing land constraints and soil degradation To get needed breakthroughs in farm productivity, farm input use -- such as fertilizer, organic inputs, animal traction, and conservation investments -- needs to rise substantially

In general we show that key elements of raising land productivity (and labor productivity) are fertilizer, manure, and animal traction These are especially useful in increasing yields in maize and cotton, which are the key crops that can usher in the new era of intensification of cropping and increase of yields The problem is that fertilizer, animal traction, and manure use are well below desirable levels and policies and programs need, even in this era of tight budgets, to encourage and enable farmers to use more of these inputs

2 Strategies to raise farm productivity will need to differ, however, between favorable and unfavorable agroclimatic zones With proper conditions, much increased productivity can be expected in the favorable zones (mainly the Guinean zone) Expectations for cropping intensification are more modest for the agroclimatically unfavorable and fragile zones (the Sahelian and Sudanian), and attention will need to be paid to alternative income sources off-farm in the latter zones This will promote food security in the agroclimatically unfavorable zones and increase effective demand for agricultural products from favorable zones

3 Off-farm employment and the farm productivity agendas are linked. In many areas off-farm income is a critical means to pay for farm inputs and investments Moreover, much of the growth of nonfarm activity is linked to growth of farm output Growth in off-farm employment opportunities in rural areas is essential to achieving food security and economic transformation in Burkina Faso

The liquidity constraint suggested by the significance of nonfarm income in farmers' decision must be addressed either through an appropriate credit policy, and/or through policies aimed at developing income generating activities in rural areas The World Bank has already engaged in such activities in its food security component of the agricultural sector adjustment program in Burkina

But we worry about the long-term distributional effects of the importance of nonfarm income on productivity, particularly as we found that nonfarm income is not equitably distributed over households Programs that increase access to these sources of income are thus expected to in turn increase access to farm modern inputs by the poor

There are two implications of the importance of nonfarm income in the productivity equation

- Micro-enterprise promotion programs that provide rural employment while reducing the cost of farm inputs and increasing the off-farm multipliers from farm output growth are desirable

- New cropping technology proposed for farmer adoption must not only be financially and economically profitable, but also attractive relative to alternative uses of household resources (e g , livestock and nonfarm production)

4 Cash cropping programs spur productivity through providing cash to buy improved inputs, and depending on how they are organized, increase access from the supply side to improved inputs and to low-risk output marketing opportunities.

When the technical conditions allow, the main cash crop (cotton) and the most productive food crop (maize) are complements not competitors (in cross-price terms), which runs counter to pessimism about cash cropping eroding food crop agriculture With appropriate technologies (animal traction) and incentives (guaranteed markets for the cash crop and strong support for maize) farmers in the Southwest of Burkina have expanded their cultivation of both cotton and maize This coincides with similar farm-level findings of complementarity in Mali (Dione 1989)

5 Sahel farmers respond to market mechanisms, but only on the condition that there is a propitious set of technologies, institutions, and physical conditions The institutional setting and policies appear to have promoted agricultural growth during the first half of the 1980s in Burkina, the government had placed greater emphasis on promoting the rural sector through incentive cotton prices (as well as rural organization and water retention technology development, not explored here) These policies appear to have contributed to agriculture performance above the norm during a time when other African countries in the semi-arid zone had negative agricultural growth

For policies such as the devaluation of the Franc CFA to have a positive impact on cash crop and aggregate supply response, policymakers should not ignore but rather reinforce sectoral programs such as animal traction development and fertilizer distribution

6 Animal traction programs are very important for Burkina Faso – in the 1960s and early 1970s, inexpensive packages were offered to farmers in a promotion program but adoption rates was low Since the cotton boom of the 1980s there appears to be much higher demand by farmers, but there are demand-side constraints (cash and credit constraints) to obtaining equipment Programs that make the equipment available widely and cheaply will help Rather than viewing AT as just a way to clear more land, we have underscored its role in raising land yields especially for cash crops in the southern zones As farm wages are bid up by increasing off-farm opportunities, and as land constraints increase, we expect agrarian capital formation to play an increasingly important role in intensification that is both labor and land saving

7 Fertilizer was found to be important. Reduction of the fertilizer subsidy over the 1980s coincided with a decrease in its use. But fiscal constraints prohibit return to the days of massive fertilizer subsidies. We need to seek a middle path, where programs and policies address the need to get fertilizer cheaper to

farmers A key way to do this is to press hard on transport costs and the quantity/quality of rural infrastructure For example, the Premier Ministere (1993) study of potential impacts of devaluation shows that we can greatly lower fertilizer costs through improving the transport system and infrastructure

This middle path implies substantial public and private investment in agricultural research, human capital, and production and market infrastructure Policy reform alone (exchange and interest rate policy, market liberalization, privatization), while important, is not sufficient to spur higher agricultural productivity, resource, technology, and market constraints on agricultural growth must be tackled directly by allocating government and donor resources to overcoming them

Public investment should be such that it complements and spurs private investment on-farm, in the input distribution system, and in primary product processing It is essential that government and donors invest in understanding how to promote the economic use of the tools of sustainable intensification -- fertilizer, animal traction, organic inputs, and soil conservation investments

Thus the debate should be reopened on identifying cost-effective ways of increasing access to inputs, by improving the delivery of inputs and giving farmers the means to pay for them. This effort is especially appropriate in West Africa FCFA zone whose macroeconomic environment has become more favorable through structural adjustment This should be a priority policy issue in the 1990s and beyond

DETERMINANTS OF FARM PRODUCTIVITY AND SUPPLY RESPONSE IN BURKINA FASO

CHAPTER 1 INTRODUCTION

1.1 Importance and Characteristics of Agriculture

Agricultural is the main sector of the economy with regard to employment and rural income, food security, and foreign exchange It constitutes a third of gross domestic product (GDP) and provides the principal employment of over 80 percent of the population (EIU, 1994)

Food output (mainly millet and sorghum) is growing slowly, behind the population rate, and millet/sorghum average land productivity is also growing slowly (around 1 percent yearly) The upshot is that imports have now become 27 percent of national food consumption Cereal imports have increased from 77,000 metric tons in 1980 to 177,000 metric tons in 1991 (World Development Report, 1993, Sanon et al , 1993) Maize has bright production prospects (Matlon, 1990) but is still a minor part of food output, and its average land productivity is growing moderately, around 2 percent yearly (FAO)

Cotton, the main cash crop, had rapid growth in area under cultivation in the 1980s (from 66,601 ha in 1973 to 74,948 ha in 1980 to 185,750 in 1991 to 176,900 ha in 1992 (SOFITEX 1993), as well as very rapid average land productivity growth over 1961-1991 (3 8 percent yearly) (FAO) Cotton and livestock constitute about 60 percent of exports (hence paying for food imports) In 1988, cotton accounted for $63 8 million of $ 140 9 million of exports, while livestock and skins and leather accounted for $ 13 1 million In 1990, cotton accounted for $ 94 million of the total $ 272 million exported (EIU, 1992, 1994) Cotton significantly contributes to rural incomes, as an estimated 15 to 18 billion FCFA cotton revenue is injected into the rural sector each year Cotton production directly provides employment for 70,000 farm households (about 735,000 people) while the related downstream activities (small scale textile industry, transportation) employ an additional 156,000 households or 1,100,000 people (Sanon et al , 1993)

Burkina Faso's agriculture is almost entirely smallholder, dominated by an estimated 600,000 to 650,000 farms, each averaging 2 to 7 ha per farm, together accounting for 95 percent of agricultural production It is rainfed -- only 1 8 percent of cropped area is under irrigation Production is highly conditioned by rainfall Rainfall can fluctuate substantially over years, hence so can production For example, production decreased by 22 percent from 1986 to 1987, and increased by 40 percent from 1987

to 1988

Cropping is predominantly of millet and sorghum -- which covered 80 percent of total cultivated area over 1984-88 Cotton, maize, and peanuts each covered about 6 percent of cultivated land Marketed surplus rates for grains are low, and rates for cotton and livestock are high An important share of rural incomes are now earned in nonfarm activities mainly connected upstream or downstream to agriculture, and in migration

Pressure on arable land is already high (even higher when measured in terms of "carrying capacity" FAO (Higgins et al 1982), ranks Burkina as densely-populated in the unfavorable agroclimate zones (Sahelian and Sudanian zones) where two-thirds to four-fifths of the rural population live Population density is moderate for now in the favorable agroclimate zone in the south (the Guinean zone), but a World Bank study (Lallement 1990) shows that population is migrating south quickly and pressure on land mounting Burkina agriculture is having to move quickly from "extensive" to "intensive"

Further, the "carrying capacity" of arable land is being rapidly undermined by soil degradation and erosion in many areas, as well as by bushland loss through overgrazing There was a rapid increase in the late 1980s, however, of water retention investments by villagers in the Sahelian and Sudanian zones (supported by complementary capital in the form of trucks and extension from the government) (Sanders et al , 1994)

Persistent degradation and slow productivity growth imply that the elements of cropping intensification and of accompanying soil conservation are not being put in place as quickly as needed Fertilizer use rates, mainly on cotton, dropped over the decade from a low of 25 kg/ha on cotton in 1973, it rose to 130 kg/ha in 1983, and then dropped to 107 kg/ha in 1987 (as 1983-1987 was the period of gradual removal of the fertilizer subsidy), and then rose from 122 to 165 from 1988 to 1992 (SOFITEX, 1993) Our hypothesis (not tested here) for the latter rise is that there was increased farmer awareness of the need for fertilizer on cotton, and a gradual intensification of cotton production on the available land of sufficient quality for cotton production, as the area dedicated to cotton increased

On other crops except for maize, fertilizer use is very minor (see chapter 2) Manure use is well below recommended use to counter soil fertility loss, and animal traction is used only by a minority of farmers in the favorable agroclimate zones (see Chapter 2) Infrastructure in many areas is still poor

1.2 Policy Issues

Over the period when Burkina Faso experienced the fastest growth in its agriculture, incentive price

policies were used both in cash and food crops According to World Bank (1988), the producer price for first-grade cotton was increased by 61 percent from 1982 to 1985, the price of sesame seeds doubled, and the price of peanuts increased by 9 percent before leveling off due to unfavorable world prices These actions were positively correlated with output increases Producer prices for food crops were also raised the prices of sorghum and maize were increased respectively by 33 and 45 percent, showing the intention of the government to raise farm income by a transfer from urban consumers and rural net buyers to rural net sellers However, parallel market prices usually prevail in this sector (Savadogo and Wetta, 1991), and only the grain procurement by the state (around 10 percent of total supply) uses official prices

Fertilizer subsidies were instituted in the late 1970s, but whittled away over the 1980s as part of Burkina's "homemade Structural Adjustment program" (1983-1989), accompanied by a decline in fertilizer use except on cotton during the period of removal of the subsidy (see section 1 1) To promote fertilizer use in the cotton-producing areas, the government started a fertilizer subsidy program which reached its peak in 1981 when farmers paid only 36 percent of the cost of fertilizer The gains in cotton productivity were commonly associated with the increased use of chemical fertilizers Because of the budgetary burden (an outlay of 1 4 billion FCFA in 1982), subsidies were progressively reduced starting in 1983, until their complete elimination in 1987 As shown in Sanon et al , the subsidy removal was accompanied by lower producer income and lower use of fertilizer (see our section 1 1 for figures)

The fertilizer distribution system caters mostly to cotton producers, and was administered by the cotton parastatal SOFITEX (Société des Fibres et Textiles) in association with regionalized structures of the Ministry of Agriculture (Centres Régionaux de Promotion Agropastorale--CRPA) Although the structural adjustment program concluded with the World Bank and the IMF (started in 1991) brought with it some degree of liberalization in distribution, private merchants have yet to play a significant role As a consequence, fertilizer is not available in non-cotton zones where cereals are the major crops

Animal traction (AT) use was encouraged through extension but no massive provision programs were put in place as they were for peanut areas in Senegal in the 1970s

As Burkina embarked on its home-made macroeconomic adjustment program, the rural sector was singled out as a key sector where progress needed to be made Likewise, the 1991 structural adjustment program placed a major role on the agricultural sector through the Agriculture Sector Adjustment Program (ASAP) ASAP's goal is to encourage and redynamize agriculture to improve food security and improve natural resource management, through use of fertilizer, AT, and soil conservation As part of adjustment, cereal and input markets were liberalized In January 1994, Burkina Faso, with the rest of the FCFA countries, devalued drastically the franc CFA Hence the emphasis has been on standard

structural adjustment policies to increase incentives in the food system. The focus in agriculture is on coarse grains, cotton, and livestock, as well as minor crops peanuts and sesame

1.3. Gaps in knowledge and Our Objectives

This report focuses on the following issues related to the above agricultural and policy challenges

(1) What are the effects of fertilizer and manure use on land and labor yields -- as prime methods of intensification (increasing use of factors other than the scarce factor, which is becoming land)? Knowing this will tell us how inadequate use of these inputs keeps Burkina from reaching its production potential, and how incentive policies for these inputs will raise productivity

(2) What are the land and labor productivity effects of AT -- can it be used as a tool for intensification (beyond its traditional use for extensification)?

(3) What price and nonprice factors drive farmers use of fertilizer, manure, and AT? How can their use be promoted?

(4) How have cotton incentive policies affected cotton output and aggregate output (that is, just a crop mix shift or an aggregate output increase)?

(5) What is driving crop mix shifts toward maize and cotton from millet and sorghum, and how do these shifts affect land productivity in the face of growing land constraints?

(6) How do the income diversification strategies of rural households affect their farm productivity?

Hence, the issues addressed by this report center on increase of use of improved variable inputs and capital to raise productivity, to intensify production under conditions of growing land constraints -- what Lele and Stone (1989) call "policy led intensification", and how crop mix (especially the increase of production of key cash crops, cotton and maize), might effect land productivity These questions are central to information needs to implement the new agricultural policy goals of dynamizing food and cash crop agriculture -- in turn crucial for long term food security in Burkina Faso Given that opportunities and potential differs by agroecological zone, the questions need to be addressed by zone

1.4 Methods and Data

We address the above questions in three ways

(1) Factor productivities -- average and marginal land and labor productivities by crop and zone and technology group -- are described using farm-level data for the first half of the 1980s

(2) In turn, these factor productivities are conditioned by use of variable inputs such as fertilizer, manure, and labor, and of capital such as AT, we examine factors that determine use of these inputs and capital -- such as availability of farm labor, and cash availability especially through nonfarm income sources

(3) Moreover, different crop mixes imply different overall farm productivity, and prices and nonprice factors affect this mix, as well as crop supply and factor demand We examine these relationships

This study concentrates on determination of farm-level agricultural productivity and supply response To do so, we use a production function approach to identify marginal productivities and thus assess the relative importance of factor constraints This work builds on earlier studies by CEDRES/University of Ouagadougou, ICRISAT, INERA, IRAT, IRCT, MSU, and SAFGRAD/Purdue

The study also uses a profit function approach to derive supply functions for outputs and demand functions for inputs, and draws inferences concerning farmers' responsiveness to price and non-price factors based on the values of the resulting elasticities

An important aim of the research is to demonstrate the impact of technology use, in particular use of AT We develop models that account for the adoption of this technology The modeling of production and supply response is placed within the context of an endogenous sample selection which estimates parameters for the two groups of adopting and non-adopting farmers, upon accounting for the determinants of adoption

We use farm-level data from a survey by ICRISAT (conducted by Peter Matlon) from 1981-1985 The data set is very detailed and differs from most available Sahel rural data sets (1) Rather than just farm management information, we have data on all the household's activities on and off farm, so we can relate general household strategies such as income diversification to farm investments and productivity, (2) Our data cover 5 seasons and 6 villages in 3 zones so we can examine how interyear and interzone difference affect the responses to our research questions Moreover, we thus have enough output price variability to examine the effects of price changes (especially interesting in the case of cotton) affect supply, (3) We have significant samples of AT and manual households so can examine technology choice effects

1.5 Terms and Concepts

"Productivity" is a measure of the output derived from a standard unit of input it shows how efficient

is the producer's use of the input That efficiency is conditioned or determined by the technology, the level of use of the input, and levels of use of complementary inputs For example, land productivity is the average output per unit of land used, and is conditioned by land used, and the farmer's use of fertilizer and animal traction It is also conditioned by other characteristics of the farmer and her/his milieu -- education, rainfall, soil quality, and so on

"Average productivity per unit input" is the output divided by the input level (e g total millet divided by total land used) This is often called "yield", but we use "average land productivity" and "average labor productivity" to highlight the input. "Marginal productivity per unit input" is the additional output (at the margin) produced by an extra unit of input used (e g how much millet an additional hectare of land will produce, say beyond the average land used), conditioned by the same set of conditioners as noted above To compare across goods, to compare with factor prices, or to aggregate over goods, productivities are commonly valued at the output price The marginal product of land, multiplied by the price of the good produced by that additional unit of land, is the "marginal value product of land"

Farm productivity measures can be defined with any number of crops in the numerator -- from one to all When there are more than one they are aggregated using prices as weights Likewise, there can be one or more inputs in the denominator, again summed by their prices When all crops of the farm are in the numerator and all inputs in the denominator, one has an index of "total factor productivity" When a single input is used (with one or more outputs) one has "partial factor productivity"

If the producer is economically rational and there is no constraint to the use of an input, in theory the marginal value product should equal the factor price If, however, for example, there is a constraint in the farmer's use of the input (say a credit constraint), of e g capital, then the marginal value product of capital can exceed the price of capital, farmers could then efficiently use more capital (as marginal return falls until marginal value equals the seed price)

Moreover, in theory if there is efficiency of allocation of a given input, the marginal value product of an input for one crop should equal the same for any other crop a farmer grows If they are not equal, there is some factor access constraint or non-optimal behavior due to presence of risk or transaction costs

In this document we work with all the above concepts and measures, but place a greater emphasis on single crop productivity measures so that allocation efficiency can be examined and specific input-to-crop allocation data are available We also calculate total factor productivities (TFP), but TFP is normally more interesting in the case of longer time series and more aggregate data (when large exogenous changes such as research and development can be charted) There is a tradeoff here in Africa between farm-level and meso or macro data sets, the former being usually short time series but with rich intercrop and inter-

farm-type information, and the latter being usually longer time series but lacking detail to determine crop specific factor yields

Average productivities are simply calculated using average output divided by input used by farms of a given type (say animal traction-using farms in the Guinean zone of Burkina Faso) By contrast, calculation of marginal productivities require estimation of production functions or profit functions

The production function is output explained by use of variable inputs (labor, land, fertilizer) and capital inputs (land, equipment), and other conditioning factors such as rainfall Given an estimate from the function of the marginal effect of e g labor on millet output, one can and we did examine how this marginal impact changes when there are different levels of the conditioning factors (such as how much more productive is an extra unit of labor when fertilizer use is higher)

One can then ask what determines use of inputs and conditioning variables -- including policy and other household-level determinants like nonfarm income For example, we studied what determined the adoption of animal traction, and then split the sample into traction users and manual households, and then asked how their productivity differed by estimating production functions for the groups

"Supply response" measures the strength of the direct effect of prices and non-price variables on farm supply The question of supply response assumes that the variable inputs have adjusted to the changes in prices and conditioning variables, so that the resulting change in output is a net effect We compute price and non-price elasticities of supply in the framework of differentiated technologies These are valuable policymaking guides, showing for example the role of technology and other non-price factors in determining the flexibility to respond to economic incentives

1 6 Plan of the study

The rest of this study is as follows Chapter 2 provides further background on past research and debate concerning the determinants of productivity in the West African semi-arid tropics, with a focus on Burkina Chapter 3 describes the sample data, concentrating on the characteristics of the study zones and of the sample households Chapter 4 presents the patterns of sample input uses and average factor productivities for the country as a whole and for the zones and technology groups Chapter 5 models technology choice in the framework of a binary choice model, and also defines the framework of selectivity modeling used in the next chapters A production function model is developed in Chapter 6 and marginal factor productivities derived Chapter 7 develops and estimates a supply response model from which price and non-price elasticities are derived In Chapter 8, the research results are summarized, with their implications for policymaking

Table 1 1 Area, production and average products of cereals, 1961 91

(Area in ,000 Ha, Prod in ,000 MT)

	MAIZE				MILLET				SORGHUM			
	AREA	PROD	KG/HA	KG/L	AREA	PROD	KG/HA	KG/L	AREA	PROD	KG/HA	KG/L
1961-65	157	100	634	40	728	293	402	119	946	467	493	189
1966-70	158	97	617	36	766	343	447	128	1 059	557	526	208
1971 75	107	68	637	23	801	307	384	105	1 090	568	521	194
1976-80	101	89	887	28	793	362	456	112	1 056	601	569	187
1981	143	119	832	35	922	443	480	130	1 089	659	605	193
1982	135	111	822	32	909	441	485	127	1 048	609	581	175
1983	125	71	568	20	928	391	421	111	1 083	611	564	173
1984	121	77	636	21	723	372	515	103	965	594	616	165
1985	143	142	993	39	974	587	603	160	1 077	798	741	218
1986	165	155	939	42	1 171	680	581	183	1 330	1 011	760	271
1987	176	131	744	35	1,168	632	541	167	1 176	848	721	224
1988	277	227	819	59	1 277	817	640	212	1 295	1 009	779	261
1989	221	257	1 163	65	1 278	649	508	165	1,362	991	728	252
1990	216	258	1,194	64	1,150	449	390	112	1 250	751	601	188
1991	185	296	1 600	73	1,135	757	667	186	1,295	1,113	859	273

Figures are rounded to the nearest thousand for area and production and to the nearest digit for average products

Kg/L = output, in kg per agricultural worker

Source FAO

Table 1 2 Area, production and average products for cash crops, 1961-91

(Area in ,000 Ha, Prod in ,000 MT)

	PEANUT				COTTON			
	AREA	PROD	KG/HA	KG/L	AREA	PROD	KG/HA	KG/L
1961-65	121	65	532	26	42	7	158	3
1966 70	142	76	539	28	71	25	349	9
1971-75	152	73	480	25	68	34	499	12
1976 80	147	67	456	21	75	59	780	18
1981	128	78	609	23	65	58	892	17
1982	155	71	458	20	72	76	1,056	22
1983	137	82	599	23	76	79	1,039	22
1984	143	83	580	23	82	88	1,073	24
1985	167	123	737	34	95	115	1,211	31
1986	229	152	664	41	127	169	1,331	45
1987	233	146	627	38	170	175	1,029	46
1988	243	161	663	42	170	179	1,053	46
1989	176	131	744	33	162	179	1,105	46
1990	205	140	683	35	173	176	1,017	44
1991	219	152	694	37	180	176	978	43

Figures are rounded to the nearest thousand for area and production, and to the nearest digit for average products

Kg/L=output, in kg, per agricultural worker

Source FAO

CHAPTER 2 BACKGROUND and DEBATE ON DETERMINANTS OF AGRICULTURAL GROWTH IN BURKINA

Agricultural growth is equal to the product of gains in land productivity (yield) and growth in area cultivated The factors that affect agricultural growth can be grouped into traditional inputs (land, labor, livestock, manure), modern inputs (fertilizer, animal traction, irrigation) and conditioning or institutional factors (natural factors such as agroclimate and rainfall, government intervention such as agricultural research and pricing and marketing policies, and village level institutions such as the village groups in Burkina) Off-farm income has revealed itself as a key non-conventional determinant of agricultural productivity in semi-arid areas as it provides a source of cash to buy farm inputs In this chapter, we review the general debate in Burkina on key factors that influence productivity and agricultural growth -- a subset of said factors are addressed empirically in this report. Hence our goal here is to provide a general context for the chapters that follow

2.1 Land

The current debate on land that could affect land productivity in Burkina is land tenure The country is in a transition between the traditional land tenure systems where land rights are transmitted from generation to generation within the family lineage, to a modified tenure system where land belongs to the State with individuals having user rights The policy objective in the long term is to secure long term user rights through land registration, similar to a system that was used in Kenya Whether more secure tenure of landholding is necessary to induce farmers to make short and long-term productivity and conservation investments is however not a settled debate The African evidence is mixed, Clay and Reardon (1994) and Place and Hazell (1993) show tenure to be important to investment in Rwanda, but Place and Hazell's findings for Ghana are ambiguous

The land distribution debate is not significant in Burkina or most of the Sahel because of relatively equal distribution of land per person (see chapter 3)

In the present report study, we consider the impact of land area expansion on productivity and do not address the tenure issue

2.2 Labor

Beside land, labor is the main input in the current production system. Of particular relevance is the productivity of labor under varying climatic or technological conditions The IFDC study on Burkina

suggests that labor availability leads to extensification By considering two different time periods, the starting man/land ratio was found to be positively correlated to the growth in area cultivated In particular, ratios of less than 3 persons per hectare were associated with a less than 4 percent increase in area over time, while man/land ratios greater than 3 were associated with area growth rates exceeding 5 percent per annum We study the impact of family and hired labor on productivity, and the role of the wage rate in supply response

2.3 Demographic change

Population pressure on land has caused spontaneous and state-sponsored migration from the Plateau to the fertile and less populated river banks in the South and Southwest following the controlling (in the mid to late 1970s) of the river blindness vector that populated these banks

These population movements have had a positive impact on overall agricultural productivity Comparing the agricultural performance of indigenous and migrant farmers in the Hauts-Bassins CRPA in the Southwest, Savadogo (1990) found migrant farmers to be more receptive to new technological packages including the use of animal traction and fertilizer

The negative side of these uncontrolled migrations is that migrants tend to replicate their extensive cultivation system, thus causing land degradation (McMillan et al 1993) Sponsored migration such as the AVV scheme (which started to relocate population from the Plateau to the White Volta River banks in 1973) was supposed to enhance new production techniques and to control land degradation Successful at first in promoting new cropping systems and raising farm income, the AVV system broke down less than two decades after its initiation, as some farmers left the zone in search of new opportunities in newly-opened and promising zones such as the Kompienga dam area in the eastern part of the country (McMillan et al)

2 4 Soil degradation

A very important determinant of yield losses in Burkina Faso over the long term is soil degradation and the resulting loss of fertility Soils are shallow and lacking the three major nutrients, especially the first two nitrogen, phosphorus, and potassium Organic matter content is low, and decreasing at an estimated rate of 2 percent per year (Sanon et al) due to acidification Soil degradation is amplified by the agricultural system and social organization which cause continuous mining of soil nutrients without replacement

The increasing demographic pressure on the land leads to the breakdown of the traditional fallow

system which was effective at restoring fertility Crop residues which could contribute to restoring soil fertility are gathered and used as fuel or livestock feed IFDC estimates that total loss of nutrients (nitrogen+phosphorus+potassium) when crop residues are not replaced increased from 37 kg/ha per year over the 1979-83 period, to 47 kg/ha over 1984-88 To counter these trends, the use of fertilizer and manure must increase

2.5 Chemical Fertilizer

There are both long term and short term benefits to the use of fertilizer The long term benefit is associated with the conservation of the resource base which is rapidly degrading The short term benefit, which determines the farmers' decision to use it, is the increased productivity that the use of fertilizer entails Our results in this paper point to the positive short term impact of fertilizer on productivity and supply

The consumption of fertilizer in Burkina Faso is however very low The Ministry of Agriculture estimates that current use of chemical fertilizer averages 11 6 kg/ha. which is sufficient to restore only 10 percent of the nutrients mined over the period 1979-88 (IFDC) In particular, replacement is low for nitrogen and potassium This is one of the key impediments to productivity gains in African agriculture Using data on 36 Sub-Saharan African countries, USDA (1994) finds that chemical fertilizer use averages 10 kg/ha, and that 18 of these countries use less than 5 kg of fertilizer per hectare This is well below the minimum required level of 50 kg/ha for sustained growth, and constitutes one of the big differences between Africa and Asia Eight countries out of ten in Asia reach the minimum level of fertilizer use

The increased use of fertilizer seems to be related to government policies in an environment where agriculture is risky Besides cost, three other factors constrain the use of fertilizer in Burkina The first and most pervasive factor is availability The problem of availability of fertilizer at a national level is linked to the history of fertilizer introduction The second constraint to the use of chemical fertilizer is risk arising from the inappropriateness of the fertilizer formula for cereals and from the erratic climatic factors mentioned above The most current formula of NPKSB (nitrogen, phosphorus, potassium, sulfur, borum) used is suited for cotton and not for cotton, and IFDC recommends the development of a new formula NPKS (without borum) for cereals

Finally, there is the interplay of a liquidity constraint and the time preference of farmers The liquidity constraint stems from an insufficient or inadequate credit system, and the limitation of own liquidity The agricultural credit system is short term in nature, and limited to the cotton zone Private banks that are supposed to finance agriculture such as the Banque Internationale pour l'Industrie et

l'Agriculture du Burkina (BICIA-B) do not loan to the agricultural sector because of riskiness The Caisse Nationale de Crédit Agricole (CNCA) is the "farmer's bank" but concentrates its operation in the cotton zone where risk is more easily managed by a group liability credit scheme whereby the total amount of the loan owed by a village is deducted from the cotton sales receipt of the entire village An apparent preference for the present which is reinforced by riskiness is also present, which limits the use of own cash (however limited) to buy fertilizer

2.6 Alternative intensification inputs

Government agricultural services have attempted to promote the use of alternative or complementary sources to chemical fertilizer, including manure/compost and rock phosphate known as Burkinaphosphate The application of manure or compost can help reduce soil acidification and restore organic matter The Institut de Recherche du Coton et des Textiles exotiques (IRCT) estimates that an application of 5 MT/ha of manure every other year will counterbalance the estimated 2 percent annual loss of organic matter Unfortunately, the supply of manure is limited and this recommendation is rarely followed The Fonds de l'Eau et de l'Equipement (FEER) has made it an objective to increase the construction of compost pits in the Central Plateau Partial statistics show that about 5,000 compost pits were constructed at the farm level between 1990 and 1993

The use of Burkinaphosphate started in 1977 but remained low, as quantities sold averaged only 650 MT per year over 1978-92 The recommended dose for an effective and sustained result is 400 to 600 kg/ha Problems of low solubility and therefore a delayed reaction discourage the use of rock phosphate by farmers Research has shown that mixing rock phosphate, plant residues and manure in a compost pit increases the solubility of the phosphate and hence the effectiveness of the compost

2.7 Soil conservation techniques

Water retention techniques, which are not investigated in the present study because of lack of data, are seen as a key complementary input to fertilizer Because water is a limiting factor in much of Burkina due to high runoff, techniques such as bunds, tied ridges and zai[1] can significantly improve infiltration, limit erosion and increase the effectiveness of fertilizer Rochette (1989), Ohm and Nagy

[1] Zai is a traditional technique used in the Yatenga region to increase infiltration It consists of a depression made in the soil, with manure or other organic material deposited in the depression The seed is planted in the depression which collects water, thus preventing dryness and improving germination and normal plant growth

(1985), Sanders et al (1990) and Cleaver (1993) report the yield and soil fertility effects of these land management technologies

Data from FEER show that about 67,000 ha of land were managed with bunds over the 1980-90 period The pace of management however slowed down since 1991, as only 6,000 ha of stone bunds and 3,500 ha of earth bunds were constructed over 1991-93 This coincides with a period when FEER is reconsidering its "top down" approach toward a greater involvement by farmers in defining their objectives That is, among the many alternatives including land improvement, it will henceforth be up to the farmers in a given village to request the area of intervention they prefer

2.8 Animal traction

Animal traction is the major technique used in agriculture for land preparation and weeding in Burkina It is estimated that 15 percent of all farms and more than 40 percent of farms in the cotton zone own some kind of animal traction equipment

Eicher and Baker (1982) note that animal traction has historically been associated with the following benefits (i) potential increase in yields through improved seed bed preparation, deeper plowing, more timely planting and weeding, moisture conservation (and we add manure transport and incorporation), (b) potential increase in the hectarage cultivated, (c) income generation through off-farm transportation, (d) reduction in drudgery (hence labor freeing), (e) longer-term benefit of improving soil fertility through application of manure from animals, deeper plowing, plowing under crop residues (and we add tied-ridging for water retention and soil conservation) Traction is mainly used for plowing, as well as seeding and weeding Its use and spread is related to cash cropping, especially peanuts and cotton Most feasibility studies justify it on basis of more acreage and yields

In the 1960s-70s, governments and donors promoted a 'total oxen cultivation package' – oxen (or donkeys or horses) plus tool bar and attachments such as plow, seeder, ridger and sometime carts This package can be very expensive relative to rural household incomes An oxen traction package was $1000 in 1977, a donkey traction package $500 (cited by Eicher/Baker, page 145, from Zerbo and Le Moigne 1977 and Barrett et al 1982) Compare this to $1500/household income in the Guinean zone (1981-1985), of which $1140 is cash income (Reardon and Mercado-Peters, 1993)

Eicher and Baker also note that "Surprisingly, although animal traction has been promoted for more than 50 years in Africa, research results on the impact of animal traction at the farm level are largely impressionistic" (p 142), and research on traction impacts has been conducted mainly on experiment stations

Historical evidence on yield effects is mixed Farm-level results have been mixed Sargent et al (1981) reviewed 27 traction projects and found that most had not lived up to expectations because of the high cost of animals and equipment, low acreage and yield effects, and lack of reliable institutional support Whitney (1981) found that traction farmers increased acreage by 39 percent but with no change in yields Barrett et al (1982), showed that, for eastern Burkina, acreage and yield effects were modest, but labor inputs were reduced 20-25 percent per acre

In general, researchers have found that the economics of animal traction are problematic for subsistence farmers producing only millet and sorghum, and become more favorable in cash cropping areas Barrett et al (1982) found important cash flow problems for traction adopters Internal rates of return were positive over 10 years, but net returns for oxen farms were below net returns before adoption for first 4 years due to a slow learning curve Eicher and Baker found in a review of research in the 1970s that "the presence or absence of a cash crop is a central determinant of farm-level profitability of animal traction" (using evidence from northern Nigeria, peanuts in Senegal, cotton in southern Mali, and cotton in northern Cameroon)

Research has also shown that support services (credit and veterinary services) are crucial Equipment adapted to key activities (weeding, tied ridging) is not usually available, and there is a persistent issue of affordability

In the present study, the role of animal traction is stressed by showing the differences in supply response, average and marginal productivity, between manual (i e hand tools) farms and animal traction users

2 9 Nonfarm income effect on farm investment and on productivity

Contrary to conventional wisdom from the early 1980s and before, Sahelian farmers engage substantially in nonfarm activities [2] This fact is now recognized and incorporated in policymaking regarding the rural sector in Burkina Faso FEER, which emanates from the Ministry of Water and is a major public investor in the rural sector, is abandoning its narrow view of the rural economy as primarily based on agriculture In arid and semi-arid zones such as the Central Plateau, the role of non-agricultural activities is being recognized as essential Hence, this government Fund is considering a massive intervention in helping farmers to invest in any type of profitable activity Likewise, as a support

[2] See Reardon et al 1993 for review of evidence from the 1980s, and Reardon et al 1988 and 1992 for Burkina-specific results reviewed in chapter 3 here, as well as McMillan et al 1993 and Savadogo and Wetta (1992) for Sudanian zone results

to its agricultural sector program in the context of structural adjustment, the World Bank has financed a number of rural income-generating activities with the goal to increase rural income from non-agricultural sources, in areas where agriculture is the riskiest (Savadogo and Larivière, 1993)

There are five important consequences of the importance of nonfarm income for farm productivity analysis

(i) Nonfarm activities affect the product market as they include processing, transport, and marketing activities, and they affect the input market, as they include provision of inputs to farms (farm labor, animal traction implement repairs, and so on)

(ii) Nonfarm activities can be crucial sources of cash (along with cash cropping and livestock husbandry) for farmers' investments in animal traction, fertilizer, and seed, directly, and animals for manure, indirectly (This effect is treated more below and then in a subsequent report) Yet as nonfarm income is poorly distributed, but it is important to investments, then the poor will not be as able as richer households to share in productivity and resource conservation measures, which will affect income and asset distribution over time This is worrisome and highlights nonfarm activity and input access issues in this report

(iii) Yet, particularly in unfavorable agroclimates, nonfarm activity can compete with farm investments for both time and capital Agricultural researchers, environmentalists, and policymakers who propose investments in the farm or the natural resource base in these zones may be surprised to find that investments off-farm are more attractive to farmers

(iv) Nonfarm activities can relieve pressure on the land and thus spare fragile margins

(v) Nonfarm income can be important to household food access and thus affect nutrition, which in turn can affect labor productivity (Strauss and Thomas, 1994)

2.10 Government support policies

Government intervention can enhance farmers' willingness to innovate by improving the profitability of agriculture First, infrastructure provision is one example Good roads can lead to reduced transport cost and thus the cost to the consumer, which may translate into higher demand for farm products and hence better prices for farmers The role of road quality in cost reduction was documented by Savadogo et al (1992) for Burkina Faso Road infrastructure is, however, poor in Burkina Faso There is a lack of good feeder roads to move products from farms to a central market, within a production zone The usable transportation modes under these conditions cannot capture the economies of scale related to volume, as they consist mostly of donkey carts and two-wheel vehicles The second infrastructural

constraint is the lack of good roads linking the surplus to deficit areas For example, the road linking the productive Southwest to the Sahel (the Bobo-Dédougou-Ouahigouya road) has been unusable for the last twenty years, forcing grain moving between the two zones to transit through Ouagadougou, and therefore increasing distance twofold Although the 1986-90 five-year development plan stressed the particular need to provide better road linkages between production and consumption zones, financial constraints have put these intentions on hold

Second, government intervention may be helpful in farmers' organization Old fashioned development intervention where the farmer was considered as a passive actor (at least in the definition of objectives and needs) is known not to work The involvement of farmers in the definition of objectives can be done on an individual basis, but not in areas concerning the commons Thus, in areas such as natural resource management, a village-level organized group is the best party in a dialog on the relevant issues The government through its appropriate structures or NGOs where available can help set up such organizations

Third, government price (output and input) policies are important determinants, and are reviewed in chapter 1

Chapter 3. DATA, ZONES, AND SAMPLE HOUSEHOLD CHARACTERISTICS

In section 3 1 of the chapter, the data and survey are described Section 3 2 describes study zones Section 3 3 describes sample household characteristics including input use, incomes, and asset holdings

3.1. Data and Survey

The data in this report are drawn from the ICRISAT survey (conducted by Peter Matlon) from June, 1981 to December, 1985, covering 150 rural households located in six villages representing the three principal agroclimatic zones of Burkina Faso, covering the range of conditions within the semi-arid region the Sahelian, Sudanian, and Guinean zones (This region covers 500 million hectares in Africa)

Within each study zone, ICRISAT selected one village on an important feeder road and the second more remotely located The villages in all study zones are medium to large, and fairly concentrated geographically with bush areas separating them from other villages [3] The two study villages in the Sahelian zone are located 20 kilometers from the administrative center and market town of Djibo, near the Malian border, about six hours by road northwest of Ouagadougou, along the Ouahigouya/Djibo road Djibo contains local extension offices, a veterinary office, and a regional livestock market in addition to the regular permanent market with grain sellers In the Sahelian zone, the road is hard packed dirt, both villages are relatively near the road Well water is a major constraint in the area The two study villages in the Sudanian zone are located on the Mossi Plateau, near the market town of Yako (population 20,000), about two hours west of Ouagadougou The paved (in 1984) road from Ouagadougou gives way to the well-traveled dirt road to Koudougou (a major town) that runs past Kolbila at 20 kilometers to the west of Yako Ouonon is on a difficult meandering dirt path 20 kilometers east of Yako Well water is a major constraint in the area The two study villages in the Guinean zone are located near the administrative center and market town of Boromo, about 220 kilometers southwest of Ouagadougou Kolbila is a 4 kilometer dirt road trip from the paved national highway running from Ouagadougou to the Cote d'Ivoire The other village, Koho, is 20 kilometers further from the main road, but on a fairly passable cart path, and with access to the rail line to Bobo Dioulasso

The survey was intensive 18 questionnaires were employed at various times to record data on household size and composition, land use and tenure, production (input/output), income sources, crop

---

[3] This section draws on Vierich, 1985 for details of village and region infrastructure

and livestock transactions, credit, consumption, and crop and animal stocks Most of these were administered in frequent passage, either fortnightly or monthly Matlon (1988) provides detail on the questionnaires

The basic behavioral and sampling unit used in the survey and analysis is the household In sample selection, ICRISAT used the following definition of household

> " the smallest group of persons usually, but not exclusively, kin related who form a more or less independent production and consumption unit during the cropping season To operationalize this definition we set two conditions based on observed group behavior and consistent with farmers' own criteria for defining households first, that members of a household work jointly on at least one common field under the management of a single decision-maker, and second that members draw an important share of their staple food stuffs from one or more granaries which are under the control of that same decision-maker (Matlon 1988, p 4)

The above definition was a compromise given that a) there are strong relations between the household as defined and the broader compound, kin group, and village, b) there is substantial complexity of structures among households, in terms for example of conjugal units, c) in some situations the consumption and production units do not strictly coincide, or the latter contains more than one of the former, d) there is substantial interseasonal and interannual flux in the membership/size of the households These complications are discussed in Norman et al (1981), Vierich (1985), Reardon (1985), and Matlon (1988)

3.2 Study Zones

Table 3 1 presents characteristics of the study zones and villages and the sample households Table 3 2 shows crop mix in value terms Table 3 3 shows labor, fertilizer, and manure use Appendix 1 provides yearly detail on input use

3.2.1. Rainfall and Soils

Burkina Faso comprises four agroclimatic zones with important differences regarding agricultural potential The northernmost and least agriculturally prone zone is the Sahelian zone, where annual rainfall averages less than 350 mm The Sudano-Sahelian zone is an intermediate zone, with annual rainfall varying between 350 mm and 600 mm The Sudanian zone covers the isohyets between 600 mm and 800 mm, and the Sudano-Guinean zones isohyets higher than 800 mm For planning purposes, the

government (Ministry of Agriculture) uses the following delineation of the territory West (1,000 mm/year or above), Central Plateau (650-1000 mm), and the Sahel (less than 350 mm per year) (IFDC, 1991) In the present study, the survey villages span these three regions, and are aggregated into three agroecological zones, Sahelian, Sudanian, and Guinean

Long-term average rainfall rises as one goes south, while the long-term variability (over years) of rainfall falls -- hence production risk falls Rainfall during the 1981-85 study period was about 80 percent of the long-term average The variability of rainfall in the Sahelian and Sudanian zones was much higher than the Guinean zone's during the study period, and this variability was higher in the study period relative to long-term patterns In the Guinean zone, rainfall was only slightly lower than the long-term figure and variability was minor Harvest years[4] 1982/3 and 1984/5 started with very poor harvests due to low rainfall in cropping seasons in 1982 and 1984 The other three seasons in the data (in 1981, 1983, and 1985) were relatively good rainfall years

Inter-year variation of producer prices (here reflected in the millet price coefficient of variation) is relatively high Given the presence of inter-zone trade in coarse grains, the relation between rainfall and price variability is ambiguous By contrast, variability in CPI is less in all zones compared to that of the millet producer price This reflects the import of cheaper grains, especially into the Sahelian and Sudanian zones For instance, cheap maize is imported from the south into and consumed in the Sahelian zone in drought years (Reardon et al 1987)

Rainfall intensities (rainfall per hour) in WASAT are two to four times greater than in temperate climates This promotes topsoil erosion and water loss through runoff The intraseasonal distribution of rainfall is also very erratic, even in "normal" years (Matlon 1987)

The soils in the Sahelian zone are deep and sandy Soil texture varies from loamy sands in the Sahelian to sandy loams in the Sudanian zone Vertisols are only found in isolated patches The soils in the Sudanian zone are clay-sandy and gravelly-sandy soils and are mostly shallow with low natural fertility The soils are structurally-inert and have poor water-holding capacity The soils in the Guinean zone are clay sandy of intermediate depth and fertility (Matlon, 1987, 1988)

3.2.2. Population Density

Population density in the study villages is 41 persons per square kilometer in the Sahelian zone, 54

---

[4] "Harvest year t/t+1" is 12 months, starting with the harvest immediately after the rainy season in calendar year t, and running through the rainy season in calendar year t+1

in the Sudanian, and 55 in the Guinean These figures are lower, especially in the Sahelian and Sudanian zones, and much higher in the Guinean zone, than zone-wide figures calculated by IFDC based on census data shown below The Plateau accounts for most of the land (50 percent), with a ratio of cultivated to agricultural land of 35 percent over the 1984-88 period The West, with a little over one quarter of total area, has the lowest population density and the highest agricultural land percentage (50 percent), of which 16 percent was under cultivation over the 1984-88 period The Sahel, with only 26 percent of area suitable to agriculture, has the highest land pressure with 40 percent of the agricultural land under cultivation over 1984-88 The higher population density of the Sahel is attributable to the Yatenga province which with 200 people per km^2 has the highest population concentration among all provinces At face value these numbers would indicate low population density in some areas However, FAO research (Higgins et al 1982) argues that using population per unstandardized land unit masks the fact that in a given zone the amount of land capable of sustaining agriculturally a given population might be much lower than the simple area Instead, it is necessary to weight land area by quality indices (Higgins et al , 1982) Binswanger and Pingali (1988) calculated "agroclimatic population densities" for a wide range of countries, using information on land quality, cropping technology, and assumptions about population growth trends Their results ranked countries such as Burkina Faso and Niger in the "high density" category, along with countries such as Bangladesh and India Matlon (1987) applied the FAO approach to the three study zones He compared "sustainable population" (in persons per square kilometer) with 1980 population in the three zones, assuming traditional cropping and livestock systems In the Sahelian and Sudanian zones, he found population density to be beyond the carrying-capacity of the land, due mainly to severe environmental degradation The current density is below the sustainable population density in the Guinean zone Lallement (1990) shows, however, that there has been rapid migration from northern to southern zones in Burkina, and so one would expect the land constraint to be growing in the Guinean zone

3.2.3. Cropping system

Production of coarse grains, pulses, and cotton in these zones primarily uses low variable input, hand-tillage technology in the Sahelian zone Use of fertilizer, manure, and animal traction increases as one goes south, up to a moderate level in the Guinean zone Rainfed cropping is predominant, although there are low-lying basins or pools of water, particularly in the Guinean zone, that are used for cropping in the dry season and for some irrigation in the wet season Gardening occurs around wells and barrages More detail on the cropping system as practiced by sample households is given in section 3 3

3.3 Characteristics of Households' Income Composition, Cropping, and Livestock Husbandry

In Table 3 3, characteristics of the sample households are presented by zone, averaged over the four year study period (with interannual and interhousehold coefficients of variation noted) [5]

3.3.1 Income Levels and Distribution

In Table 3 3 household income per AE in FCFA and Gini coefficients (measures of income distribution inequality, the larger, the more inequality) are shown per zone, as averages over the study period Income was measured by combining the net imputed value of home-consumed crop output, plus crop sales, plus livestock net sales and the imputed value of home consumption of animals, plus net receipts from local nonfarm activities, plus migration remittances from household members, plus transfers from inside and outside the village of nonhousehold members (including from family members residing outside the village)

In the Sahelian, Sudanian, and Guinean zones respectively, incomes per AE were 42205, 29197, and 55261 -- which in per person terms are 59087, 37956, and 71,839, or $151, $97, and $184 per person (using the 1982-1985 calendar years average exchange rate of 391 FCFA per dollar US) The World Bank GNP per person average for Burkina Faso for the same period was $175 [6]

Total household income Gini coefficients do not vary much over the years per zone, and are not very different between zones in a given year, ranging between 5 and 7 Generally the Guinean zone has the most inequality, and the Sahelian the least For the Passore province in the Sudanian zone, Savadogo and Larivière found a Gini coefficient of 60 for 1993, suggesting a stability of inequality over time

When we use income per AE (hence controlling for the substantial variation in households size) the coefficients are 34, 30, and 30 for the Sahelian, Sudanian, and Guinean zones, respectively Matlon (1979) for northern Nigeria found a range for the same variable of 27 - 30 over villages

---

[5] Apart from the simple household average variables, in particular demographic variables, the figures for Table 3 are averages weighted by the size of the household in AE terms, as well as a weighting coefficient to adjust for bias toward animal traction households introduced by the stratified random sampling procedure used by ICRISAT to constitute the household sample These weights were applied both to strata and overall sample results per zone Note that the sample size for the Guinean zone in 1981 was only one-half of what it was in the other three years due to invalidated survey results in Koho village for that year This biases the results for that year

[6] Bourque and Gagnon, 1988, p 2

3.3.2 Income Composition and Diversification

Hill (1982) laments that even up through the time of her writing, the traditional view persisted that the typical African farm household is only or mainly farmers, with very minor activity outside the agricultural sector Early work in Nigeria by Norman (1973), Matlon (1979), and Hill (1982) tried to correct this misconception More recent studies in Botswana and Zambia (Low 1986), Kenya (Collier and Lal, 1986), Burkina (Reardon et al 1992, McMillan et al 1993), Senegal (Kelly et al 1993), Niger (Hopkins and Reardon 1993), Loveridge (1992) and a few others (see Reardon et al 1993 for review) confirm that African farmers substantially diversify their incomes beyond farming into nonfarm activities, thus reversing that traditional image In general the more recent studies (in the 1980s) showed a degree of diversification beyond that found in the earlier studies in the 1960s and 1970s For example, the 1970s Northern Nigeria studies found study village averages of 23-30 percent of income from nonfarm sources, while in semi-arid West African studies from the 1980s reviewed by Reardon et al (1993), nonfarm income (agroclimatic zone averages) varied from 20 to 64 percent of total income (simple average of 39 percent), and non-cropping income (this time including livestock income) ranged from 31 to 83 percent (simple average of 48 percent)

Income composition in Burkina (Reardon et al 1992) for our case study was as follows (1) Sahelian 49 percent crop income, 14 percent livestock income, and 37 percent nonfarm income, (2) Sudanian 60 percent crop income, 6 percent livestock income, and 20 percent nonfarm, (3) in the Guinean, 37 percent crop income, 20 percent livestock income, and 40 percent nonfarm This helps to explain why total income ranking of zones (Guinean, Sahelian, Sudanian, 1, 2, 3) is not correlated with agroclimate ranking of zones (Guinean, Sudanian, Sahelian) Savadogo and Lariviere (1993) estimate the share of nonfarm income in the Sudanian zone, using data from 1992/93 at 33 percent, varying between 19 and 57 percent over the sample villages Moreover, Reardon et al (1993) show that most nonfarm income in the Sahel is from "production-linkage" activities (upstream and downstream from local agriculture -- i e supplying inputs and services to the farm or using outputs from the farm in processing and marketing) The other nonfarm income is either from migration, or linked to local towns

But nonfarm income is poorly distributed, with both share and absolute levels much higher for richer households than poorer households in a given zone the poorest are most dependent directly on cropping Comparing the share of nonfarm income in total household income for the lower income tercile versus the upper tercile, we find in Burkina 19 vs 46 percent in the Sahelian zone, 14 vs 26 percent in the Sudanian, and 29 versus 51 percent in the Guinean zone

3.3.3 Crop mix

Table 3 3, based on our sample's output patterns, over the four years, shows that in the Sahelian zone, millet constitutes 84 percent of crop output value in imputed terms, sorghum another 6 percent, hence together 90 percent, with no important differences in mix over (total) income tercile groups Maize, peanuts, cowpeas, and rice are each 1 percent White sorghum and maize are limited to patches of more fertile and/or humid soils next to seasonal swampy areas

The cropping system in the Sudanian zone is dominated by millet (19 percent of imputed crop output value), and sorghum at 46 percent Other minor crops include maize, 2 percent, peanuts and cowpeas together 13 percent, and cotton 1 percent The crop mix does not differ much over income terciles

In the Guinean zone, millet constitutes 13 percent of total crop output value in imputed terms, sorghum 30 percent, maize 7, and cotton 31 percent, pulses are minor (only 4 percent), and rice is 12 percent (grown near ponds), and "other" (vegetables and tubers), 4 percent (grown near ponds) Crop mix differs over income terciles millet's share is higher for the poor, sorghum higher for richer households, cotton is higher for the poor, rice higher for the rich, and "other" (vegetables, tubers) higher for the rich richer households tend to grow more "high entry barrier crops" that require access to soil and water (access that is affected by socioeconomic factors) Poorer households grow cotton because it is a source of cash with low entry barrier, that is they can merely apply to grow cotton to SOFITEX, the cotton parastatal (operating only in the Guinean zone) Beside guaranteeing a market outlet and transport for the cotton, the parastatal provides fertilizer credit

3.3.4 Animal Traction Use

The portion of farm households using animal traction equipment over the study period are 9%, 14%, and 19% in the Sahelian, Sudanian, and Guinean zones respectively That is, equipment increases proportionately with agroclimatic potential Hence, hand tillage is by far the dominant method It appears that the greatest growth in animal traction is occurring in the Guinean zone, starting from a low base (Matlon, 1988) The equipment was not available on credit from the parastatal or other public institution

3.3.5 Land: Distribution, Tenure, Fallowing Practices

Table 3 2 shows average household cultivated land per AE in hectares, per zone, as well as Gini coefficients per zone For the Sahelian, Sudanian, and Guinean zones respectively, cultivated hectares per AE were 92, 58, and 65 The coefficient of variation of the averages over years is less than 10% for the Sahelian and Sudanian, but 18% for the Guinean zone Corresponding to these figures are 5 4,

4 6, and 5 3 hectares per household But note that using national data, the Guinean zone is not more densely populated Due to land quality differences comparison with other regions is risky, but note that Matlon (1979) found in Northern Nigeria that cultivated land per household ranged from 1 9 to 3 hectares, and per AE from 35 to 69

The cultivated land Gini coefficients over households were, for the Sahelian zone, 51- 54 over 1981-4, for the Sudanian, 47 - 60, and for the Guinean, 43 - 60 The per AE coefficients were 28 for the Sahelian, 33 for the Sudanian, and 30 for the Guinean (with low levels of variation over years for each zone) The Gini coefficient by both measures is higher in years of poor rainfall Ghai and Radwan (1983) report household land Gini coefficients of for example 55 for Kenya, 50 for Botswana, and 42 for Ivory Coast (all in smallholding sectors), figures close to our's

ICRISAT measured the "duration of the last fallow" per household, and found on average that it was 5 years in the Sahelian, 9 years in the Sudanian, and 13 years in the Guinean zone, hence land is used less intensively as one goes north to south

Matlon (1988) found that shifting cultivation has given way to increasingly intensive grass fallow systems in bush land, and to nearly continuous cultivation near habitations There is little variation in tenure systems within and across study villages The systems can be classified as "indigenous" or traditional in that use rights are still perceived as separable from proprietary rights Use rights are vested at the household level, and proprietary rights at the level of the kin group or village Thus, land is not yet alienable by individuals via sale, rental, nor is it used as collateral Prevailing land tenure systems not only provide security, but have also resulted in a relatively equitable distribution of overall land use rights across households

3.3 6 Labor: Household size, labor use in crops, hired labor market

Table 3 3 shows that the average households in the Sudanian and Guinean zones are largest (10 persons, vs 8 in the Sahelian zone) There is substantial variation over households (with coefficients of variation 40-60 percent) The average household size per zone varies little over years, however Savadogo and Lariviere (1993) also found (for 1992/93 data in the Sudanian zone) an average household size of 9 Dependency ratios range from 40-50% The average household does not differ much across zones and strata in its demographic characteristics, except that poorer households are larger and have more children

Table 3 4 shows that (total = family plus hired) labor use per hectare is lowest in the Sahelian and highest in the Sudanian zone, where population density is also highest per unit of arable land This

reflects the substitution of labor for land

Table 3 4 shows that the rough order of (total) labor-intensity is maize, cotton, sorghum, and millet The ratio of labor use per hectare of the most to least intensive in each zone is 2 to 2 5 times In general millet is slightly more labor intensive than sorghum (except in the Sahelian zone) Maize and cotton are equally labor-intensive in the Guinean zone

Guinean farmers use three times more hired labor than do Sudanians, who in turn use six times more than the Sahelians In the Guinean zone, 23 percent of total labor is hired, versus only 8 and 2 percent in the Sudanian and the Sahelian Compare those figures to 35 percent, 50 percent, and 55 percent for share of hired labor in total labor in Shirapur, Aurepalle, and Kanzara in the Indian SAT (using the ICRISAT India sample Walker and Ryan 1990)

Hired labor is used most intensively on cotton, then millet/sorghum, then least on maize (though family labor is used most intensively on maize) This appears to be due to nature of tasks, periodicity, and size of fields Maize is produced on small fields near the compound Interestingly, the ranking of crops in intensity of hired labor is reversed from the above if, instead of using total hired labor, we use share of hired labor in total labor used millet and sorghum are now first in the Guinean with 31 and 25 percent hired labor in total, and cotton drops to third with 22 percent, and only 11 for maize

For cotton, manual households use 1 1 times the family labor that AT households use, and similar amounts of hired labor, so in total, manual households use 1 07 times the labor per hectare that AT households do This 5 year average includes a year, 1981, where there was an anomaly where AT households used more labor per ha. than manual households If this year is excluded, the average ratio (manual total labor use to AT) is 1 15 Hired labor use is similar between the groups Hence, AT comes out saving family labor (which can then be used for food crops, hence AT attenuates competition for labor between cash and food crops) AT saves family labor only in cotton and millet cropping But maize AT farmers use less total labor than do manual households in all zones

Table 3 5 shows labor use variation between a good (1983) and poor (1984) year Total labor per hectare decreases with a drop in rainfall in the Sahelian zone, but actually increases slightly in the other zones By contrast, hired labor use decreases sharply in the northern and middle zones with the drought Partly these results can be explained by the relatively small change in rainfall in the Guinean zone

3.3.7 Fertilizer and manure use

Table 3 6 shows fertilizer use on average over 1981-85, and Table 3 7 shows variation in its use between a good year (83) and a poor year (84) Fertilizer use increases very rapidly from north to south,

with almost no chemical fertilizer used in the Sahelian zone, to 11 kgs/ha in the Sudanian, to 39 kgs/ha in the Guinean zone Compare these levels to those for all subsaharan Africa in 1985, 9 kgs/ha, and all developing countries, 58 5 kgs/ha (Bumb 1988)

AT households use a third more fertilizer than manual households in the Sudanian and a tenth more in the Guinean zone The differences may reflect wealth differences and crop mix

In the Guinean zone, cotton uses by far the most fertilizer (about 109 kgs/ha, twice developing country average use), followed by maize (about 46 kgs/ha), then use drops abruptly to less than 5 kgs for sorghum and millet -- the key food crops This pattern is partly due to agronomic response of the crop, partly to the value of the crop to the household, and partly to the difficulty of incorporation of fertilizer (millet tends to be in poorer soils far from household) (Prudencio), and partly because the cotton parastatal gives fertilizer credit (although there are spillovers of fertilizer thus obtained to other crops)

Interestingly, the ranking of crops in fertilizer use is roughly the same in the Sudanian, but at a generally lower level, with 1/4 less to cotton than in the Guinean zone, and only 18 kgs for maize Surprisingly, much more fertilizer is used on grain than in the Guinean zone, 3-4 times more for sorghum and millet

Interestingly, fertilizer application does not vary systematically with rainfall in the Sudanian or the Guinean zone -- instead, more is used in the drought year In the Guinean case this could be because there was an increase in land to cotton, and their drought was mild

Table 3 7 shows manure use over 1981-85, and Table 11 shows variation in its use between a good year (83) and a poor year (84) We do not show other organic matter known to be applied to fields (household waste and crop residues) due to lack of data

Manure use increases rapidly as one goes from north to south, with only 150 kgs/ha in the Sahelian zone, to 411 kgs in the Sudanian, to 995 kgs/ha in the Guinean AT-owners use twice as much manure per ha as manual households in the Sudanian zone, and fourfold more in the Guinean zone Heavier, clay soils in the south require AT for manure incorporation, and in the south, cattle and AT ownership and manure use are correlated Yet cattleholding and manure use are not correlated over zones, as there are more cattle per person in the north than in the other zones

In the Guinean zone, maize gets by far the most manure (7384 kgs /ha), then cotton (1314 kgs/ha), then sorghum (427 kgs /ha), then very little for millet (155 kgs/ha) Part of this allocation is due to agronomic requirements in that order, part is due to the value of crop to household (Prudencio)

Interestingly, about the same amount of manure is applied to the same crops in the Sudanian zone The big difference in total manure use between the middle and south is due to differences in crop mix,

not application rates per crop By contrast, millet gets the lion's share of the little manure applied in the north, with sorghum getting none

Appendix 1 shows that in the north, manure application varies with rainfall, as it does in the south, but not in the middle, where it varies against rainfall

3.3.8 Livestock Holdings and Distribution

Large areas of the Sahelian zone are suited only to livestock grazing due to low rainfall, poor soils and low cropping potential of the land Hence, animal husbandry is an important activity This has led to denuding of grazing areas over the last 3-4 decades, and the reduction of the amount of wild fonio, a wild grass used as food in the hungry season (Vierich, 1985) Livestock are held as a form of savings or insurance as formal and informal capital markets are poorly developed, and due to the strong interyear fluctuations in cropping outcomes

In Table 3 2, livestock holdings per AE in value terms (FCFA) and Gini coefficients are shown, for 1983 and 1984 only, due to data limitations Livestock per AE for the Sahelian, Sudanian, and Guinean zones respectively, were 16,824, 11,503, and 9,015 FCFA per AE – about $43, $29, and $23

The Gini coefficients (averaged over the two years, 1983/4 and 1984/5) were 68 in the Sahelian, 35 in the Sudanian, and 68 in the Guinean zone Hence, assets are more unequally distributed than income, which is a common finding Here animal assets are much more concentrated than land

2.3 9 Food Self-Sufficiency From Own-Production

In Table 3 3, the columns showing the "production sufficiency ratio" (PSR) depict the degree of food self-sufficiency from own production We consider a household as "production sufficient" if it produced enough food to feed the household members adequately (by FAO standards) over the entire year until the next harvest The "Production sufficiency ratio" is the fraction of the year that it was able to do so For example, PSR = 50% means that the household produced enough to feed itself from produced stocks during half of the year after the harvest, for the balance it needed to resort to purchases, receipts of transfers, and gathering

Two columns are presented The first shows the average PSR per stratum, the second shows the average percentage of households with PSR > 100% (i e at least self-sufficient) As expected, generally the Guinean zone households are self-sufficient, with average of 105%, but only 46% of the households attain self-sufficiency (hence it is the big producers that bring up the average). In the Sudanian zone, the average PSR over the study period was only 82%, and on average only 20% of the households were

production sufficient The inter-year variation is greater than in the south By contrast and surprisingly, in the Sahelian zone, on average over the study period (that included 2 droughts in 5 seasons), the average PSR was 119 %, but only 48 % attained self-sufficiency, so as in the south there are some households that bring up the average, but the high inter-year variation (from the interspersion of the severe droughts) is unlike the south where rainfall was much more stable But in some years most households in the north were surplus producers This result is the counterpart of the finding of extreme variability in yields in the Sahelian zone (see Chapter 4)

Reardon and Mercado-Peters (1993) show that the majority of households in each zone in all years are net buyers of grain Reardon et al 1987 show for this sample that the marketed surplus rate for grain is very low, less than 10 percent This coincides with findings for an earlier survey in Eastern Burkina by MSU (see e g Ouedgraogo 1983)

Table 3 1 Land availability by agricultural region

	WEST	PLATEAU	SAHEL
Total area (km^2)	60,072	139,136	73,633
Ag land (,000 ha)	3,010	4,350	1,945
Percent Ag land	50	31	26
L U C (,000 ha), 1984-88	494	1,537	772
L U C /Ag land (percent)	16	35	40
Population per ag land (res/km^2)			
1973-83	33	76	91
1984-88	40	92	101

Source IFDC, 1991

L U C Land under cultivation

Table 3.2 Sample Characteristics

	(Northwest) Sahelian	(Center) Sudanian	(Southwest) Guinean
1 Cropping Technology			
Hired Labor (%total)	4%	10%	24%
Animal Trac (%hh's)	9%	14%	19%
Fallow Time (years)	5	9	13
2 Rainfall			
Rainfall-long term	480	724	952
CV long-term rain	34	25	21
Study Period Rainfall	410	563	779
CV Study Period Rain	60	36	14
3 Crop Output and Incomes			
total income /ae	42205	29197	55261
gini income/ae	34	30	30
Avg Prod Suff (PSR,%)	119	82	105
Share of hh's with PSR > 1	48	20	46
CV of Prod Suff	75	42	46

Table. 3.2 continued

	(Northwest) Sahelian	(Center) Sudanian	(Southwest) Guinean
4 Assets/Demography			
Land per AE* (hecs)	92	58	65
Gini land/AE	28	33	30
Livestock per AE (CFA)	16824	11503	9015
Gini livestock/AE	68	35	68
Household size	8 0	10 3	10 3
Household size in AEs	6 0	7 7	7 9
CV household size	14	08	14
Dependency ratio	42	50	45
Persons per sqr km	41	54	55
5 Price Variability			
CV of Producer Millet Price	24	34	20
CV of CPI	17	23	17

* AE = Adult equivalent (calculated by weighting household members by coefficients reflecting age/sex composition)

** For long term rainfall, zone is the broad geographic area, for the other variables, it is the simple average of the study villages

a) Long-term rainfall data are from ORSTOM and from the National Meteorological Service of the Government of BF Data are through 1983 and include 29 years for Sahelian, 38 years for Sudanian, and 58 years for Guinean zone Source Sivakumar and Gnoumou (1987) Number in parentheses is interannual coefficient of variation

b) ICRISAT/Burkina baseline survey data on rainfall in study villages Averages are over 4 years, 1981-4 rainy seasons Numbers in parentheses are interannual coefficients of variation Average for zone is simple average of village figures

The data in the table are drawn from Matlon (1988a) and base line data authors' calculations

CVhh is the 4-year average annual coefficient of variation, CVyr is the coefficient of variation of the 4-year average

Livestock: Averages only for 1983-1984

The data were computed by authors from primary data

Table 3 3 Value of crops in total crop production

	Millet	sorgh	maize	cotton	peanuts	cowpea	rice	other	total (cfa/ae)
Sahelian 83, income tercile									
lower	81	08	01	0	02	01	02	05	21049 = 100 %
middle	86	04	02	0	01	*	0	08	27255 = 100 %
upper	85	06	01	0	01	01	01	05	42160 = 100 %
overall	84	06	01	0	01	01	01	06	30155 = 100 %
Sudanian 83, income tercile									
lower	21	43	02	0	07	07	0	20	15687 = 100%
middle	13	50	02	0	07	06	0	21	17741 = 100 %
upper	24	45	02	02	08	05	*	15	31236 = 100 %
overall	19	46	02	01	07	06	0	19	21555 = 100 %
Guinean 83, income tercile									
lower	18	22	05	40	04	01	10	02	28540 = 100 %
middle	10	33	08	31	04	01	12	01	40846 = 100 %
upper	10	36	07	21	02	01	15	10	45473 = 100 %
overall	13	30	07	31	03	01	12	04	38286 = 100 %

Table 3.4 All Labor Use per Hectare per Household

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
MILLET									
own	311	309	306	598	613	583	328	359	309
hired	8	11	8	60	49	67	148	153	142
total	319	320	314	658	662	650	476	512	451
SORGHUM									
own	555	441	621	550	580	540	408	398	413
hired	15	34	5	45	42	47	143	143	130
total	570	475	626	595	622	587	551	541	543
MAIZE									
own	534	604	475	927	1042	872	853	892	852
hired	3	5	1	25	32	24	101	124	94
total	537	609	476	952	1074	896	954	1016	946
COTTON									
own				717	1185	694	743	811	724
hired				97	22	110	207	192	214
total				814	1207	804	950	1003	938
ALL CROPS (WEIGHTED BY AREA TO EACH)									
own	324	317	330	572	597	560	517	532	514
hired	8	12	5	50	44	77	158	160	158
total	332	329	335	622	641	637	675	692	672

Table 3 5 Labor per hectare Use in 1983 divided by use in 1984 (good/bad year)

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
all crops									
hired	2 8	1 7	9 0	1 7	1 8	1 7	6	6	6
all labor	1 1	1 1	1 0	8	8	8	7	7	7
millet	1 1	1 1	1 0	8	8	7	7	7	7
sorgh	1 0	1 0	1 0	8	7	8	8	7	8
maize	1 2	1 4	9	3	4	3	6	6	7
cotton							7	8	7

Table 3 6 Fertilizer and manure, per hectare per household

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
FERTILIZER									
all	0 2	0 02	0 3	11	8 3	12	39	37	41
mill	0 2	0 02	0 35	6 4	3 4	4 6	1 4	1 1	1 5
sorg	0 01	0 02	0	13	10	14	4 5	3 3	5 2
maiz	0	0	0	18	19	17	46	36	49
cott				76		56	109	113	109
ratio 83by84, all crops									
	0	0	0	3	3	3	8	7	8
MANURE									
all	152	174	132	411	315	470	995	323	1345
mill	115	113	117	170	108	221	155	28	226
sorg	0	0	0	329	261	363	427	39	624
maiz	3862	5669	2269	8114	6209	9121	7384	4351	8588
cott				1405		1459	1314	402	1776
ratio 83by84, all crops									
	1 9	1 8	2 0	6	5	7	2 8	2 5	3 0

APPENDIX YEARLY INPUT USE PATTERNS

LABOR PER HECTARE PER HOUSEHOLD

A AGGREGATE CROPPING MILLET+SORGHUM+MAIZE+COTTON

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981									
own	369	362	374	667	638	692	523	474	560
hired	16	25	9	97	80	112	127	134	123
total	385	387	383	764	718	804	650	608	683
1982									
own	294	261	328	697	720	674	626	630	624
hired	8	10	6	58	55	169	200	169	218
total	302	302	271	334	755	775	843	826	799
1983									
own	297	303	289	425	491	390	442	472	428
hired	11	12	9	44	42	45	139	148	135
total	308	315	298	469	533	435	581	620	563
1984									
own	286	280	291	591	682	555	569	622	550
hired	4	7	1	26	23	27	242	257	237
total	290	287	292	617	705	582	811	879	787
1985									
own	374	377	370	480	458	490	425	463	410
hired	3	5	1	27	20	30	81	92	77
total	377	382	371	507	478	520	506	555	487
83by84									
hired	2 8	1 7	9 0	1 7	1 8	1 7	6	6	6
total	1 1	1 1	1 0	8	8	8	7	7	7
AVG									
own	324	317	330	572	597	560	517	532	514
hired	8	12	5	50	44	77	158	160	158
total	332	329	335	622	641	637	675	692	672

B MILLET

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981									
own	355	352	358	681	700	666	317	362	242
hired	16	25	9	141	107	167	121	140	90
total	371	377	367	822	807	833	438	502	332
1982									
own	282	255	311	725	768	675	399	360	421
hired	8	10	7	62	59	65	156	160	154
total	290	265	318	787	827	740	555	520	575
1983									
own	279	295	260	427	487	395	325	331	322
hired	11	12	10	54	47	58	106	121	98
total	290	307	270	481	534	453	431	452	420
1984									
own	269	273	266	617	629	611	338	399	316
hired	2	4	1	19	11	23	296	267	306
total	271	277	268	636	640	634	634	666	622
1985									
own	370	368	337	541	480	566	262	342	243
hired	2	3	1	23	20	24	63	77	60
total	372	371	338	564	500	590	325	419	303
83by84									
total	1 1	1 1	1 0	8	8	7	7	7	7
AVG									
own	311	309	306	598	613	583	328	359	309
hired	8	11	8	60	49	67	148	153	142
total	319	320	314	658	662	650	476	512	451

C SORGHUM

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981									
own	575	477	607	643	595	689	331	354	316
hired	16	30	12	74	70	77	128	139	121
total	591	507	619	717	665	766	459	493	437
1982									
own	535	399	611	671	687	655	458	446	465
hired	6	13	3	57	55	59	155	120	177
total	541	412	614	728	742	714	613	566	642
1983									
own	564	471	611	426	491	390	375	390	368
hired	11	29	2	39	40	39	124	111	130
total	575	500	613	455	531	429	499	501	498
1984									
own	551	419	643	568	690	524	474	469	476
hired	32	72	4	29	26	30	181	247	154
total	583	491	647	597	716	554	655	716	630
1985									
own	551	440	635	441	439	443	402	333	442
hired	12	25	2	28	20	31	81	100	70
total	563	465	637	469	459	474	483	433	512
83by84									
total	1 0	1 0	1 0	8	7	8	8	7	8
AVG									
own	555	441	621	550	580	540	408	398	413
hired	15	34	5	45	42	47	143	143	130
total	570	475	626	595	622	587	551	541	543

D MAIZE

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981									
own	743	1036	524	1155	1111	1191	996	947	1026
hired	3	7	1	13	11	16	126	142	116
total	746	1043	525	1168	1122	1207	1122	1089	1142
1982									
own	453	485	414	1449	1526	1396	987	883	1035
hired	6	9	2	9	21	1	163	117	184
total	459	494	416	1458	1547	1397	1150	1000	1219
1983									
own	444	484	397	341	539	246	572	534	587
hired	6	11	0	5	9	3	67	108	51
total	450	495	397	346	548	249	639	642	638
1984									
own	393	345	446	1028	1297	910	907	1284	815
hired	0	0	0	30	100	0	114	139	107
total	393	345	446	1058	1397	910	1021	1423	922
1985									
own	635	673	595	662	738	618	802	811	799
hired	0	0	0	68	17	98	35	113	13
total	635	673	595	730	755	716	837	924	812
83by84									
total	1 2	1 4	9	3	4	3	6	6	7
AVG									
own	534	604	475	927	1042	872	853	892	852
hired	3	5	1	25	32	24	101	124	94
total	537	609	476	952	1074	896	954	1016	946

E COTTON

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981									
own				870	1347	768	834	668	940
hired				350	44	414	130	121	135
total				1220	1391	1182	964	789	1075
1982									
own				732		732	935	1020	886
hired	.			81		81	291	247	317
total				813		813	1226	1267	1203
1983									
own	.			434		434	608	710	560
hired				15		15	209	229	200
total	.			449		449	817	939	760
1984									
own	.			742	577	743	827	974	778
hired							304	275	313
total							1131	1249	1091
1985									
own				806	1024	797	510	681	457
hired				41		42	101	87	105
total				847	1024	839	611	768	562
83by84									
total							7	8	7
AVG									
own				717	1185	694	743	811	724
hired	.			97	22	110	207	192	214
total	.			814	1207	804	950	1003	938

F COMPARISON OF LABOR USE OVER CROPS

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
MILLET, AVG									
own	311	309	306	598	613	583	328	359	309
hired	8	11	8	60	49	67	148	153	142
total	319	320	314	658	662	650	476	512	451
SORGHUM, AVG									
own	555	441	621	550	580	540	408	398	413
hired	15	34	5	45	42	47	143	143	130
total	570	475	626	595	622	587	551	541	543
MAIZE, AVG									
own	534	604	475	927	1042	872	853	892	852
hired	3	5	1	25	32	24	101	124	94
total	537	609	476	952	1074	896	954	1016	946
COTTON, AVG									
own				717	1185	694	743	811	724
hired				97	22	110	207	192	214
total				814	1207	804	950	1003	938
ALL CROPS (WEIGHTED BY AREA TO EACH), AVG OVER YEARS									
own	324	317	330	572	597	560	517	532	514
hired	8	12	5	50	44	77	158	160	158
total	332	329	335	622	641	637	675	692	672

G FERTILIZER, PER HA PER HH

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981									
all	0 6	0	1 1	16	12	19	32	25	38
millet	0 6	0	1 1	6 2	3 4	8 3	0	0	0
sorg	0	0	0	20	15	20	1 5	2 3	1 1
maiz	0 6	0	0	27	30	25	33	52	22
cott				11		13	90	73	103
1982									
all	0 1	0	0 2	9 6	9 5	9 6	32	31	33
millet	0 1	0	0 2	5 5	8 1	2 4	0 5	1 3	0
sorg	0	0	0	11	10	11	4 7	2 1	6 3
maize	1 8	0	4 1	4 7	0	7 9	41	19	51
cott				55		55	86	91	84
1983									
all	0	0	0	4 2	2 6	5 0	38	36	38
millet	0	0	0	3 3	1 9	4 1	1 1	0	1 6
sorgh	0	0	0	4 7	3 1	5 6	5 2	2 2	6 7
maiz	0	0	0	0 8	0	1 2	52	18	65
cott							111	120	107
1984									
all	0 3	0 1	0 4	15	9 9	18	47	49	46
millet	0 2	0 1	0 4	4 4	2 8	5 1	4 9	4 4	5 1
sorg	0	0	0	19	12	22	4 2	5 5	3 6
maiz	0	0	0	48	60	43	46	29	50
cott							138	158	132
1985									
all	0 01	0 01	0 01	8 8	7 5	9 4	48	44	49
millet	0 01	0	0 04	2 5	0 8	3 2	0 7	0	0 8
sorg	0 04	0 1	0	12	11	12	6 9	4 6	8 2
maize	0	0	0	7 6	4 2	9 6	57	63	55
cott	.			97		101	120	125	118

Fertilizer continued

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
83by84									
all	0	0	0	3	3	3	8	7	8
AVG									
all	0 2	0 02	0 3	11	8 3	12	39	37	41
mill	0 2	0 02	0 35	6 4	3 4	4 6	1 4	1 1	1 5
sorg	0 01	0 02	0	13	10	14	4 5	3 3	5 2
maiz	0	0	0	18	19	17	46	36	49
cott				76		56	109	113	109

H MANURE USE, PER HA PER HH

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981									
all	295	354	246	335	253	408	1392	780	1843
millet	198	190	205	213	133	274	0	0	0
sorg	0	0	0	241	181	298	175	111	216
maiz (1000's)	8 8	14 5	4 6	5 8	4 7	6 6	15 6	12 4	16 7
cott				0	0	0	2082	903	2839
1982									
all	139	123	157	515	449	581	752	257	1047
millet	117	88	150	184	59	331	275	0	434
sorg	0	0	0	441	455	427	491	11	794
maiz (1000's)	2 9	3 8	1 9	10 2	9 6	10 7	5 1	3 5	5 8
cott				0	0	0	725	332	956
1983									
all	150	180	117	280	169	339	1884	360	2622
millet	144	164	120	138	74	172	348	0	533
sorg	0	0	0	208	171	228	841	27	1227
maiz (1000's)	1 4	2 0	0 7	5 9	1 9	7 8	9 4	3 2	11 8
cott				0	0	0	2745	493	3822
1984									
all	78	99	58	472	357	518	681	142	880
millet	37	52	23	98	138	78	135	61	162
sorg	0	0	0	392	281	433	497	31	686
maiz (1000's)	3 7	3 9	3 4	9 3	6 3	10 6	5 3	1 8	6 1
cott				0	0	0	710	200	880
1985									
all	98	112	84	455	346	503	266	80	334
millet	79	73	85	216	134	249	18	79	4
sorg	0	0	0	361	216	428	132	16	197
maiz (1000's)	2.5	4 2	0 8	9 4	8 6	9 9	2 2	0 8	2 6
cott				1405		1459	311	82	381

Manure continued

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
83by84									
all	1 9	1 8	2 0	6	5	7	2 8	2 5	3 0
AVG									
all	152	174	132	411	315	470	995	323	1345
mill	115	113	117	170	108	221	155	28	226
sorg	0	0	0	329	261	363	427	39	624
maiz (1000's)									
	3 9	5 7	2 3	8 1	6 2	9 1	7 4	4 4	8 6
cott				1405		1459	1314	402	1776

Chapter 4. AVERAGE LAND AND LABOR PRODUCTIVITIES AND TOTAL FACTOR PRODUCTIVITIES

In this chapter we describe aggregate trends in average land and labor productivity for crops, and then zone-level patterns from farm data

Before going to this, however, we feel it important to make an aside on the narrowness of measuring productivity only using crop output and input data First, a narrow focus on crop output and crop productivity neglects the important nonfarm dimension of farm household's activity, that can be nearly half of its income If one measures farm output per person only by the value of crop output per person, one neglects nearly half of the output of the household, the nonfarm part There is thus much more economic activity in rural areas in Africa than just crop statistics show -- and this corroborates important work on African rural microenterprises by Liedholm, Mead, et alia That Reardon et al (1993) also found that most nonfarm activity is related upstream or downstream to agriculture further strengthens the case to count the full output in both sectors of the rural household toward its "productivity" The above argument reflects on the "numerator" of the yield measure The flip side of the argument touches on the "denominator" of the labor productivity measure in the crop sector as members of the household are working part or full time in the nonfarm sector, it would be inappropriate (though usual in aggregate statistics) to divide crop output by rural persons inside a certain age bracket ("the active") One would have to remove from the denominator the equivalent in persons of the time used off-farm, thus increasing the crop yield measure This can easily be done in farm-level studies and could be applied to remeasuring aggregate productivity

Second, a commodity sector perspective is needed to help identify important opportunities to raise productivity at levels of the food system above the farm (e g , in processing or marketing activities, or through policy change) Knowledge of consumer or export demand is also needed to guide development of new farm production technology A useful focus for future productivity work is on the efficiency of the whole food system, from the farmer, through the market chain, to the consumer (Antle 1985) If improvements are made in the efficiency of farm-level production, but they are not passed on to the consumer because of inefficiencies or structural rigidities "downstream", the benefits are lost Yet it is important to note that food market development and productivity agendas are linked Food markets cannot be developed adequately without raising farm productivity and providing the conditions necessary to enable African farmers to receive and respond effectively to market signals Moreover, increasing the efficiency of the off-farm parts of the food system is crucial both to consumer welfare and to increasing

farm productivity Hence, improved food system performance will require productivity gains both at the farm level and at other levels of the system, such as processing and marketing Which level of the food system is the highest priority for research and policy interventions will depend on circumstances in the commodity subsectors concerned The nature of consumer demand constitutes an important parameter that determines what can and should be done to expand the volume of business within the subsector, and what this implies for the potential to expand farm-level production

Below, when treating the aggregate (using FAO data), we use the agricultural population of labor age as the denominator, and crop output as the numerator In the sections dealing with farm-level data, we use actual labor time (of family plus hired labor) as the denominator (for labor yields) and crop output as the denominator For both we use cultivated land as the denominator for the land-yields

4 1 Aggregate Patterns in Crop Productivity

Tables A1 1 and A1 2 in the Appendix to this chapter show the evolution of selected indicators of performance for the main food and cash crops over the last 30 years

Food crops The absolute levels of production has increased twofold for each of the three crops (maize, millet and sorghum) from the 1961-65 average to 1991

Area has increased less in relative terms, suggesting gains in land productivity The per hectare yields do indeed suggest important gains in maize, and moderate gains in sorghum and millet (Figure 1 1) The average growth rates in land productivity are estimated at 2 0 percent for maize and 1 3 percent for millet and sorghum combined, using an exponential trend over the period of observation

Labor productivity is proxied by total production over the active agricultural population Figure 1 2 shows that some progress has been made over time in labor productivity Using an exponential trend over the period 1961-91, the average annual progress in maize is estimated at 1 percent (low due to the frequent year to year fluctuations), while millet and sorghum labor productivity grew at a rate of 0 8 percent per annum Figure 1 3 shows the evolution of labor productivity for the combined cereals, with an annual growth rate of 0 7 percent

Cash crops There have been some impressive gains in productivity for cash crops over the post independence era The production of cotton went from a negligible 7,000 MT per year over 1961-65, to nearly 180,000 MT in the late eighties Concomitantly, area has increased fourfold (Table A1 2) The gains in average productivity are substantial for both land and labor (Figures 1 4 and 1 5) The yield of cotton grew at an annual rate of 7 5 percent, and labor productivity at a rate of 10 1 percent

Growth in peanut production has been less substantial Labor productivity experienced little growth, averaging 25 kg/worker in the seventies and 35 kg/worker in the eighties The growth rates are estimated at 0 9 percent for yield and 0 8 percent for labor productivity

4.2 Disaggregating the aggregate picture

The farm-level data allows us to "dig below" the country-level data discussed in section 1, examining differences by agroecological zone, over year-types for each zone, and over farmer types in each zone This disaggregation is important to our understanding of determinants of productivity change, and policy and technology implications

First, aggregate data used for national and FAO statistics is usually based on administrative regions which do not lend themselves to understanding the role of the agroclimatic zone, which is crucial for understanding productivity differences Farm-level data, by contrast, are often selected with agroclimatic zones in mind There are often large differences in farm productivity over zones within a country Land and labor productivity in (agroclimatically-) unfavored zones is on average well below that in (agroclimatically-) favored zones, that have higher and more stable rainfall

Second, annual aggregate growth rates mask the large differences in yields over years, and how those differences vary by zone That variation is highest in the semi-arid areas with greatest rainfall variation

Third, yields can differ greatly over technology regimes, as in case of AT as shown below

4.3 Average land productivity from farm-level data

Table 4 1 shows average land productivity (for which we use the term "land yields" interchangeably in this section, and which means kilograms of output per hectare), over 1981-1985 (with yearly figures in the appendix), by agroclimatic zone (Sahelian, Sudanian, and Guinean) Table 4 2 shows the ratio of 1983 (good year) to 1984 (poor year) figures to indicate variation The tables break down the figures into overall per zone, AT group, and manual group Each average is weighted by area under the crop in each household

Millet average land productivity averaged over the 5 years show the Sahelian with lowest yields (246, versus 318 in middle and 371 in south In the Sudanian and Guinean zones, AT does not make for a land productivity advantage, it even detracts in the Sahelian zone AT for millet is mainly used for

adding land under cultivation, not intensifying cultivation (through deeper plowing advantages as is the case with maize)

The drought years bring the Sahelian average down, however, Appendix 1 shows that in the good years in the Sahelian zone, millet land productivity figures were at least as high as in the other zones This makes sense given that millet is grown on poorer soils in the Guinean zone and in no zone does it receive much fertilizer or manure The highest average land productivity figure (upper bound average) in each zone was 451, 458, and 486 for the north, middle, and south, so the millet land-yield potential at least using current technologies does not differ much over zones

Millet average land productivities fluctuate enormously in the north with rainfall the ratio of yield in the Sahelian zone in a good year (83) to a bad year (84) is 6 -- four times the average difference between Sahelian and Guinean zones The interyear ratio is only 1 6 in the Sudanian and 7 in the Guinean, reflecting less rainfall variability Average land productivities do not fluctuate in the same direction over zones, hence there might be a potential for millet trade

Sorghum land productivity in the Guinean zone is 1 5 that in the Sahelian and Sudanian zones In good rainfall years, sorghum land productivities differ more over zones than do millet's, as sorghum is more responsive to higher rainfall and soil conditions Curiously, appendix 1 shows that the highest land productivity is recorded in the Sahelian zone in 1981, but this is an anomaly in the pattern Excluding this anomaly, highest sorghum land yields are 408 in the sahelian, 545 in the Sudanian, and 644 in the Guinean As with millet, AT does give a land yield advantage in sorghum, and even detracts somewhat in the Sahelian and the Guinean zone, for reasons similar to those discussed for millet

Sorghum land yields fluctuate a good deal in the two northern zones between good and bad years (e g 1983 and 1984), 1 7 in the Sahelian, and 1 9 in the Guinean Fluctuation is thus much less than millet in the Sahelian, but more than millet in the other two zones The latter is expected because millet is more drought-resistant than sorghum This was not the case in the Sahelian zone, but Appendix 1 shows that sorghum dropped more than millet in the first pair of years (good 1981, bad 1982) in the Sahelian zone, and dropped much less than millet in the second pair of years (good 83, bad 84) Yields fluctuate in the same directions in all zones, but there still appears to be potential for trade because the land yields of the Guinean and Sudanian zones are much higher in the poor years than the Sahelian zone

Maize land yields are on average 1 2 times higher in the Guinean zone compared to the Sudanian We report yields in the Sahelian zone but they are much lower than in the other zones, and very little maize is grown there The highest land-yield was 1661 for the Sudanian and 2414 for the Guinean As with millet and sorghum, AT does not make for an average productivity difference, except in 1981 and

82 in the Guinean zone We will see in Chapters 6 and 7 that it makes a substantial difference at the margin

Maize land yields fluctuate more than for the other grains, due to its being more sensitive to soil moisture, and the effect shows more in the Guinean than the Sudanian zone Yields fluctuate in the same direction in all zones between years, but there still appears to be potential for trade because the levels are so much higher in most years in the Guinean zone

Cotton land yields are four times higher in the Guinean zone (where cotton farming is common and is supported by the cotton parastatal) than in the Sudanian zone (where only a few practice it) The highest land-yield in each zone was 425 for the sudanian, and 1056 for the Guinean

Unlike grains, cotton cropping has much higher land yields with AT, 1.4 times higher Partly this is from greater capacity and flexibility in plowing and weeding operations, and partly from complementary inputs especially manure, incorporated by AT It can also be from being able to clear additional land for millet and sorghum to reserve the best land for cotton and maize grown in rotation

Land yields change little over the period in the Guinean zone, overall less than the grains

4 4 Labor yields

Table 4 3 shows average labor productivity -- called labor yield in this section -- (kilograms of output per hour) over 1981-1985 (with yearly figures in the appendix), by agroclimatic zone (Sahelian, Sudanian, and Guinean) Table 4 4 shows the ratio of 1983 (good year) to 1984 (poor year) figures to indicate variation The tables break down the figures into overall per zone, AT group, and manual group The averages are computed by summing all output over sample households, divide by all labor to that crop over all households, hence the average is weighted by labor expended per household

Millet labor yields, unlike land yields, are not directly correlated with agroclimatic level On average, Sahelian labor yields are 1.5 times the Sudanian, and 9 times the Guinean labor-yields averaged over the 5 years show the Sudanian with lowest (5 kgs/hour or 4 kgs/day) versus 77 kgs/hr (6 2 kgs/day) for the Sahelian and 84 kgs/hour (6 7 kgs/day) for the Guinean. Appendix 1 shows the highest millet labor-yield at 1 47 kgs/hour (11.8 kgs/day) for the Sahelian, .66 kgs/hour (5 3 kgs/day) for the Sudanian, and 1 27 kgs/hour (10.2 kgs/day) for the Guinean Hence even the best-year figure shows a U-shape as one goes from north to south

Sahelian farmers get relatively high labor-yields because they augment their labor by much greater land cultivated (hectares per AE in the Sahelian zone were on average 92, versus 58 in the Sudanian

and 65 in the Guinean Marginal land is also usually poorer, and millet is more hardy and can be grown on it It is less likely that such strategies can be employed for sorghum and maize, that are more sensitive to soil quality

The ordering shifts over years, however, in the first three years, Sahelian labor yields are higher than Sudanian's, then reversed in the last two years In general Guinean labor yields are highest, but note that in the good year 1983 Sahelian levels were the highest

Average hired labor yields are more difficult to evaluate because so little hired labor is used for millet (see below), which is why hired labor yields drop rapidly from 58 in the Sahelian zone to 3 2 in the Guinean zone, as the use of hired labor rises rapidly from north to south

In the Sahelian and Sudanian zones, AT use does not increase labor yields relative to manual farms But in the Guinean zone AT farm millet labor yields are 1 3 times the manual farmers' Appendix 1 shows that this advantage is roughly correlated with amount of yearly rainfall

Millet labor yields fluctuate enormously in the north, for example (good) 1983's are 5 4 (poor) 1984's -- about the same variation as in land yields This ratio fell to 2 5 in the Sudanian and to 1 0 in the Guinean In general labor yields fluctuated as much or more than land yields, and in the same direction

Unlike millet, sorghum's labor yields are roughly correlated with agroclimatic level (rises as one goes south) The 'land flexibility advantage' of the northern zone that holds for millet does not hold for sorghum as the extra land, usually marginal and of poorer quality, is not as suitable for sorghum

The best labor yields in each zone was 1 11 kgs/hour (8 9 kgs/day) for the Sahelian, 85 kgs/hour (6 8 kgs/day) for the Sudanian, and 1 37 kgs/hour (11 kgs/day) for the Guinean zone Hence, the 'best year' figures give a weak J-relationship as one goes from north to south

As with millet, hired labor yields are difficult to evaluate because so little is used, and descends rapidly from the Sahelian zone (42 kgs/hr) to the Guinean, which uses the most hired labor (4 3)

Only in the Sudanian zone does AT make for a (weak) labor yield

Sorghum labor yields fluctuate less than millet in the Sahelian zone and more than millet in the other zones The fluctuation of labor yields exceeds that of land yields in the middle and southern zones, apparently because it is easier to adjust labor per hectare than land per laborer (for sorghum)

Maize labor yields, similar to sorghum but contrary to millet, are roughly correlated with agroclimate, with very low labor yields in the north where little is grown (45 kgs/hour or 3 6 kgs/day), 1 42 kgs/hour or 11 4 kgs/day in the Sudanian, and 1 46 kgs/hour or 11 7 kgs/day in the Guinean The "best year" labor-yield for maize was 87 kgs/hour (7 per day) in the north, 2 65 kgs/hour or 21 2

kgs/day) for the Sudanian, and 2 43 kgs/hour (19 4 kgs/day) for the Guinean The 'best' figures give a strong step-function from north, to middle-south One should note, however, that the good figures for the Sudanian zone are based on much less maize than produced in the Guinean zone, that is, the good pockets of land in the good years in the Sudanian zone produce about as well as their Guinean counterparts, but the there are fewer pockets and good years in the Sudanian than in the Guinean

Hired labor yields are again difficult to evaluate because so little is used, and descends rapidly from the Sahelian zone's 152 kgs/hr to the Sudanian's 163, to the Guinean's 18, as the latter uses the most hired labor (see below)

In the Sahelian and Sudanian zones, there is a weak labor-yield advantage of AT, and a weak disadvantage in the Guinean zone This is because maize is usually produced near the compound in a manure-intensive and labor-intensive way, and does not lend itself well to AT for the relatively small amounts produced

Labor yields for maize fluctuate enormously in the north, where little is grown Note that there was much greater fluctuation (say between 1983 and 84) in maize labor-yields in the Sudanian and Guinean zones than for the other crops, and much more fluctuation than in land yields for maize -- which again shows that for maize, like sorghum, there are constraints on the availability of suitable land

Cotton labor yields, as with maize and sorghum, are correlated with agroclimate (rises as one goes south) from low in the Sudanian (32 kgs/hour or 2 6 per day) to 75 kgs/hour (about 6 kgs/day) in the Guinean The "best year" labor yield was .58 kgs/hour (4 6 kgs/day) for the Sudanian, and 1 74 kgs/hour or 13 9 kgs/day for the Guinean

Unlike for the grains, AT has a strong labor yield advantage in the Guinean zone (as was the case for land yields as well) there is a very strong advantage of AT (factor of 1 6)

Our comments on interyear fluctuation focus on the Guinean zone as there is so little cotton produced in the Sudanian zone Labor yield fluctuation for cotton is between that of maize and the basic grains Cotton's labor yield fluctuation is again, as the case of maize and sorghum, greater than the land yield fluctuation, again because of constraints on land suitable to cotton

4.5 Yield gaps over zones -- how are they composed

Total labor use per hectare in the Sudanian zone is 1 9 that of the Sahelian zone (average over crops and years), which leads along with better rainfall to land yield gap of 1 2 But note that Sudanian farmers use 6 times the land per AE as do Sahelian farmers The greater labor use and better land

yields, but lower labor yields, by the Sudanians translates into lower grain output per AE compared to the Sahelians Using just millet (extrapolated to whole farm) as illustration, note that Sahelians grow 226 kgs millet per AE, while Sudanians grow 184 kgs Sudanians use more labor to compensate for less land and still do not close the per person output gap with the Sahelians The comparable figure is 341 kgs /AE for the Guinean zone -- whose labor use and land use is in between the Sudanian and the Sahelian's, but land yields are higher But this reduction of yield gap per person by the Sahelians means that they are having to push onto extensive/fragile margins to overcome a land yield disadvantage This is important for the Sahelian environment debate

4.6 Total Factor Productivity

Table 4 5 shows the Törnqvist-Theil indices for total factor productivity (TFP) using the formula proposed by Christensen and Jorgenson (1970), based on Divisia input and output indices for 1981-85 TFP for AT and manual households varied essentially with rainfall in all zones The variation was greater in the north, and weaker in the south, as expected In general the AT households had higher indices than the manual households in drought years, apparently because of the flexibility they had to manage risk and

allocate resources [7]

---

[7] The Törnqvist approximation to the Divisia output index (or discrete divisia output index) is defined as (for detailed derivation see for example Chambers 1988 pp 232-239)

$$\ln(Q_t/Q_{t-1}) = 0.5 * \Sigma_i [R_{it} + R_{i,t-1}] [\ln(q_{it}) - \ln(q_{i,t-1})], \quad (1)$$

where

Q_t = index for output at time t
R_{it} = output revenue share (output i, time t)
q_{it} = output i at time t

Similarly, approximation to the input index is

$$\ln(X_t/X_{t-1}) = 0.5 * \Sigma_i [S_{it} + S_{i,t-1}] [\ln(x_{it}) - \ln(x_{i,t-1})], \quad (2)$$

where

X_t = index for input at time t
S_{it} = input cost share (input i, time t)
x_{it} = input i at time t

If the Divisia input index (2) is derived from a profit maximization behavior, the shares in the indexes are the shares of each input cost from total revenue On the other hand, if the index is based on cost shares, production technology has to exhibit constant returns to scale (Chambers 1988) For example, Ball (1985) used cost shares in the discrete Divisia indices as in the formula above, and he constrained the analysis to constant returns to scale technology
The Törnqvist-Theil index for total factor productivity is defined as

$$\ln[TFP_t/TFP_{t-1}] = 0.5 * \Sigma_i [R_{it} + R_{i,t-1}] [\ln(q_{it}) - \ln(q_{i,t-1})] - 0.5 * \Sigma_i [S_{it} + S_{i,t-1}] [\ln(x_{it}) - \ln(x_{i,t-1})]$$

$$= \ln(Q_t/Q_{t-1}) - \ln(X_t/X_{t-1})$$

$$=> TFP_t/TFP_{t-1} = (Q_t/Q_{t-1})/(X_t/X_{t-1})$$

Thus, the Törnqvist-Theil index of total factor productivity can be computed by dividing the Divisia output index (1) by the Divisia input index (2) These three indices are presented in table 5
Output indices were constructed with millet, sorghum, maize and cotton outputs and their prices Input indices were constructed only with variable inputs, fertilizer and hired labor and their prices For other inputs, like household labor, manure and land, we didn't have prices and they had to be excluded from the index.
Note that the Törnqvist-Theil quantity index is exact only for a homogeneous translog production (or utility) function (Diewert 1976) These indices do not necessarily match our estimates for production technology, since we used a quadratic approximation

APPENDIX 1, TEXT FIGURES

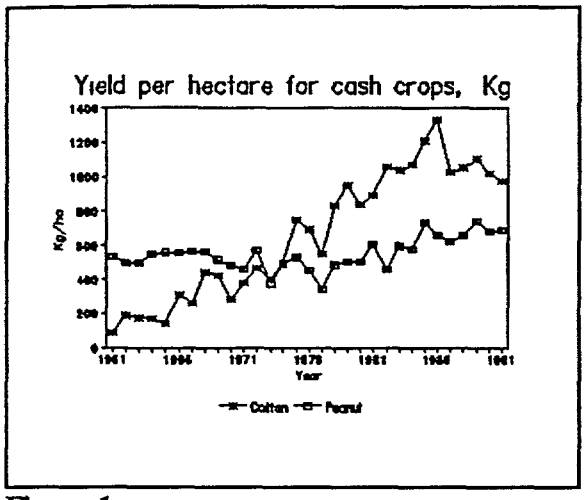

Figure 1

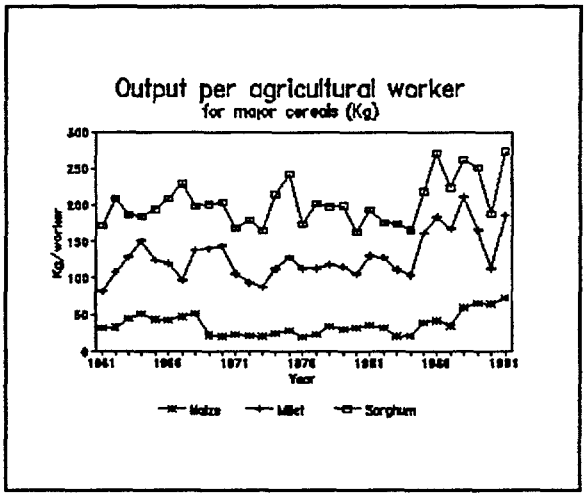

Figure 2

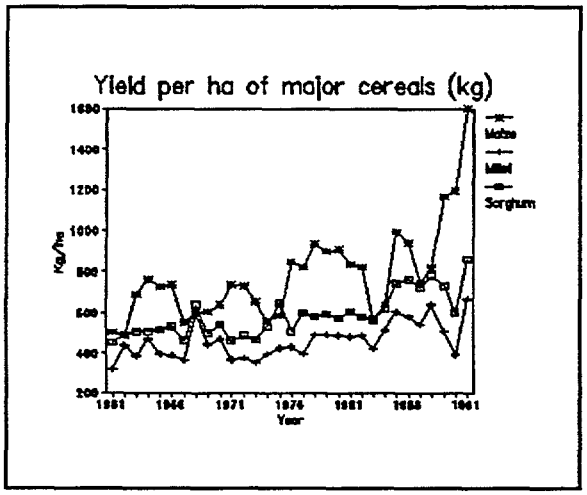

Figure 3

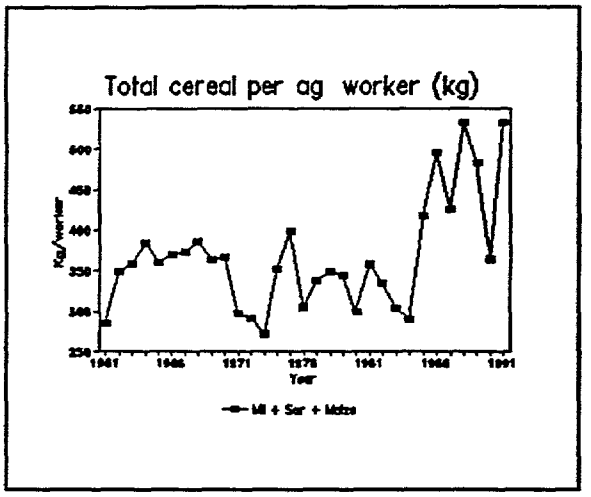

Figure 4

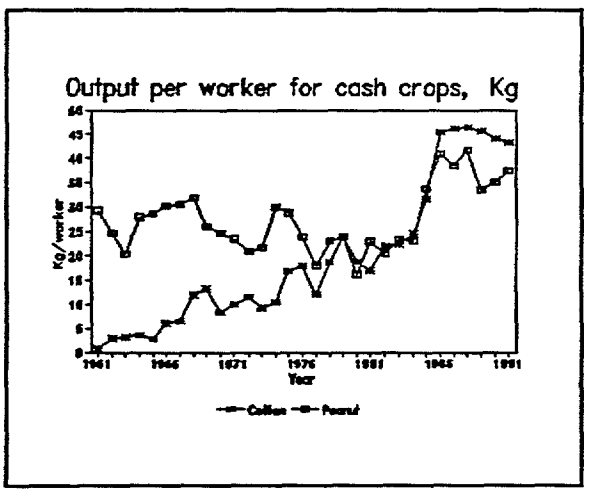

Figure 5

APPENDIX 2, TEXT TABLES

Table. 4 1 LAND AVERAGE PRODUCTIVITY Average 1981-5

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
MILLET	246	283	209	318	317	318	371	374	382
SORGHUM	351	385	313	377	357	388	536	562	526
MAIZE	249	257	232	1097	1192	1047	1351	1429	1349
COTTON							919	703	1009

Table 3.2 LAND AVERAGE PRODUCTIVITY, RATIO OF GOOD YEAR (1983) TO POOR YEAR (1984)

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
MILLET	6 0	5 1	7 5	1 6	3 1	1 3	7	8	6
SORGHUM	1 7	1 4	2 7	1 9	1 9	1 8	1 1	1 0	1 1
MAIZE	7 0	7 3	6 2	1 9	2 2	1 7	1 4	1 1	1 5
COTTON							1 1	1 0	1 2

Table 4.3 AVERAGE LABOR PRODUCTIVITY (total labor = own + hired), average 1981-5

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
MILLET	77	87	67	50	50	50	84	74	93
SORGHUM	66	8	51	64	6	68	1 04	1 07	1 02
MAIZE	45	43	48	1 42	1 34	1 49	1 46	1 49	1 43
COTTON				0 32	0 24		0 96	75	1 18

Table 4 4 AVERAGE LABOR PRODUCTIVITY, RATIO OF GOOD YEAR (1983) TO POOR YEAR (1984)

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
MILLET	5 4	4 6	7 4	2 4	3 7	1 8	1 0	1 2	9
SORGHUM	1 6	1 3	2 8	2 5	2 6	2 4	1 4	1 4	1 4
MAIZE	5 4	5 1	6 9	5 9	5 6	6 1	2 3	2 4	2 1
COTTON							1 5	1 3	1 7

Table 4 5. TOTAL FACTOR PRODUCTIVITY

Törnqvist-Theil Total factor productivity (TFP) indices by zone and by technology group for 1981-85, based on divisia output and input indices

Sahelian Zone

Harvest Year	Total Factor Productivity		
	Traction Households	Manual Households	All Households
81	1 00	1 00	1 00
82	0 52	0 44	0 48
83	1 12	1 09	1 13
84	0 16	0 27	0 22
85	0 26	0 30	0 29

B Sudanian Zone

Harvest Year	Total Factor Productivity		
	Traction Households	Manual Households	All Households
81	1 00	1 00	1 00
82	0 83	0 59	0 72
83	1 21	0 96	1 11
84	0 51	0 33	0 45
85	1 24	1 02	1 17

C Guinean Zone

Harvest Year	Total Factor Productivity		
	Traction Households	Manual Households	All Households
81	1 00	1 00	1 00
82	0 82	0 72	0 79
83	1 14	1 08	1 14
84	0 77	0 79	0 79
85	1 06	1 21	1 12

The labor input used here is total labor (own and hired) in divisia input index, labor has been weighted by wage rate

APPENDIX, SUPPORTING DETAILED-TABLES

AVERAGE LAND PRODUCTIVITY

A MILLET

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981	451	538	377	458	483	439	475	422	564
1982	175	166	184	275	265	285	253	307	221
1983	432	493	360	319	355	299	328	348	317
1984	72	97	48	197	116	235	486	428	507
1985	99	123	74	343	368	333	314	367	301
3by4	6 0	5 1	7 5	1 6	3 1	1 3	7	8	6
AVG	246	283	209	318	317	318	371	374	382

B SORGHUM

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981	707	489	778	545	531	557	644	592	677
1982	195	197	193	384	362	405	354	299	389
1983	278	396	219	352	359	348	610	647	592
1984	167	289	82	189	188	189	566	650	532
1985	408	556	296	414	346	445	507	624	440
3by4	1 7	1 4	2 7	1 9	1 9	1 8	1 1	1 0	1 1
AVG	351	385	313	377	357	388	536	562	526

C MAIZE

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981	469	410	512	1661	1665	1658	2414	2313	2476
1982	88	74	104	1231	1351	1149	1231	669	1458
1983	413	553	246	910	1187	776	1244	1289	1226
1984	59	76	40	491	551	464	901	1196	829
1985	217	175	259	1194	1207	1186	967	1682	756
3by4	7 0	7 3	6 2	1 9	2 2	1 7	1 4	1 1	1 5
AVG	249	257	232	1097	1192	1047	1351	1429	1349

D COTTON

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981				269		255	644	445	772
1982				425		425	1056	858	1172
1983				124	124		994	763	1104
1984							911	773	957
1985							990	679	1041
3by4							1 1	1 0	1 2
AVG				272			919	703	1009

RESULTS FOR AVERAGE LABOR PRODUCTIVITY BY ZONE, CROP

A MILLET

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981									
own	1 29	1 53	1 05	0 68	0 69	0 66	1 74	1 17	2 32
hired	31 5	20 9	42 0	3 6	4 5	2 6	4 6	3 0	6 3
total	1 23	1 42	1 03	0 56	0 59	0 53	1 27	0 84	1 70
1982									
own	0 62	0 65	0 59	0 39	0 35	0 42	0 69	0 85	0 53
hired	21 9	16 2	27 6	4 4	4 5	4 4	1 7	1 9	1 4
total	0 60	0 63	0 58	0 35	0 32	0 39	0 49	0 59	0 39
1983									
own	1 53	1 67	1 38	0 74	0 73	0 76	1 02	1 05	0 99
hired	36 9	39 8	34 0	6 3	7 5	5 1	3 1	2 9	3 2
total	1 47	1 60	1 33	0 66	0 66	0 66	0 76	0 77	0 75
1984									
own	0 27	0 36	0 18	0 29	0 19	0 39	1 34	1 07	1 61
hired	37 8	22 0	53 6	10 1	10 1	10 1	1 6	1 6	1 7
total	0 27	0 35	0 18	0 28	0 18	0 37	0 73	0 64	0 82
1985									
own	0 28	0 33	0 22	0 68	0 77	0 59	1 15	1 07	1 24
hired	163 4	31 9	294 8	16 0	18 4	13 7	4 9	4 8	5 0
total	0 28	0 33	0 22	0 65	0 74	0 57	0 93	0 88	0 99
3by4									
total	5 4	4 6	7 4	2 4	3 7	1 8	1 0	1 2	9
AVG									
own	0 80	0 91	0 68	0 56	0 55	0 56	1 19	1 04	1 34
hired	58	26	90	8	9	7 2	3 2	2 8	3 5
total	0 77	0 87	0 67	0 50	0 50	0 50	0 84	0 74	0 93

B SORGHUM

	Sahelian				Sudanian				Guinean		
	All	MAN	AT		All	MAN	AT		All	MAN	AT
1981											
own	1 15	1 03	1 28		0 85	0 89	0 81		1 91	1 67	2 14
hired	40 6	15 8	65 4		7 3	7 5	7 2		4 9	4 2	5 6
total	1 11	0 96	1 26		0 76	0 80	0 73		1 37	1 20	1 55
1982											
own	0 41	0 49	0 32		0 57	0 53	0 62		0 75	0 67	0 84
hired	39 3	14 4	64 2		6 7	6 6	6 8		2 3	2 5	2 2
total	0 40	0 48	0 32		0 53	0 49	0 57		0 57	0 53	0 61
1983											
own	0 60	0 84	0 36		0 81	0 73	0 89		1 66	1 66	1 66
hired	52 5	13 5	91 6		8 8	8 9	8 8		5 2	5 8	4 5
total	0 58	0 79	0 36		0 74	0 68	0 81		1 25	1 29	1 21
1984											
own	0 41	0 69	0 13		0 32	0 27	0 36		1 25	1 38	1 12
hired	11 7	4 0	19 3		6 6	7 0	6 3		3 0	2 6	3 5
total	0 36	0 59	0 13		0 30	0 26	0 34		0 88	0 91	0 85
1985											
own	0 87	1 26	0 47		0 90	0 79	1 01		1 43	1 87	1 0
hired	65 4	22 1	108 7	15 3	16 6	14 1		6 2	6 2	6 2	
total	0 83	1 20	0 47		0 85	0 75	0 94		1 15	1 44	0 86
3by4											
total	1 6	1 3	2 8		2 5	2 6	2 4		1 4	1 4	1 4
AVG											
own	0 69	0 86	0 51		0 69	0 64	0 74		1 4	1 45	1 35
hired	42	14	70		8 9	9 3	8 6		4 3	4 3	4 4
total	0 66	0 8	0 51		0 64	0 6	0 68		1 04	1 07	1 02

C MAIZE

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981									
own	0 69	0 40	0 98	1 54	1 68	1 39	2 43	2 44	2 41
hired	688	56	1319	95	85	104	19	16	21
total	0 69	0 39	0 98	1 51	1 65	1 37	2 14	2 12	2 17
1982									
own	0 20	0 15	0 25	0 85	0 89	0 82	1 10	0 76	1 44
hired	26	8	44	464	64	865	6 9	5 7	8 0
total	0 20	0 15	0 25	0 85	0 87	0 82	0 94	0 67	1 22
1983									
own	0 88	1 14	0 62	2 69	2 23	3 15	2 25	2 41	2 09
hired	48	48		208	131	286	17 9	11 8	24 0
total	0 87	1 12	0 62	2 65	2 19	3 11	1 96	2 00	1 92
1984									
own	0 16	0 22	0 09	0 47	0 43	0 51	0 97	0 93	1 02
hired				5 5	5 5		8 1	8 6	7 7
total	0 16	0 22	0 09	0 45	0 39	0 51	0 87	0 84	0 90
1985									
own	0 35	0 26	0 44	1 78	1 64	1 92	1 51	2 07	0 95
hired				41	70	12	38	15	60
total	0 35	0 26	0 44	1 63	1 60	1 66	1 38	1 82	0 93
3by4									
total	5 4	5 1	6 9	5 9	5 6	6 1	2 3	2 4	2 1
AVG									
own	0 46	0 54	0 48	1 47	1 37	1 56	1 65	1 72	1 58
hired	152	22	272	163	71	253	18	11	24
total	0 45	0 43	0 48	1 42	1 34	1 49	1 46	1 49	1 43

D COTTON

	Sahelian			Sudanian			Guinean		
	All	MAN	AT	All	MAN	AT	All	MAN	AT
1981									
own				0 29	0 25	0 33	0 74	0 67	0 82
hired				4 0	7 4	0 6	4 7	3 7	5.7
total				0 23	0 24	0 22	0 64	0 56	0 72
1982									
own				0 58		0 58	1 08	0 84	1 32
hired				5 2		5 2	3 6	3 5	3.7
total				0 52		0 52	0 83	0 68	0 97
1983									
own				0 29		0 29	1.54	1 08	1 99
hired				7 9		7 9	4 4	3 3	5 6
total				0 27		0 27	1 14	0 81	1 46
1984									
own				0 34	0 60	0 08	1 01	0 79	1 23
hired							2 9	2 8	3 1
total				0 34	0 60	0 08	0 75	0 62	0 88
1985									
own				0 23	0 36	0 10	1 74	1 21	2 28
hired				1 9		1 9	9 6	9 4	9 9
total				0 23	0 36	0 10	1 46	1 07	1 85
3by4									
total							1 5	1 3	1 7
AVG									
own				0 35	0 40	0 28	1.22	0 92	1.53
hired				3 8		3 1	5	4 5	5 6
total				0 32	0 24	0 96	0 75		1 18

CHAPTER 5

THE DETERMINANTS OF TECHNOLOGY CHOICE

5 1. Introduction

The objective of the present chapter is to develop a model that accounts for differences observed between manual farms and animal traction (AT) users, as highlighted in the foregoing analyses In most studies on production, animal traction or technology choice in general is modeled as a dummy variable affecting either the intercept term or selected parameters The implicit assumption is that the choice of the technology is exogenous, i e not conditioned by the explained variable or other household characteristics such as household size and income that may be present in the model

Here we model productivity in the framework of an endogenous selectivity model The selectivity modeling rests on two hypotheses The first, which we maintain, is that animal traction affects productivity in a pervasive way, that is, it affects the values of most relevant parameters The second is that animal traction adoption is a function of key household characteristics The modeling therefore consists in identifying the determinants of technology choice and estimating the production models using that information This chapter develops and estimates the technology choice model, which is then used in the next two chapters to provide consistent estimators for the relevant parameters

In this chapter and the next two, models are estimated for two zones The first is the Guinean zone, which, as the previous chapters showed, has the highest agroclimatic current level and agricultural potential The second zone groups the Sudanian and the Sahelian zones, and is hereafter referred to as the Sudano-Sahelian zone Unless migration is taken into account, zone selection can be fairly considered as independent from the household so that the usual statistical properties hold for separate subsample estimation

The rest of this chapter proceeds as follows Section 2 presents the structure of the selectivity model Section 3 develops the binary choice model used in the selection and section 4 discusses the estimation issues related to this model In section 5 we validate the model by considering its aptness to explain technology choice Section 6 concludes

5.2 Structure of the selectivity model

The general objective is to estimate systems of production functions and output supply and input demand functions which may be cast in the following general form

$$y_{ht} = f(X_{ht}, \beta) + \epsilon_{ht} \tag{4-1}$$

where y_t and X_t are respectively a vector and a matrix of explained and explanatory variables, β is a vector of parameters and ϵ_t a vector of random disturbances

These equations are estimated for each of two regimes representing the status of technology Regime 1 represents households that have adopted animal traction (AT=1) while regime 2 represents manual households, i e those using hand tools (AT=0) It is assumed that a household's decision to select itself into one or the other regime is the result of expected benefits Technology choice is modeled not as an investment model, but as a binary choice model in the following way

$$AT^*_{ht} = W_{ht}\theta + u_{ht} \tag{4-2}$$

where AT^* is an unobserved latent variable determining households' technology choice Thus, AT^* may be thought of as the expected benefit (known only to the farmer) of investing in animal traction The observed binary variable, AT, has the value 0 for $AT^* \leq 0$ (manual households) or 1 for $AT^* > 0$ (households having actually chosen AT) W is a set of household characteristics hypothesized to be correlated with adoption, and Θ a vector of parameters This model allows the prediction of the probability of adopting animal traction, given a household with characteristics W

Once a household selects itself into one regime on the basis of its expectations as to the benefits of AT, it faces a given set of production relationships System (1) is therefore rewritten for each of the two regimes

$$\begin{aligned} y^1_{ht} &= f(X^1_{ht}, \beta^1) + \epsilon^1_{ht} \quad (h=1,\ldots,N^1) \\ y^2_{ht} &= f(X^2_{ht}, \beta^2) + \epsilon^2_{ht} \quad (h=1,\ldots,N^2) \end{aligned} \tag{4-3}$$

where the superscripts 1 and 2 respectively refer to regime 1 (AT=1) and regime 2 (AT=0), N^1 and N^2 are the number of households in each group Note that the parameters are made to differ between groups

One may consider the estimation of model (3) by partitioning the sample into the two groups and running separate regressions for each group Unfortunately, the presence of equation (2) that underlies the grouping will lead to biased estimates of the separate models (Heckman, 1976, 1979) This selection bias results from the non-zero correlation between the error terms ϵ^1 and ϵ^2 present in model (3) with the disturbance u in the selection rule (2) A consequence of this correlation is that ϵ^1 and ϵ^2 have non-zero expected values given (2), thus violating the least squares assumption that guarantees unbiasedness

The expression for the expected value of the error terms of (3) can be derived if the joint distribution of ϵ^1, ϵ^2 and u is known It is customarily assumed that ϵ^1, ϵ^2 and u are jointly distributed as trivariate normal In this case, the expectations are given by

$$\begin{aligned} E(\epsilon^1_{kt}|AT^* > 0) &= E(\epsilon^1_{kt}|u_{kt} > -W_{kt}\theta) \\ &= \sigma_{1u}\left[\frac{\phi(W_{kt}\theta)}{\Phi(W_{kt}\theta)}\right] \\ E(\epsilon^2_{kt}|AT^* \le 0) &= E(\epsilon^2_{kt}|u_{kt} \le -W_{kt}\theta) \\ &= \sigma_{2u}\left[-\frac{\phi(W_{kt}\theta)}{1-\Phi(W_{kt}\theta)}\right] \end{aligned} \tag{4-4}$$

where σ_{1u}=Cov(ϵ^1,u), σ_{2u}=Cov(ϵ^2,u), ϕ and Φ are the density and cumulative distribution functions of the standard normal variable evaluated at the point $W_{kt}\Theta$ The expressions $M_1=\phi/\Phi$ and $M_2=-\phi/(1-\Phi)$ are the inverse Mills ratios It is apparent from the above that ϵ^1 and ϵ^2 will have zero expectation only if they are not correlated with u, which would imply a non-endogenous switching between the two regimes and justify the use of simple separate subsample estimation

Heckman has proposed a two-step method to correct for the bias First, the binary choice model (2) is estimated and the resulting values of the vector Θ are used to compute the vectors of inverse Mills ratios, M_1 and M_2 Second, equation (3) is estimated for each subsample by including as regressors M_1 in the AT subsample and M_2 in the manual subsample Formally, the resulting system is

$$y_{ht}^{1} = f(X_{ht}^{1}, \beta^{1}) + \delta^{1}M_{ht}^{1} + v_{ht}^{1} \quad (h=1,.\ ,N^{1})$$
$$y_{ht}^{2} = f(X_{ht}^{2}, \beta^{2}) + \delta^{2}M_{ht}^{2} + v_{ht}^{2} \quad (h=1,.\ ,N^{2}) \qquad (4\text{-}5)$$

where v^1 and ^{2} have zero expected value, so that the resulting estimators of β^1 and β^2 are unbiased

5.3. A probit model of technology choice

This chapter specifies and estimates the selectivity rule represented by equation (2) The two most common models of binary choice are logit and probit We choose a probit selection rule to model household technology choice here

Technology adoption at the household level is a function of several factors Access to credit or other forms of liquidity constitutes a key factor, as shown by Carter (1989) for Nicaragua using farm household data The present study posits that household access to cash either through savings (livestock holdings) or non-agricultural income is a key factor enabling households to adopt new technology that are embodied in capital Other household characteristics including the age of the principal decision maker are also hypothesized to affect adoption

The form of the estimating equation is

$$AT_{ht}^{*} = \theta_0 + \theta_1 NONFARM_h + \theta_2 SIZE_{ht} + \theta_3 ROAD_t + \theta_4 AGE_{ht} + \theta_5 TOPO_{ht} + \theta_6 SOILDIV_{ht} + u_{ht} \qquad (4\text{-}6)$$

where u is assumed to be normally distributed with a unit variance The assumption of the unitary variance allows an unambiguous identification of the β parameters, which are otherwise identified up to the scale parameter σ^2=var(u) The explanatory variables are defined below

SIZE is the size of the household, measured in terms of adult equivalents It is hypothesized that larger sizes are associated with AT adoption

ROAD is a dummy variable representing the facility of access of the village to regional centers through feeder roads, taking on the value 1 for an easy access It is expected that good road access will enhance AT adoption

AGE is the head of the principal decision maker This variable is expected to negatively affect adoption, as older decision makers are likely to be less prone to innovation

NONFARM is the income from non-agricultural sources including income from livestock, measured as a cross-section variable by taking for each household its average annual income over the survey period The measured thus obtained is a proxy for permanent, expected income which excludes accidental year to year variations We expect more non-agricultural income to be positively related to technology adoption

TOPO is an area weighted average of plots' toposequence Households having access to heavier soils situated in the lower toposequence are likely to adopt animal traction This variable is therefore expected to be negatively correlated with adoption

SOILDIV measures households' land quality diversification and is computed by the Simpson's index

$$SOILDIV = 1 - \sum_i \left[\frac{\textit{area of quality } i}{\textit{household's total land area}} \right]^2 \qquad (4\text{-}7)$$

We expect SOILDIV to negatively influence adoption of AT as it implies many small plots and diverse areas difficult to plow

In the Sudano-Sahelian zone model, a dummy variable, SUDAN, is included to represent the Sudanian sample This variable aims at capturing average treatment differences between the Sahelian and Sudanian agroclimates

5.4. Estimation of the probit model

The data pertaining to the two zones defined for the purpose of analysis (Guinean and Sudano-Sahelian) are used to estimate the model given by (4-6) Two issues were dealt with to guarantee the small sample properties of the estimators

The first is the problem of unbalanced sample The survey purposefully assigned an equal number of households to the two technology strata, resulting in an over-representation of animal traction households in the sample The Manski-Lerman method (Poirier, 1981) was used to correct for sample imbalance The method assigns the following weights to each subsample

$$\zeta_j = \frac{P_j}{p_j}, \quad j = 0, 1 \tag{4-8}$$

where P_j and p_j are the proportions of households with technology j (manual or AT) in the population and in the sample respectively

The second issue is related to the proper treatment of nonfarm income There are indeed reasons to believe that nonfarm income may depend on household structure For instance, larger households may find it easier to spare labor from cropping and household chores to work off-farm If nonfarm income is endogenous, estimating equation (4) without instrumenting nonfarm income would lead to biased results Following Rivers and Vuong (1988), we tested the null hypothesis of exogeneity of the income variable, using the following specification

$$\log(NONFARM_h) = W^*_{ht}\,\Pi + \eta_{ht}, \tag{4-9}$$

where W^*_{ht} contains, besides the right hand variables in equation (6), the following household characteristics

- dependency ratio
- dummy for single conjugal unit
- dummy for household head=head of compound
- average livestock assets per adult equivalent
- dummy for ethnic group=bwa (only in Guinean zone)

The log-linear specification assures that the predicted values for nonfarm income are positive

The least squares residuals from the above equation were rescaled (back to the same unit as NONFARM) and the result added as a regressor v_{ht} to (6), giving

$$AT^*_{ht} = \theta_1 NONFARM_h + W_{1ht}\Theta + \rho v_{ht} + \epsilon_{ht} \tag{4-10}$$

where W_1 is the vector of the regressors other than NONFARM in equation (6)

Under the null hypothesis that NONFARM is exogenous, ρ assumes the null value This was tested using a standard t-test on ρ, and the null hypothesis was maintained for both study zones Thus, nonfarm income is treated as an exogenous variable in the rest of this study

Estimation was carried out using maximum likelihood on equation (6) The weights computed in (4-8) were used to correct for sample imbalance

5.5. Validation of the probit model

The results of the animal traction technology adoption model are summarized in Table 1 We use several criteria to assess the adaptability of the model to the issue of technology choice

The statistical analysis of the parameter estimates shows that nonfarm income has a positive effect on the probabilities of adopting animal traction technology in both the Sudano-Sahelian and the Guinean zones These effects are significant in the Guinean but not in the Sudano-Sahelian

The size of the household measured in terms of active members has a positive and significant impact on the probability of adoption in the two zones This suggest that beyond income, labor availability is an important determinant of the adoption of an animal traction package Indeed, empirical investigations suggest that households with four or less members may find it difficult to use a traction equipment, this being particularly true for oxen traction (Sanon et al)

Road access has an unexpected negative impact on the probability of adoption This effect is significant in the Sudano-Sahelian, but not in the Guinean zone

The age of the household head has a negative impact on adoption, with this effect being significant in the Guinean but not in the Sudano-Sahelian zone

Judging by the hit-miss table at the bottom of Table 1, the variables included are apt in stratifying the sample into AT and manual farmers The proportion of correct prediction is 74 percent in the Sudano-Sahelian zone and 69 percent in the Guinean zone The model is however more apt in predicting the correct outcome for non-adopters (97 percent in the Sudano-Sahelian zone and 95 percent in the Guinean) than for adopters (39 percent and 44 percent respectively in the two zones)

We further examine the implications of the results by considering the combined impact of non-farm income and household size on the probability of adopting animal traction We restrict this to the Guinean zone, where both nonfarm income and household size have statistically significant coefficients The results in Table 2 show that the probability of adoption increases substantially from low nonfarm income, small farm size households (08), to high nonfarm income, large farm size households (89) Among large farms, the probability of adoption almost doubles from 0 38 to 0 70 when one moves from the 5th nonfarm income percentile to the 95th nonfarm income percentile

These results suggest that non-farm income is the crucial liquidity source for investment in animal traction, a relatively costly package for most farmers In fact, nonfarm income is a substitute for formal and informal credit to finance such capital acquisition formal credit mechanisms (such as commercial banks) do not finance AT investments, nor does the cotton parastatal credit scheme (which is mainly used for purchase of fertilizer), nor does informal credit (from moneylenders in the village) to any significant extent (Christensen, 1989)

5.6. Conclusion

This chapter has developed a model that accounts for sample stratification into manual and animal traction households The probit model was apt in modeling technology choice, as shown by its predictive power The estimated parameters will be used to compute the inverse Mills ratios that are used as regressors in the production models

Table 5 1 Probit results for AT adoption

Variable	Guinean		Sudano-Sahelian	
	Estimate	Std error	Estimate	Std error
Intercept	-0 404	0 781	-0 861	1 185
Nonfarm	0 694E-06*	0 418E-06	0 967E-06	0 912E-06
Size	0 143*	0 028	0 196*	0 0372
Road	-0 129	0 269	-1 151*	0 360
Age	-0 0315*	0 0148	-0 0116	0 0010
Topo	-0 0703	0 177	-0 193	0 292
Soildiv	0 0686	0 178	-0 224	0 880
Sudan			-0 038	0 288
Log likelihood	-98 19		-125 90	
$\phi(\ )$	0 360		0 299	

An asterisk (*) denotes significance at the 10 % two-tailed level or below

$\phi(\ )$ is the standard normal density evaluated at $H\Theta$, with H held at the means of its components (equation 4) The marginal effect (at the mean) of each household characteristic on the probability of adoption is obtained by multiplying the estimated parameter by ϕ

Percent of correct predictions

Overall	68 7 in Guinean	74 0 in Sudano-Sahelian
AT = 1	43 6 in Guinean	39.2 in Sudano-Sahelian
AT = 0	94 7 in Guinean	97 1 in Sudano-Sahelian

Table 5 2 Estimated probabilities of AT adoption for different levels of nonfarm income and household size, Guinean zone

HOUSEHOLD INCOME (F CFA)	HOUSEHOLD SIZE		
	LOW (5 06)	MEDIUM (8 69)	HIGH (13 02)
5TH PERCENTILE (27,000)	077	183	389
25TH PERCENTILE (83,553)	083	194	404
MEDIAN (152,883)	091	208	423
75TH PERCENTILE (343,552)	114	244	476
95TH PERCENTILE (1,193,669)	269	463	701
HIGHEST (2,200,000)	533	727	890

All other variables involved in the calculations (see equation 6) are held at their sample means ROAD=0 439, AGE=50 31, TOPO=2 08, SOILDIV=0 339 The estimated probability at the sample mean for all variables is 0 324

CHAPTER 6

DETERMINANTS OF PRODUCTIVITY

6.1 Introduction

Since the series of farm management studies in the semi-arid tropics of Africa in the 1960's and 1970s (e g Norman, 1973), land constraints have increased in these zones formerly thought to be land-abundant (Matlon, 1990), factor and credit markets have structurally changed, and nonfarm activity by farm households has apparently greatly increased to the point where in Burkina Faso, for example, it constitutes about half of farm household incomes and four-fifths of cash incomes (Reardon et al , 1992) Moreover, farm households, especially in cash crop zones, have invested in agrarian capital formation, particularly in animal traction We posit that these changes should affect productivity across farm types and agroecological zones, and make two contributions to knowledge about determinants of agricultural productivity in Africa in this chapter

First, past studies in the West African semi-arid tropics (e g Barrett et al , 1982, and Jaeger and Matlon, 1990) have either used only one or two years of data, or one agroecological zone, or an aggregate crop category These have been instructive, but have not been able to inform the debate on intercrop differences, especially between cash and food crops, and on interzone differences, which is an important element of current debate on agricultural research strategy In this chapter, we use a four-year panel over three agroecological zones, in Burkina Faso, stretching from low to high potential areas, and differentiate among the main crops including the subsistence foodgrains, millet and sorghum, and cash crops, maize and cotton

Second, past farm-level productivity work in Africa tended to use exogenous sample stratification based on farm characteristics -- generally farm size, use of animal traction versus use of manual, i e handtool, technology, access to credit, use of new seed varieties, land tenure status, and income stratum In this chapter we follow past research by stratifying farm households according to use of animal traction (a factor we expect to have significant effects on structural production parameters) Our contribution relative to the approach taken in past studies, however, is to endogenously stratify the sample using a binary choice model, an approach rarely taken in productivity research (with a few recent exceptions such as Carter, 1989), and then estimate production functions, controlling for selectivity bias

This approach also allows us to test the (indirect) effect of nonfarm income on productivity

through its effect on technology choice embodied in agrarian capital acquisition The study of the effect of nonfarm income on capital acquisition is not absent in earlier work (e g Barrett et al , 1982, in eastern Burkina), but it has been relatively neglected in farm-level work, and generally neglected in aggregate-level research, because of the rarity of rural nonfarm income data Yet this intersectoral dimension is important. narrowly focusing farm productivity research on the farm sector means ignoring the context in which farm activities are inserted rural households, which are "multisectoral firms", husband resources over the year to produce a vector of farm and nonfarm outputs to maximize food security and income, and to manage risk. Off-farm uses of household resources can compete with cropping uses Yet off-farm income can also increase farm productivity by providing liquidity where access to input credit is limited (common in West African Semi-Arid Tropics, see Christensen, 1989) It can ease households' access to improved production technology, for example to the expensive animal traction package Since opportunities to generate income from non-farm activities are limited, we posit a positive effect for nonfarm income in investment of animal traction equipment in Burkina Modeling this effect in a selectivity framework allows nonfarm liquidity to enter the analysis without appearing directly in the production function, it makes more sense that it affect the choice of fixed inputs that in turn determine technology, rather than directly influencing output.

The chapter proceeds as follows In section (2), the model is discussed In section (3), selectivity regression results and marginal factor productivities are discussed

6.2 Model

6.2.1 Model structure

The purpose of the model is to explain productivity differences between farms and zones through the role of agrarian capital, animal traction in the present case

We start with a production function with the goal of estimating marginal productivities The production function is given in general form by

$$Q^i = F(X^i, Z^i), \quad i = 1, \quad ,n \tag{1}$$

where Q^i is the output of crop i using a vector of variable inputs X^i and fixed inputs Z^i

Estimation of (1) poses the problem of simultaneity bias if the variable inputs and the output levels are simultaneously determined (Marschak and Andrews, 1944) To eliminate this bias, we jointly estimate the production and the variable input demand functions The input demand functions are derived under the maintained hypothesis that farmers attempt to maximize the returns to the fixed factors, and are given in general form by

$$X_j^i = f^i(r_1/p_i, \ldots, r_m/p_i, Z_1^i, \ldots, Z_q^i), \quad (i=1,\ldots,n,\ j=1,\ldots,m) \tag{2}$$

where p_i is the price of output i, and r_j the market price of variable input j

We posit that one consequence of the use of animal traction is to modify the structural production parameters in a significant way Hence, we estimate (1) and (2) for two sub-samples AT and manual farmers Since AT ownership is likely to be dependent on household characteristics, the sample partitioning is made endogenous by explaining the choice of animal traction The framework of this model was developed in Chapter 4

6.2.2 Regression specification

The production function is chosen to be quadratic, a representation flexible up to the second order

$$\begin{aligned} Q_{ht}^i = a_0^i &+ \sum_{k=1}^{m} a_k^i X_{kht}^i + \sum_{l=1}^{q} c_l^i Z_{lht}^i + \frac{1}{2}\sum_{j}^{m}\sum_{k}^{m} b_{jk}^i X_{jht}^i X_{kht}^i \\ &+ \frac{1}{2}\sum_{k}^{m}\sum_{l}^{q} g_{kl}^i X_{kht}^i Z_{lht}^i + \frac{1}{2}\sum_{l}^{q}\sum_{r}^{q} d_{lr}^i Z_{lht}^i Z_{rht}^i + \epsilon_{ht}^i, \\ h &= 1, \ldots, N \quad t=1, \ldots, 5, \quad i=1, \ldots, 4 \end{aligned} \tag{3}$$

where i, h and t index respectively the crop, the household and the year, and j, k, l the inputs There are 4 crops (millet, sorghum, maize, and cotton) The variable inputs include labor and fertilizer, but in implementation, chemical fertilizer was treated as a fixed input because of non-varying prices over the period of observation The variable labor input is an aggregate of family and hired labor The Z-vector includes land, manure, rainfall, and toposequence as a proxy for land quality Manure was treated as a fixed factor because it was essentially a non marketed good

The estimating form of equation (2) was derived from the first order conditions of profit maximization using (4)

$$X^i_{Lht} = \frac{1}{b^i_{LL}}(-a^i_L + \frac{w_t}{p_u} - g^i_{LK}K^i_{ht} - g^i_{LF}F^i_{ht} - g^i_{LM}M^i_{ht}) + \mu^i_{ht} \qquad (5\text{-}4)$$

where L, K, F and M stand for labor, land, chemical fertilizer and manure Crop prices and farm labor wage are included in the price variable vector

The estimated parameter values of the technology choice model were used to compute the inverse Mills ratios M_1 and M_2 which were added as regressors in (3) and (4) The resulting system of equations was estimated for each subsample using full information maximum likelihood As the system is nonlinear in both the variables and the parameters (the derived input demand function is nonlinear in the structural parameters), only maximum likelihood estimators are known to be efficient.

All equations were estimated for each of the two zones (Guinean and Sudano-Sahelian) using the data described in chapters 3 and 4

6.3 RESULTS

6.3.1 The extent of selectivity bias

The inclusion of the Mills ratios in the regressions is intended to correct for selectivity bias due to endogenous sample selection The extent of bias due to selectivity is provided by the coefficients of the inverse Mills ratios The results are presented in table 1 These coefficients allow the formulation of counterfactual statements about households behavior were they to switch from one technology to the other (see e g Shehata, 1991)

All selection coefficients are negative (with the exception of the labor demand equation for millet in the Guinean zone), with half being significant. A negative selectivity parameter for manual households means that had these households rather chosen to use AT, they would be producing more and demanding more labor than the households presently using AT A negative term for the AT group on the other hand means that had these households chosen to use only manual techniques, they would be producing less and demanding less labor than the households presently using manual technology This would be the case ceteris paribus (i e equal access to land and other inputs)

Overall, the signs and magnitude of the selectivity terms provide a further justification for the use of an endogenous selection model in assessing the impact of technology on Sahel farm productivity To further validate the model, the Appendix presents the calculated predicted values of the labor demand and output levels together with actual values One notes that, apart from the labor demand for AT millet and the output and labor demand for manual maize, the predicted values do not differ markedly from the observed numbers

6.3.2 Marginal factor productivities

The parameter estimates of the production functions are shown in Table 6 2 These parameters are used to compute the marginal productivities to the fixed and variable inputs Marginal products are computed at the means of the variables, and are multiplied by the average output prices to obtain marginal value products for each zone To assess the significance of the marginal productivities, the standard errors of the production coefficients are used to compute standard errors for the marginal productivities

6.3.2.1 Sudano-Sahelian zone

The marginal value products, MVPs, of labor are significant (table 3) In both crops, in the traction group, the MVPs of labor exceed the average wage rate of 21 francs/hour, while those of the manual group are well below the wage This implies that animal traction makes labor more productive (twice so) but there is still an excess demand for it on traction farms, perhaps due to constraints in the labor market (e g, because of temporal covariance over farms in labor use) The labor MVPs are fairly close across crops in both groups, suggesting economic rationality in labor allocation

Traction households apply much more manure, especially on sorghum, as expected The productivity of manure on sorghum in the traction group is actually more than in the Guinean zone, but in neither zone is the effect of manure on sorghum statistically significant Very little fertilizer is used on either crop

The AVPs of labor are well above the MVPs for all crops (although they are relatively close for traction group sorghum) Note that this result is not imposed by model specification because concavity was not imposed This implies labor constraint Interestingly, although the traction group's MVPs of labor were much higher than manual group's, the AVPs of labor do not differ much between the two groups

In the Sudano-Sahelian zone, animal traction does not provide much advantage in land

productivity at the margin (on the extra hectare) in the same way that it provided extra productivity at the margin for labor The MVPs of land are relatively close over all crops except manual group millet which is somewhat higher Yet sorghum uses more labor per hectare than does millet, for both groups, and so the millet result is not due to more labor allocation to millet, nor to more fertilizer or manure application, but perhaps to millet better adaptation in the face of climatic stress common in this zone By contrast, the AVP of land is unambiguously higher for sorghum than for millet, explicable by the greater labor allocation (about 20 percent) to sorghum as compared to millet (beside more fertilizer and manure, albeit at a low level, also being applied to sorghum)

MVPs of land are well below AVPs of land for all but millet in the manual group, this makes sense in that there are limits to fertile land in this zone and much of the new land at the margin is more fragile and of lower quality -- an indication of a land constraint in this zone, corroborated for example by Matlon (1990)

6.3.2.2 Guinean zone

The marginal value products, MVPs, of labor are significant except that of maize in the manual group In the traction group, the MVPs of labor exceed the average wage rate of 28 francs/hour except in the case of maize where they are equal, this indicating a relative labor shortage Moreover, MVPs of labor of the traction group exceed those of the manual group, although they are relatively close for millet This implies that animal traction makes labor more productive especially in the labor-intensive crops As in the Sudano-Sahelian zone, there is an excess demand for labor on traction farms, again perhaps due to constraints in the labor market.

In the manual group, MVPs of labor are at (the case of millet and cotton) or below (for maize and sorghum) the wage rate This implies either excess supply of labor to these crops or a capital constraint to make own-labor more productive for maize and sorghum

The labor MVPs are fairly close across crops in the traction group, suggesting economic rationality in labor allocation, perhaps due to greater flexibility in resource use afforded by traction They are not close in the manual group (with millet and cotton close, but maize and sorghum substantially less than the level of the first pair) The average MVP for the traction group (32 francs/hour) is above that of the manual group (22 francs/hour), as traction is labor-augmenting Traction households also apply more manure Manure and labor have positive significant interaction effects in most of the estimated models Manure is mainly applied on the cash crops (cotton and maize) and has a particularly strong and

significant effect on cotton in the traction group, as shown in table 6 However, fertilizer MVPs results were positive but unfortunately the standard errors are high and thus the results not statistically significant

The AVPs of labor are about twice as high as the MVPs, again a result not imposed by model specification because concavity was not imposed But the average AVP for the traction group (71 francs/hour) exceeds that for the manual group (61), suggesting higher overall labor efficiency in labor-augmenting traction technology, as expected

The MVPs of land vary by the labor intensity of the crop For traction households, land MVPs of cotton and maize are higher than those of millet and sorghum The average MVP of cotton and maize is at least four times that of sorghum and millet This might reflect (a) farmers' practice of growing millet and sorghum on lower quality land, (b) much lower use of fertilizer, manure, and hired labor on millet and sorghum, and (c) possibly greater effort and management given to cash crops Thus, millet and sorghum appear to be treated as subsistence or "safety first" crops For manual households, the MVPs of land for cotton, maize, and sorghum are higher than that for millet, probably because millet is allocated poorer land In the manual group, millet, but in the traction group, both millet and sorghum, are allocated marginal, low quality land

The MVPs of land for the labor-intensive crops (cotton and maize) for the traction group is more than twice that of the manual group, given that labor and fertilizer use by both groups is similar for these two crops, the difference may be due to traction households' greater manure application, greater ability to crop more fertile (but heavier, clay soils), and general greater efficiency of land use

The AVPs of land again vary roughly according to labor intensity of the crop, with cotton and maize higher than sorghum and millet for traction households, and for manual households, maize is highest, followed by cotton then sorghum then millet For all households, the AVPs are close between the two cash crops and again between the two subsistence crops, but the average for cotton/maize far exceeds that of sorghum/millet

Table 6 1 Selectivity parameter estimates (standard errors in parentheses)

	In production functions (eq 5)		In labor demands (eq 6)	
	AT=1	AT=0	AT=1	AT=0
Guinean zone				
Millet	-337	-308*	-522*	58 5
	(412)	(131)	(318)	(166)
Sorghum	-44 2	-1700*	-174	-690*
	(235)	(546)	(157)	(252)
Maize	-105	-318*	-35 6	-186*
	(133)	(119)	(55 8)	(52 0)
Cotton	-403	-410	-426	-78 3
	(378)	(593)	(329)	(489)
Sudano-Sahelian zone				
Millet	-210	-753*	-322*	-743*
	(161)	(238)	(131)	(126)
Sorghum	-410*	-313*	-574*	-710*
	(248)	(169)	(147)	(150)

Parenthetical figures are standard errors An asterisk (*) denotes significance at the 10 percent, two-tailed level

For the interpretation of the results, note that the selectivity parameter is attached to a positive number for the AT regime and to a negative number for the manual regime

Table 6 2 Parameter estimates for production and labor demand functions
Guinean, AT sub-sample

	Millet		Sorghum		Maize		Cotton	
	Parameter	SE	Parameter	SE	Parameter	SE	Parameter	SE
Intercept	1522	907 2	499 5	1108	161 0	785 6	1788	3092
Labor	600	0807	0 617*	1440	9050*	1840	7795	1498
Labor squared	1839E-03	2860E-04	5385E-03	1078E-03	2197E-02	4896E-03	2010E-03	6015E-04
Labor*Land	0420	01476	2628	05928	9128*	2535	3750E-02	02898
Labor*Fertiliz			7772E-03	9593E-03	8124E-03	1791E-02	4850E-03	2919E-03
Labor*Manure	7844E-05	6668E-04	1859E-04	9206E-05	2647E-04	1339E-04	5776E-05	5247E-05
Land	52 19	146 1	-91 12	205 3	733 6	533 4	168 4	502 4
Fertilizer	22 57*	2 140	17 30	61 46	51 92	17 42	5 309	6 671
Manure	8536	8 256	7383	5394	1927	1417	3647	2834
Rainfall	1 946	9652	1394	1 473	1055	7879	1 998	4 053
Land squared	52 15	38 95	-60 44	65 47	84 63	77 08	263 3	148 8
Land*Fertilizer			3518	2 819	8148	5 521	0242	7804
Fert. squared			0814	3104	03328	0760	2549E-02	6760E-02
Manure squared	9393E-04	8572E-04	6792E-05	1070E-04	4301E06	1374E-05	4083E-05	5607E-05
Manure*Rain	571E-03	01054	8257	5730E-03	1715E-03	1387E-03	3487E-03	3758E-03
Fertiliz*Rain			01389	06456	05770	01850	4046E-02	8683E-02
TOPO	75 75	77 70	54 47	182 8	43 39	98 18	49 18	447 2
TOPO*Fertiliz			8654	10 56	2 694	1 287	3558	1 386
TOPO*Manure	07223	1 522	01346	0617	02212	01663	2421E-02	04652
Mills ratio								
in production f	336 7	411 7	-44 19	234 9	104 7	132 9	-403 2	378 1
in labor demand	521 7	318 0	173 6	157 0	35 46	55 82	-425 5	329 0
R-squared								
in production f	53		50		61		79	
in labor demand	16		75		64		15	

An asterisk (*) denotes significance at the 10 percent two-tailed level or below

Table 6 2 Cont d Parameter estimates for production and labor demand functions
Guinean, manual sub-sample

	Millet		Sorghum		Maize		Cotton	
	Parameter	SE	Parameter	SE	Parameter	SE	Parameter	SE
Intercept	183 9	269 5	232 1	1102	32 97	320 0	1035	1573
Labor	5387*	1118	4303	1176	4654	1412	4351	06300
Labor squared	1375E-02	2025E-03	6762E-03	1317E-03	4983E-02	1571E-02	2617E-03	6489E-04
Labor*Land	5752	1071	2961	06647	1 892	6077	1678	0469
Labor*Fertiliz					0251	9447E-02	3768E-03	4488E-03
Labor*Manure					1607E-03	7831E-04	5123E-05	1695E-04
Land	16 81	130 6	527 1	342 0	82 58	570 8	6853	462 0
Fertilizer	2 854	8 621	1 878	5 898	06650	63 65	7 526	9 135
Manure	0201	562 6	4621	7352	2610	2061	4891	1 406
Rainfall	1183	3208	4833	1 145	01807	3284	1 501	1 968
Land squared	106 8	104 3	225 8	144 4	154 7	157 4	17 12	342 5
Land*Fertiliz					22 60	35 65	4819	2 526
Fert. squared					02729	6957	3019E-02	01662
Manure squared					1506E-04	2306E-04	1038E-03	1748E-03
Manure*Rain					2606E-03	1903E-03	1461E-02	1793E-02
Fert *Manure					3995E-02	06770	0108	8135E-02
TOPO	24 64	38 94	65 15	114 0	2 296	20 24	45 05	191 1
TOPO*F					07289	5 533	1220	9921
TOPO*M					02923	01745	1406	1101
selection								
in production f	307 8	130 8	1699	545 7	318 3	118 7	-409 8	593 1
in labor demand	58 54	165 6	689 9*	252 1	186 1	51 99	78 35	488 7
R-squared								
in production f	62		41		70		78	
in labor demand	57		60		70		57	

An asterisk (*) denotes significance at the 10 percent, two-tailed level or below

Table 6 2 Cont d Parameter estimates for production and labor demand functions
Sudano-Sahelian zone

	AT sub-sample				Manual sub-sample			
	Millet		Sorghum		Millet		Sorghum	
	Param	SE	Param	SE	Parameter	SE	Parameter	SE
Intercept	2631	820 1	191 8	1322	1840	399 0	362 5	210 1
Labor	5750	1180	5849*	0922	4070*	05580	3386	02887
Labor squared	4255E-03	9168E-04	2879E-03	4770E-04	9988E-03	1320E-03	6089E-03	4982E-04
Labor*Land	1183	0207	1044	02004	2998	03997	2400	02553
Labor*Fertil	9921E-02	2517E-02	6387E-03	1936E-03			2038E-02	6970E-03
Labor*Manure	3272E-04	2215E-04	4511	1697E-04	7938E-04	2339	8180E-04	1647E-04
Land	145 0	77 81	170 1	154 1	179 0	75 77	19 45	81 05
Fertilizer	-60 45	75 98	34 30	20 80	1 198	7 717	11 90	9 283
Manure	3830	4453	3870	9961	6219	5653	1 557*	4887
Rainfall	7 132	1 182	7743	2 036	5 326	6989	8652	4180
Land squared	-48 23	9 906	24 90	26 07	88 45	17 06	17 45	24 19
Land*Fertiliz	1 496	2 390	1 861	8234			1 723	7707
Fert. squared	2150	4784	01617	0250			4125E-02	0364
Manure squared	3803E-06	3598E-04	9789E-04	6253E-04	9287E-05	5134E-04	1983E-04	3517E-04
Manure*Rain	9102E-03	5104E-03	1065E-03	1514E-02	1120E-02	9931E-03	2651E-02	6571E-03
Fert.*Rain	03956	07452	04567*	02722			03664	01523
TOPO	105 8	191 2	6 653	240 4	118 9	77 90	25 94	35 01
TOPO*F	8 590	24 95	5 508	4 012			2 156	2 499
TOPO*M	2691	1127	0165	2355	05930	0707	3777E-02	0823
SUDAN	1076	319 0	74 07	533 1	903 0	233 3	30 86	171 5
Selection								
in production f	210 4	160 8	-409 9*	248 4	753 1	238 3	313 3	168 6
in labor demand	322 3	130 6	574 2	147 4	743 0	126 4	710 0	150 2
R-squared								
in production f	60		65		62		75	
in labor demand	67		72		71		80	

An asterisk (*) denotes significance at the 10 percent, two-tailed level or below

Table 6 3 Marginal value products (evaluated at the sample averages of input use), Sudano-Sahelian

	AT households		Manual households	
	Sorghum	Millet	Sorghum	Millet
Labor, per hour	26 3*	28 6*	13 6*	13 6*
	(3 72)	(4 22)	(1 64)	(3 26)
Land, per ha	138	7940*	9130*	16330*
	(5800)	(2900)	(3490)	(3020)
Fertilizer, per kg	n a	n a	n a	n a
Manure, per kg	12 9	9 88	-17 2*	9 10
	(11 2)	(7 35)	(7 02)	(7 09)

An asterisk (*) denotes significance at the 10 percent, two-tailed level Standard error estimates are in parentheses

TABLE 6 4 Marginal value products (evaluated at the sample averages of input use), Guinean zone

	Animal traction households				Manual households			
	Cotton	Maize	Sorghum	Millet	Cotton	Maize	Sorghum	Millet
Labor, per hour	35 0*	28 4*	32 0	33 6*	28 6*	10 0	19 3*	28 8*
	(4 26)	(5 98)	(5 10)	(4 55)	(4 20)	(8 75)	(5 87)	(5 80)
Land, per ha	40040*	53800	10120*	5310	18440	15400	24670*	9230*
	(14400)	(30850)	(4950)	(5320)	(24900)	(27600)	(9080)	(5280)
Fertilizer, per kg	34 4	50 5	n a	n a	92 0	170	n a	n a
	(99 6)	(148)			(200)	(665)		
Manure, per kg	6 31*	0 450	4 80	n a	-26 3	0 840	n a	n a
	(2 96)	(0 855)	(3 37)		(18 5)	(2 11)		

An asterisk (*) denotes significance at the 10 percent, two tailed level Standard error estimates are in parentheses

Table 6 5 Observed and predicted means of labor demands (hours/household) stratified by crop, animal traction and zone

	Animal traction households		Manual households	
	Observed	Predicted[a]	Observed	Predicted[a]
Guinean zone				
Millet	874	1340	441	460
Sorghum	1740	1890	909	686
Maize	399	431	153	92 9
Cotton	2390	2770	1190	1160
Sudano-Sahelian zone				
Millet	1910	2240	1130	996
Sorghum	1640	2220	711	587

[a] Predicted values computed excluding the inverse Mills ratios

Table 6 6 Observed and predicted output means (kgs/household) stratified by crop, animal traction and zone

	Animal traction households		Manual households	
	Observed	Predicted[a]	Observed	Predicted[a]
Guinean zone				
Millet	670	968	321	222
Sorghum	1620	1660	925	376
Maize	536	629	199	96 3
Cotton	2780	3140	888	756
Sudano-Sahelian zone				
Millet	1190	1400	888	757
Sorghum	1050	1460	435	380

[a] Predicted values computed excluding the inverse Mills ratios

CHAPTER 7

MECHANIZATION AND SUPPLY RESPONSE and INPUT DEMAND

7.1. Introduction

In the last decade, policy reform and changes in the trade environment have led to change in agricultural prices in the Sahel as elsewhere in Africa. Yet export price increase without sufficient farm supply response at best reduces government deficits, but does not redress loss in export market share, or lead to improvement in the trade balance Grain farmgate price increase without sufficient farm supply response at most increases rural incomes but can reduce real consumer incomes in deficit rural areas and cities Thus, the long-term success of policy reform such as the recent devaluation in the Sahel will be conditioned by farmer supply response for export crops and foodgrains

While policy success depends on this responsiveness, relatively little empirical work has been done in the Sahel, or elsewhere in Africa, on responsiveness of individual crops or of aggregate output using farm-level panel data. Most work has been done using country-level series In Africa and the Sahel this has meant relative neglect of key non-price factors such as agroecological zone differences, and changes in infrastructure or technology that condition farmers' responsiveness to policy change (Ogbu and Gbetibouo 1990, Chhibber 1989) Moreover, these non-price factors can be primary "policy levers" to affect agriculture in an era when food markets have been liberalized and prices "freed", and in countries that are price-takers for export crops

This chapter examines supply response to price and nonprice factors by farms in three agroecological zones of Burkina Faso in the first half of the 1980s (5-year panel, 1981-1985) We use farm-level data for 150 farm households scattered over six villages We examine cotton (the major export cash crop), maize (a potential cash crop and "intensification" crop with good production-side prospects (Matlon 1990), millet, and sorghum (the main staple foodgrains)

Moreover, after Binswanger (1994) and Chhibber (1989), we recognize that a change in a farmgate price following policy reform (such as an increase in the cotton price following Sahel devaluation) could merely lead to a shift in crop mix rather than an increase in aggregate output -- hence, we also examine aggregate supply response The latter is relatively rare in farm-level studies in Africa

Finally, after Ogbu and Gbetibouo (1990) and Chhibber (1989) and Lele and Bindlish (1989), we recognize that nonprice factors increase in their importance as constraints to supply response the poorer

the income and infrastructure of a country Moreover, Ogbu and Gbetibouo note that these factors have been relatively neglected in African studies, and where they have they have not always targeted the most important constraints We expect, in particular, two sets of nonprice factors to be important in the Sahel, and highlight them in this work (1) agroecological differences (by zone), Matlon (1990) leads us to expect that responsiveness will be highest in the Guinean zone, the more-favored agroclimatic zone of the West African semi-arid tropics, with less response in the Sahelian and Sudanian zones, less-favored northern and middle zones, because more constrained agroclimatically (2) technology differences, specifically animal traction (AT) versus manual (hand-tool) technologies The latter has been studied with respect to yield effects (e g Barrett et al 1982, Jaeger and Matlon 1990) but has not been studied as to its effect on the supply responsiveness of farmers We hypothesize that its ability to increase the flexibility of factor allocation of farmers (e g in labor use for weeding and planting) means that farmers can change cultivated area or intensify cropping as economic incentives change Other nonprice variables that are examined in longer-series, aggregate level work, such as research and development change or infrastructure development, do not lend themselves to study with relatively short farm-level panel data

Our method is to derive supply response from the estimation of a restricted profit function This method has been only rarely applied in Africa at least using farm-level data, mainly due to data constraints (farm surveys are usually only a single year), with the recent exception of Adesina et al (1994) for rice farms in Cote d'Ivoire, focusing on landholding size differences We endogenously stratify the sample between AT and manual to compare responsiveness Comparison of technology groups using a profit function has not been undertaken in Africa, having been done only in Asia in Sidhu (1974) for tractorization

We proceed as follows Section 2 presents the conceptual framework, section 3, the model implementation, section 4, results on supply response, section 5, fertilizer use function results

7.2. Conceptual framework

This chapter models supply response in the framework of an endogenous sample partition along the lines discussed in chapter 4 Sample stratification is based on animal traction ownership, which we hypothesize as being an important determinant of supply response The model is made up of a system of input demand and output supply functions derived from a profit function, and a probit selection rule which endogenizes the sample partition into AT and manual households

7.2.1 Dual approach

We use a profit function approach to derive the estimating demand and supply functions It is known that under certain regularity conditions, the profit function (dual) is a sufficient statistic for the production function (primal) (e g Jorgenson and Lau, 1974) The maintained hypothesis in this study is that farmers attempt to maximize profit defined as the return to the variable factors, labor in the present case The restricted profit function (Lau, 1976) is defined as follows

$$\pi(p,z) = \underset{y}{Max}\{p.y|y \in T(z), z \in Z\} \tag{1}$$

where y is a vector of outputs ($y_i > 0$) and inputs ($y_i < 0$), p is a vector of output and input prices, z is a set of fixed or environmental factors and T summarizes the state of the technology constrained by z The elements in Z include, for instance, rainfall, fixed land endowment, government policy, these factors condition the level of profit which is attainable by farmers

As defined, the profit function is linearly-homogenous in prices For π to represent a competitive, profit maximizing behavior, further restrictions include strict convexity and second order differentiability If these conditions are met, the application of Hotelling's lemma yields the supply and input demand functions

$$\begin{aligned} y_i &= \frac{\partial \pi}{\partial p_i}, \quad i = output \\ -y_k &= \frac{\partial \pi}{\partial p_k}, \quad k = input \end{aligned} \tag{2}$$

These functions are homogenous of degree zero in prices following Euler's theorem Further, Young's theorem implies that the matrix of the partials of y with respect to p is symmetric

7.2.2 Functional form

The mathematical form of the profit function is chosen to be quadratic, a second order approximation to the true but unknown technology Using a four-vector output, one variable input and q fixed factors, the quadratic profit function is

$$\pi = \alpha_0 + \sum_{i=1}^{4} \alpha_i p_i + \alpha_w w + \sum_{r=1}^{q} \delta_r z_r + \frac{1}{2}\sum_{i=1}^{4}\sum_{j=1}^{4} \beta_{ij} p_i p_j + \frac{1}{2}\beta_{ww} w^2 + \sum_{i=1}^{i=4} \beta_{iw} p_i w + \sum_{r=1}^{q}\sum_{k=1}^{q} \phi_{rk} z_r z_k + \sum_{i=1}^{4}\sum_{r=1}^{q} \gamma_{ir} p_i z_r + \sum_{r=1}^{q} \gamma_{wr} w z_r \quad (3)$$

where w is the price of labor, the only variable input considered in this model

The features of the restricted quadratic profit function that make it a good candidate for modeling production are its self-duality and the linearity (in the parameters) of the derived supply and demand functions Self-duality implies that the production function consistent with the profit function is also quadratic (Lau, 1976 and Shumway, 1983) Using Hotelling's lemma, the output supply and input demand functions are as follows

$$\begin{aligned} y_i &= \alpha_i + \sum_j \beta_{ij} p_j + \beta_{iw} w + \sum_r \gamma_{ir} z_r \\ -L &= \alpha_w + \sum_j \beta_{wj} p_j + \beta_{ww} w + \sum_r \gamma_{wr} z_r \end{aligned} \quad (4)$$

where L is the variable input

Theoretically, these functions are homogenous of degree zero Unfortunately, and unlike competing systems such as the translog, the quadratic specification does not allow the testing of homogeneity through simple linear restrictions of the parameters Rather, homogeneity is often imposed by treating one output (input) as a numéraire and deflating other prices by the price of the numéraire (e g Huffman and Evenson, 1989, Shumway, 1983) The following symmetry restrictions hold for the profit maximizing farm, and can be tested or imposed in the estimation

$$\begin{aligned} &(1)\ \beta_{ij} = \beta_{ji},\ (i,j=1, \ ,4;\ i \neq j) \\ &(2)\ \beta_{iw} = \beta_{wi},\ (i=1, \ ,4) \end{aligned} \quad (5)$$

7.3. Model implementation

The model is estimated using the data described in chapters 2 and 3 Below, the variables and the econometric estimation issues are discussed

7.3.1 Variables

The output variables in system (3) are the three semi-subsistence foodcrops, sorghum, millet and maize, and the export cash crop, cotton These variables are measured as total production per farm household, in kilograms Output is aggregated over all fields and field-owning individuals in the household The variable input equation uses total household labor, i e family plus hired labor, as the dependant variable

The price vector involved on the right side of (3) includes the prices of the four outputs, and the wage rate In the profit function, the prices refer to expected prices For cotton, the price announced by the parastatal marketing company (SOFITEX) is used to represent the expected price by farmers The parastatal announces its price prior to planting and this price is usually realized at harvest The three food crops follow a different marketing channel Although official producer prices are announced by the food marketing board (Office National des Céréales), such prices are not effectively enforced as the Office's procurements are not sufficient to affect demand Therefore, the private market prices are best indicators of prices faced by the food crop producer One-year lagged market prices are used to model price expectations at the farm level

The fixed input variables in equation (3) (z-vector) include fertilizer, land, manure, and rainfall Although fertilizer appears a priori as a variable input, the parastatal marketing system kept its price nearly constant over the period of the analysis Land was measured as total hectares farmed by the household, including area under the control of the household head as well as individual household members' fields Manure was treated as a fixed factor as it was essentially a non-marketed good

The household characteristics contained in the H-vector used to model technology choice (equation 6) include nonfarm income, household size (measured as the number of adult labor equivalents), the age of the household head, a dummy for road access (near-to-surfaced road, far from), and two technical variables as proxies for land quality and land diversification Nonfarm income was measured as a cross-section exogenous variable, i e a constant average over the study period per household Because nonfarm income may also be affected by technology, a test of endogeneity was performed but failed to reject the null hypothesis of exogeneity

7.3.2 Econometric estimation

For estimation, additive error terms were appended to each equation in system (3) The inverse Mills ratios computed from the results of chapter 4 were added as regressors in the supply and demand

functions to correct for selectivity bias, and the models were estimated for each subsample Several issues related to proper estimation of the demand-supply model are discussed below

The theoretical model implies that the supply and demand equations are homogenous of degree zero and that the matrix of price parameters is symmetric The symmetry restrictions (5) were tested, using the Wald test which follows a chi-squared distribution under the null hypothesis Homogeneity was imposed by dividing all prices by the wage rate The resulting system was estimated without the labor demand equation The parameters of the price variables in this equation can however be recovered by using the parameter restrictions which result from homogeneity and symmetry

The error terms in the supply-demand system follow a SUR-type structure When cross-equations restrictions are imposed (such as the ones implied by symmetry), the efficiency of the parameter estimates can be improved by taking the cross-equation covariance matrix into account An iterative generalized least squares method was used in the estimation Because the added regressors (Mills ratios) were estimated, the resulting SUR-estimators are asymptotically efficient

7.4. Results

7.4.1 Supply response

The symmetry restrictions were tested first without homogeneity, and second with homogeneity imposed The first test led to the overall rejection of the null hypothesis that symmetry holds However with homogeneity imposed, the null hypothesis of symmetric parameters could not be rejected in the Guinean zone (for both AT and manual sub-samples) Symmetry was rejected in the Sudano-Sahelian zone in either specification (see Table 7 3 for the results) These test results support the hypothesis that farmers in the more commercial, cotton zone behave in a way more consistent with profit maximization than farmers in the more arid, more food-cropping oriented zones

Before discussing the results on supply response, we note that the coefficients of the selectivity variables are highly significant in the maize and cotton equations in the Guinean zone for AT households, and in the sorghum equation for the manual households In the Sudano-Sahelian zone, the selectivity parameter is significant for the millet and the sorghum equations among manual households, and for the sorghum equation for AT households Overall, these results further justify the need to correct for selectivity bias in the estimation on stratified samples, ignoring this correction would have induced bias in the estimated parameters

7.4.1.1 Own-price effect

The magnitude (and occasionally the sign) of price response varies between zones and between manual and AT farms In the Guinean zone, all price elasticities are positive except for maize (Table 7 4) The result for maize is surprising, but the coefficient is highly insignificant (see Table 7 3), suggesting a statistical lack of response

The own-price effect is highly significant for cotton in the Guinean model, and translates into a strong and positive response to price judging by the elasticity Note that over the study period, the cotton price increased from F CFA 55 to F CFA 89, with a mean of 68 5 (Table 7 1), providing enough variation for the proper identification of the price effects The response is larger for manual household (1 78) than for traction farmers (0 92) Although traction households may have the means to react in a more flexible way to economic incentives, the large difference in the average scale of operation between the two groups (the traction group produces three times more cotton per farm than the manual--Table 7 1) can account for the higher relative marginal response of the manual farms Using the elasticity and the results on quantities produced (Table 7 1), the absolute marginal response to a 10 percent cotton price increase is 256 kg for AT farmers and 158 kg for manual farmers The higher relative response of the manual farms also may be explained by the variation of the number of cotton growing farms 22 in 1982, 19 in 1983, 15 in 1984 and 18 in 1985 In contrast, the number of cotton growing farmers among AT households has fluctuated less 24 in 1982 and 1983, and 27 in both 1984 and 1985

In the Guinean zone, the two staple food crops, millet and sorghum, have positive but statistically non-significant response to own price Millet elasticities in both AT and manual groups are larger than sorghum The difference is particularly large in the traction group (2 14 for millet, 0 54 for sorghum), reflecting among other things the greater ease for animal traction farmers to bring into cultivation additional millet land in response to economic incentives such as price increases Sorghum land is more limited, and an increased supply would probably have to result from intensification

Results for the Sudano-Sahelian zone suggest that only sorghum in AT households has a positive (but not statistically-significant) supply response to own price Millet in the two groups, and sorghum in the manual group, have negative supply response These responses are statistically significant in the manual group but not in the traction group The negative responses in the manual group and the non-significant responses in the AT group may stem from the way farmers manage risk in an arid environment. Following a dry season (which implies high prices for the resulting crop), farmers plant less surface area. The sample results do seem to support this hypothesis, as total area planted by AT farmers increased from 7 71 ha in 1983 (a good year) to 8 98 ha in 1984 (a bad year) then decreased to

7 96 in 1985 (a good year) The same observation is true for manual farmers, whose response is however less sharp due to lesser adaptability (Table 7 5) The results thus seem to indicate that after controlling for structural and environmental factors including rainfall and land, prices have limited effect on AT farmers in the Sudano-Sahelian zone We used a Wald test to investigate the additional effect of prices in the AT group once these structural variables are in the equation The null hypothesis of this test is that prices are jointly non-significant, and it is distributed as a chi-squared with 2 degrees of freedom (there are two price terms in the Sudano-Sahelian model) The computed statistic of 8 56 rejects the null hypothesis Therefore, although prices are individually non-significant in the AT sub-sample, they do jointly contribute to shape supply response

7 4.1.2 Crop complementarity/substitutability

The cross-price elasticities indicate farmers' arbitrage between crops given a change in relative prices Of particular importance are the price relationships between cash and food crops in the Guinean zone Because symmetry was imposed (as a result of the test), the sign of the cross-price relationship between two crops is the same in either direction, and only the magnitude changes Thus, results show that cotton is a substitute with respect to millet and sorghum and a complement with respect to maize in the traction group, with results statistically significant When the price of cotton increases by 10 percent, the supply of millet and sorghum decreases by 22 9 and 9 6 percent respectively, while the supply of maize increases by 9 percent. The increase in the prices of the cereals has similar symmetric effects on cotton supply, with much lower magnitudes The results are compatible with the historically-observed complementarity between maize and cotton in the cotton zone of Burkina Cotton and maize are grown in rotation, with cotton benefitting from the organic matter generated by the maize residues, and maize benefitting from the residual chemical fertilizer applied on cotton Rotation involving cotton and sorghum is also recommended by agronomists, but this is generally not followed by farmers who find sorghum non profitable due to consumers preferences for other crops, and are ready to take land out of sorghum and into cotton or maize following good prospects on these markets The results also show complementarity between millet and sorghum, but show substitutability relationships between maize on one hand, and millet and sorghum on the other [8]

[8] The results of consumption studies in Burkina (Reardon, Thiombiano and Delgado, 1988) found substitution between maize and millet/sorghum, with an elasticity of 0 6 These consumption results have policy relevance as they point to the dilemma of enhancing the production of maize, a crop with better production prospects under moderate intensification than millet or sorghum To get the required

Complementarity relationships are all different for the manual group in the Guinean zone Here, all cereal crops are competing with cotton Thus, a 10 percent increase in the prices of millet, sorghum, and maize lower the output of cotton by 2 2, 8 6, and 2 4 percent, respectively On the other hand, a 10 percent increase in the price of cotton decreases the supply of millet, sorghum and maize by 6 7, 9 8, and 14 1 percent, respectively These results point to lower flexibility of manual farming The trade-offs between crops are clear, as technical factors do not allow a concomitant increase in the production of all crops following a change in relative prices In fact, only maize and sorghum are complementary for the manual group Supply response at the more aggregate level is addressed below

7.4.1.3 Non-price response

Table 7 6 presents the elasticities of supply with respect to non-price factors One observes important differences between zones but, in contrast with the effects of prices, the differences between manual and traction households are not in general very large

The household's total land area has a positive effect on the supply of most crops (except maize) in the two zones In the Guinean zone, the impact of an increase in farm size is strongest for millet, with an elasticity exceeding one for both AT and manual households This agrees with observed practice of the farming system, where area expansion is likely to involve marginal, less productive land which is usually allocated to millet. Farm expansion also benefits sorghum and cotton for the AT groups, and additionally maize for the manual group The smaller elasticity for cotton in the manual group (0 34 against 81) is compatible with a "safety-first" behavior in that group, where area extension aims first at guaranteeing food production. The negative and insignificant response for maize in the AT group suggests that over the period of analysis, maize benefitted little or not at all from farm area expansion In the Sudano-Sahelian zone, both millet and sorghum respond positively to area expansion, with elasticities ranging from 0 64 (sorghum in manual group) to 0 95 (millet in AT group)

The results for fertilizer conform to expectations in the Guinean zone The cotton parameters are highly significant for both AT and manual groups The parameter for maize is marginally significant (13% level) in the AT group, but negative in the manual group Cotton and maize are the main

---

substitution in production would require raising the maize price which may in turn drive down the consumption of maize, the 'food price dilemma' of Timmer There is hence a need to invest in key services (processing, transport) in order to simultaneously increase the profitability of maize to smallholders while making it affordable to consumers

beneficiaries of additional fertilizer, with elasticities of 0 55 and 0 84 for cotton in the AT and manual groups, and 0 34 for maize in the AT group The elasticities for millet are negative and significant in the Guinean zone, suggesting that millet does not benefit from fertilizer These results agree with the observed farming system, as they tend to indicate that when a farm acquires additional fertilizer, this is likely aimed at intensifying the production of the cash crops (cotton and, to some extent, maize) With other resources being limited (land, labor), there is a tradeoff which tends to lessen the relative importance of the foodcrops (sorghum and millet) The response of millet in the Sudano-Sahelian zone, and of sorghum in both zones, are economically insignificant (elasticities less than 0 1 in absolute value)

Manure use seems to benefit maize mostly, with elasticities of 0 30 and 0 24 in the traction and manual groups, in the Guinean zone Hypothetically, farmers who increase their use of manure are concentrating on maize production (agronomic results tend to support this) to the detriment of other crops However, cotton follows maize in the rotation system, and thus benefits from the residual effects of manure This may explain the positive but nonetheless non-significant cotton elasticity with respect to manure The effects of manure are economically insignificant in the Sudano-Sahelian zone, for both traction and manual groups (elasticities less than 0 1)

The impact of rainfall is, as expected, strongly positive for millet and sorghum in the Sudano-Sahelian zone, where water is a major constraint. Elasticities for millet exceed 3 and for sorghum 1 5 in the two sub-samples The marginal effect of rainfall is lower in the Guinean zone, where responses are negative for cotton in the AT group, and for millet and maize in the manual group The results tend to confirm that water is not the main constraint in agricultural production in the Guinean zone

The analyses show that both price and non-price factors contribute to affecting supply response in the two zones We did a Wald test to assess the relative importance of price vs non price-factors The null hypothesis that non-price factors do not have any additional impact (when the effects of prices are already taken into account) was overwhelmingly rejected, in all zones and for the two technologies The chi-squared statistics with 16 degrees of freedom were 327 and 382 for the AT and manual sub-samples in the Guinean zone, and 168 and 473 in the Sudano-Sahelian zone We also compared the relative contribution of the two groups of factors to the reduction of unexplained variance of the dependent variables The resulting R-squared statistics are presented in Table 7 7 The results show that on average, non-price factors contribute more to explaining the observed variations than do the price factors The most striking result is Guinean AT, where non-price factors account for 64 percent of the variance of cotton against 2 percent for the price factors This is not to be interpreted as prices being ineffective in shaping the response of cotton farmers The analysis of elasticities showed strong and

significant price elasticities for cotton What the result underscores is that beyond prices, other factors such as adequate fertilizer distribution policies are important in getting the expected increases in cotton production following the advent of economic incentive policies

7.4.1.4 Aggregate Supply response

The foregoing analyzed partial supply response, and suggests that the most commercial individual crops do respond to price incentives We further investigated the response of aggregate supply at the farm level. Knowing the response of aggregate supply is important, as this is what determines overall growth (Binswanger 1994)

A measure of aggregate output at the household level was obtained by deflating the total value of production by a weighted geometric price index One important policy question to examine is the reaction of aggregate farm level output to the change in the price of individual crops, for example, the cotton price increase from the recent devaluation of the franc CFA Aggregate output is regressed against individual crop prices along with the non-price factors The results are presented in Table 7 8

For Guinean zone AT farmers, the prices of cotton and maize have a positive (although not statistically-significant) impact on their aggregate output, with elasticities of 0 22 for cotton and 0 47 for maize This seems to indicate that the main commercial crops may contribute to increasing aggregate production in response to favorable price policies One notes that the response of aggregate production to the change in cotton or maize price is negative for the manual households, indicating that these crops do not play the role of "engine" crops for this group Rather, millet (with a significant coefficient) and sorghum are the leader crops there, with price elasticities of 0 83 and 0 12 Among the non-price factors, one notes the role of land for both AT and manual groups In the AT group, the land elasticity of aggregate response is 0 71 Thus, in relative terms, aggregate output goes up less quickly than total land, which is compatible with the hypothesis that area extension involves bringing into cultivation less productive land

Aggregate supply response results in the Sudano-Sahelian zone seem to indicate a positive impact of the millet price, and a negative impact of the sorghum price Price elasticities for millet are large for both AT and manual farmers Despite these statistically significant elasticities, one should be cautious about concluding that price policies in the more arid, Sudano-Sahelian zone could significantly enhance overall agricultural productivity The natural constraints (water, soil quality) will quickly overcome any attempt to raise productivity through some type of price policy (see Matlon, 1990) The results on land also tend to indicate that marginal land brought into cultivation is of lesser quality, as aggregate output

goes up more slowly than land area

7 5 Fertilizer demand

The fertilizer demand equation was not estimated in the framework of the present model due to insufficient fertilizer price variability However, beyond prices, many factors concur to determine farmers' demand for fertilizer The results below draw heavily on Reardon et al (1990) who stress the importance of non-price factors in fertilizer demand

Among non-price factors, cash income is hypothesized here to be a major determinant of the demand for fertilizer It is further hypothesized that there are separate effects on fertilizer purchase of cropping (grain sales) and non-farm incomes because the timing of income generation matters for the availability of liquidity to purchase inputs This is based on three factors (i) The timing of the income receipts from cropping and non-farm activities is different in Burkina (non-farm income is earned mainly in the post-harvest dry season, nearer to the moment of purchase of fertilizer at the end of the dry season, while most cropping income in the form of cash is earned during or right after harvest) (ii) Most household crop output is stored or home-consumed, and is only a minor source of cash (iii) The capital market is underdeveloped The latter point explains in part the role of non-farm income as already highlighted in chapter 4

The inclusion of income and capital assets in the fertilizer use function has been infrequent in the literature, especially for developing countries It began as a subject of controversy in the 1950's Timmer (1974) cites Griliches's (1959) argument that "there is no good theoretical reason for including income in the demand equation for a factor At least it is not derivable from the traditional theory of the firm" Timmer shows, however, that Griliches's point holds only for unconstrained profit maximization -- but not in the presence of a liquid capital constraint, which typifies situations where the capital market is underdeveloped, such as in the WASAT

Six groups for a total of 12 variables are hypothesized to determine the demand for fertilizer and manure income, assets, prices, risk, land quality and institutional factors The model is run for the Guinean and Sudanian samples, as little fertilizer is used in the Sahelian zone The results of the regressions are presented in table 7 9

One notes the insignificance of the price variable (the price of fertilizer deflated by the price of millet) in both the Sudanian and the Guinean zones Again, the low variability of the fertilizer price may explain this result The non-price variables on the other hand contribute much to explaining fertilizer demand

In the Sudanian Zone, the demand for chemical fertilizer is being positively driven by nonfarm income, cropping income, livestock, land area, manure used the previous season, and road proximity However, only the effects of nonfarm income and road proximity are statistically significant Fertilizer use is negatively driven by riskiness as measured by rainfall variability, with an insignificant coefficient Farms with soils of lesser quality seem to use more fertilizer, although the coefficient is not significant This would indicate the awareness of farmers of the land quality problems

In the Guinean zone, road access and area planted in cotton are the two positive factors of fertilizer demand The striking and interesting result is the lack of significance of nonfarm income This is compatible with the hypothesis that the capital constraint that exists for the case of animal traction adoption is overcome in the case of fertilizer Cotton growing farmers (i e more than two thirds of the sample) are able to obtain fertilizer via the cotton parastatal as a short term credit, unlike the case of longer term investments

Table 7 1 Sample means of the variables

	Guinean zone			Sudano-Sahelian zone		
	ALL	AT=1	AT=0	ALL	AT=1	AT=0
Output (kg)						
Millet	499	670	321		1,189	888
Sorghum	1,280	1,622	925		1,048	435
Maize	370	536	199		--	--
Cotton	1,852	2,783	888		--	--
Labor (hours)	4,068	5,399	2,690		3,653	1,886
Prices (F CFA/kg)						
Millet	63 6			71 0		
	(40-85)			(40-120)		
Sorghum	58 8			76 4		
	(40-81)			(40-108)		
Maize	52 5					
	(40-68)					
Cotton	68 5					
	(55-89)					
Wage rate (F CFA/hour)	25 9			21 5		
	(16-39)			(8-43)		
Fixed inputs/environment						
Land (ha)	6 1	8 3	3 9	5 7	7 9	4 2
Fertilizer (kg)	246 6	347 4	142 2	25 7	45 5	12 6
Manure (kg)	5,695 2	10,142 0	1,090 7	1,503 0	2,320 0	960 8
Rainfall (mm)	779 0		465 0			
Household characteristics						
Corrected size	10 4	13 6	7 0	8 2	11 5	6 0
Nonfarm income (F CFA)	326,110 0	456,170 0	191,450 0	113,160 0	154,380 0	85,836 0

Numbers in parentheses are the minimum and maximum sample values of the price variables

Table 7 2 Parameter estimates, symmetry and homogeneity imposed
a Guinean zone

	Millet		Sorghum		Maize		Cotton	
	Parameter	SE	Parameter	SE	Parameter	SE	Parameter	SE
AT sub-sample								
Constant	879 54	1221	895 70	1169	533 28	841 6	1094 1	1608
Price millet	553 32	397 3	118 29	240 4	5 7794	244 8	547 25	212 2
Price sorghum	118 29	240 4	360 33	275 8	177 48	264 1	556 23	187 2
Price maize	5 7794	244 8	177 48	264 1	3 6009	361 2	171 50	156 4
Price cotton	547 25*	212 2	556 23	187 2	171 50	156 4	918 18	273 9
Land	128 77*	27 95	114 63*	33 33	21 491	20 38	273 77*	47 22
Fertilizer	1 1561	0 4805	0 45032	0 5601	0 53140	0 3518	4 3918	0 79
Manure	0 71E-03	0 58E-02	0 025	0 70E-02	0 0159	0 44E-02	0 0051	0 0097
Rainfall	1 08	1 04	0 019	1 055	0 077	0 75	3 6398	1 443
Selectivity (M1)	162 31	161 8	135 46	193 8	292 18	118 0	722 64	274 7
R-squared	0 32		0 40		0 29		0 67	
Wald statistic[a] (Ho symmetry holds)	8 78 (df=6 p=0 19)							
Manual sub-sample								
Constant	47 124	543 5	832 58	742 7	290 93	355 3	953 36	707 4
Price millet	58 640	163 5	63 864	105 2	88 291	99 60	76 247	86 00
Price sorghum	-63 864	105 2	170 28	143 8	114 01	105 5	321 33	100 5
Price maize	88 291	99 60	114 01	105 5	48 387	145 1	99 089	65 66
Price cotton	76 247	86 00	321 33	100 5	99 089	65 66	558 65	125 0
Land	112 14	20 45	73 393	38 58	18 843	14 44	76 984	34 91
Fertilizer	0 36758	0 2752	0 61936	0 5132	-0 32884	0 1933	5 2202	0 4624
Manure	0 0023	0 018	0 -0045	0 0335	0 044	0 013	0 00436	0 030
Rainfall	0 0249	0 4641	0 15402	0 7055	0 070	0 3146	0 283	0 652
Selectivity (M2)	71 376	152 2	1601 3	287 3	338 71	108 0	547 28	261 4
R-squared	0 38		0 50		0 29		0 78	
Wald statistic[a] (Ho symmetry holds)	9 05 (df=6,p=0 17)							

Table 7 2 (Cont'd)
b Sudano-Sahelian zone

	AT sub-sample				Manual sub-sample			
	Millet		Sorghum		Millet		Sorghum	
	Parameter	SE	Parameter	SE	Parameter	SE	Parameter	SE
Constant	3032 9	562 0	2524 0	644 7	1745 9	227 5	1075 5	121 4
Price millet	7 2995	100 7	40 823	112 6	2731 4	866 1	1878 4	673 4
Price sorghum	40 823	112 6	156 00	154 7	1878 4	673 4	-403 76	714 2
Land	141 96	22 62	121 53	24 58	188 13	21 45	66 822	11 49
Fertilizer	0 34300	0 5975	0 34255	0 6488	2 2537*	1 361	1 9605	0 7266
Manure	0 043	0 028	0 0207	0 0307	0 064	0 029	0 020	0 016
Rainfall	8 6805*	0 9478	3 5084	1 033	5 8145*	0 5095	1 5578	0 2738
Sudan	2318 4	339 1	631 97*	390 7	1374 8*	261 0	-68 399	145 8
Selectivity (M1 M2)	57 632	133 7	322 64	144 9	365 21	229 6	559 77*	123 6
R-squared	0 56		0 52		0 57		0 67	
Wald statistic[a] (Ho symmetry holds)	8 42 (df=1 p=0 004)				29 89 (df=1 p=0 000)			

a The Wald test applies to the whole system of equations within any given sub-sample

Starred coefficients (*) are significant at least at the 10-percent, two-tailed level

Table 7 3 Price elasticities of supply

a Sudano Sahelian zone

	AT				Manual			
	Symmetry and homogeneity		Homogeneity without symmetry		Symmetry and homogeneity		Homogeneity without symmetry	
	Price millet	Price sorghum	Price millet	Price sorghum	Price millet	Price sorghum	Price millet	Price sorghum
Millet	0 03	0 15	0 97	1 35	0 84	0 61	1 00	1 75
Sorghum	0 17	0 67	1 35	0 76	1 18	0 27	1 87	0 79

Table 7 3 continued

b Guinean zone

	AT				Manual			
	Homogeneity and symmetry							
	Price Millet	Price sorghum	Price maize	Price cotton	Price millet	Price sorghum	Price maize	Price cotton
Millet	2 14	0 43	-0 02	-2 29	0 47	-0 47	0 59	-0 67
Sorghum	0 19	0 54	-0 23	-0 96	-0 18	0 44	-0 26	-0 98
Maize	-0 03	-0 80	-0 01	0 90	1 14	-1 36	0 52	-1 41
Cotton	-0 51	-0 48	0 13	0 92	-0 22	-0 86	-0 24	1 78
	Homogeneity without symmetry							
	Price millet	Price sorghum	Price maize	Price cotton	Price millet	Price sorghum	Price maize	Price cotton
Millet	1 77	-0 14	1 34	-2 66	0 94	-0 75	1 25	-1 42
Sorghum	-1 25	0 31	0 70	-0 61	-0 30	1 35	-1 04	-1 44
Maize	-1 65	-0 84	0 56	1 54	0 45	-0 61	0 01	-1 39
Cotton	- 88	-0 07	-0 28	1 16	0 77	-0 21	-1 07	1 33

Table 7 4 Annual change in area planted to sorghum and millet, Sudano-Sahelian zone

	AT sample			Manual sample		
Area (ha)	1983	1984	1985	1983	1984	1985
Millet	4 88	5 46	4 64	3 15	3 33	2 88
Sorghum	2 82	3 53	3 32	0 99	1 00	1 19
Total	7 71	8 98	7 96	4 15	4 33	4 07

Table 7 5 Elasticities of non-price factors

	AT sub-sample				Manual sub-sample			
	Land	Fertilizer	Manure	Rain	Land	Fertilizer	Manure	Rain
Guinean								
Millet	1 59	-0 60	0 011	1 27	1 38	-0 16	0 008	-0 06
Sorghum	0 58	0 096	0 16	0 009	0 31	0 095	-0 005	0 13
Maize	-0 33	0 34	0 30	0 11	0 37	-0 24	0 24	-0 27
Cotton	0 81	0 55	-0 018	-1 03	0 34	0 84	-0 005	0 25
Sudano-Sahelian								
Millet	0 95	-0 013	0 084	3 43	0 90	-0 032	0 069	3 02
Sorghum	0 92	0 015	0 046	1 57	0 65	0 056	0 044	1 65

Table 7 6 Relative contribution of price and non-price factors to the explanation of supply response, as indicated by R^2

	Guinean zone			Sudano-Sahelian zone		
	All factors	Non-price	Prices	All factors	Non-price	Prices
AT						
Millet	0 32	0 27	0 17	0 56	0 56	0 23
Sorghum	0 40	0 37	0 11	0 52	0 50	0 32
Maize	0 22	0 19	0 11			
Cotton	0 67	0 64	0 02			
Manual						
Millet	0 38	0 37	0 13	0 57	0 57	0 26
Sorghum	0 50	0 43	0 44	0 67	0 62	0 40
Maize	0 30	0 24	0 19			
Cotton	0 78	0 77	0 18			

Note Figures are coefficients of determination The results for prices are obtained with symmetry and homogeneity imposed Unconstrained R-squared values are larger

Table 7 7 Aggregate supply response estimates

	Guinean zone				Sudano Sahelian zone			
	AT		Manual		AT		Manual	
	Param	Elast	Param	Elast	Param	Elast	Param	Elast
INTERCEPT	2583 10		1789 60		-4412 00		3130 60	
	(1847)		(944 3)		(965 7)		(361 0)	
PRICE MILLET	-42 91	-0 49	30 41*	0 83	31 63*	0 97	24 45*	1 27
	(37 7)		(30 41)		(11 02)		(4 08)	
PRICE SORGHUM	-26 34	-0 28	4 56	0 12	32 10*	-1 06	22 56*	-1 26
	(65 7)		(32 0)		(12 87)		(4 77)	
PRICE MAIZE	49 86	0 47	23 36	0 53				
	(98 5)		(47 3)					
PRICE COTTON	18 17	0 22	-16 90	0 50				
	(41 0)		(19 9)					
LAND	477 05*	0 71	301 02*	0 51	258 81*	0 88	258 97*	0 80
	(68 0)		(58 4)		(36 6)		(21 62)	
FERTILIZER	4 93*	0 31	4 57*	0 28	0 03	0 00	0 06	0 00
	(1 2)		(0 79)		(0 95)		(1 34)	
MANURE	0 033	0 06	0 08	0 04	0 075*	0 08	0 08*	0 05
	(015)		(0 05)		(0 045)		(0 03)	
RAIN	3 61	-0 51	2 03	0 68	11 95*	2 40	8 46*	2 89
	(2 89)		(1 35)		(1 55)		(0 60)	
SUDAN					1107 90*		1432 50*	
					(354 4)		(143 7)	
M1, M2	317 07		2525 80*		-308 28		305 04	
	(387 4)		(437 2)		(216 6)		(230 9)	

Starred coefficients are significant at the 10 percent level or below

Table 7 8 Fertilizer demand equation estimates

	Sudanian		Guinean	
	Param	SE	Param	SE
P fert/P millet	147 09	146 8	8 82	70 74
Livestock	198E-03	17E-03	- 23E-03*	13E-03
Soil quality	-7 80	9 11	-1 58	8 03
Slope	-36 95	46.25	-9 86*	6 09
Food stock	10E-05	12E-04	72E-06	48E-05
Grain sales	42E-04	45E-04	- 186E-05	.205E-04
Log Nonfarm inc	6 62*	2 61	074	2 89
Land/AE	6 88	20 53	—	—
Risk	-418 39	350 8	227.54	196 2
Access	32 62*	7 63	8 39*	5 14
Manure use	066	054	012	008
Cotton area	—	—	.56*	33
Intercept	-205 47	154 0	-14 83	75 63
Sigma	22 38	2 53	—	—
R-squared			14	
Log-likelihood	-226 9			

Starred coefficients are significant at least at the 10 percent, two-tailed level.

In the Sudanian zone, a Tobit model was used to account for the many occurrences of zero values, often due to a problem of accessibility (see Chapter 1)

CHAPTER 8

SUMMARY AND POLICY IMPLICATIONS

8.1 Introduction

The physical, policy, and economic context in the West African semi-arid tropics (the WASAT) has changed radically from the 1960s-1970s (when the bulk of farm management studies were done) to the 1980s-1990s there has been rapid population growth, soil and natural resource degradation, declining rainfall, growing land constraints, structural adjustment programs, increased market involvement by farmers, diversification of farm household incomes into nonfarm activities, and mixed success of technology development

Moreover, there has been recent concern for stagnation of coarse grain and cash crop agriculture in the WASAT based on perceptions of low or declining agricultural productivity

The above changes and concerns point to the need to update our understanding of farm productivity in Africa To this end, and to support Development Fund for Africa objectives, AID/AFR/SD/PSGE/FSP has funded the present study in Burkina Faso, conducted by researchers from University of Ouagadougou and Michigan State University under its Michigan State University's Food Security II Cooperative Agreement with AID The overall study of farm productivity also includes case studies in Rwanda, Senegal, and Zimbabwe

Our objectives were to (1) "dig below" aggregate trends to uncover farm-level patterns in and determinants of (a) agricultural productivity, (b) crop supply response, (c) farm input demand, (2) examine how these determinants may vary by crop, agroecological zone, farm type, technology, and institutional/policy setting, (3) examine implications for strategy, policy, and programs to promote and sustain increases in agricultural productivity

8.2 Data and Methods

The study used detailed farm household data from an ICRISAT survey covering both farm and nonfarm activities of 150 households over four years (1981-1985) Having several years of survey data allows us to explore the effects of changes in prices and rainfall on productivity, supply, and input use, such variation is important in the semi-arid tropics, and data sets rarely cover more than one year and

thus allow exploration of these effects

The sample was distributed over three zones, the northwest, middle, and southwest, corresponding to the Sahelian, Sudanian, and Guinean agroclimatic zones

Our approach was as follows

First, we examined patterns in average land and labor products (over crops, animal traction versus manual farm types, zones, and years) Total factor productivity indices were calculated

Second, we explored determinants of crop productivity differences by computing marginal factor productivities over crops, farm types, and zones These figures were derived from production function coefficients

Third, we analyzed determinants of crop supply response and input demand using a profit function approach, using the same breakdown by crops, farm types, and zones

The factors examined were primarily physical production inputs -- variable inputs such as fertilizer and manure, and capital inputs such as animal traction equipment, as well as conditioning variables such as agroclimatic zone, household characteristics (e g , nonfarm income earned), supporting institutions and services (input supply infrastructure)

The study focuses on farm-level productivity Outside of our scope is the issue of how changes in farm-level productivity (and changes in policy to effect them) affect the rest of the economy

8.3 Characteristics of Burkinabe Agriculture and Aggregate Trends

Burkina agriculture is smallholder and rainfed, with a low average marketed surplus rate (around 10 percent), and important sales of cotton and livestock About half of rural incomes are now earned in nonfarm activities mainly connected upstream or downstream to agriculture, and in migration Grain imports are about a quarter of cereal consumption Cotton and livestock constitute about 60 percent of exports (they pay for the grain imports)

Growth in average land product (output per hectare) and average labor product (output per agricultural worker) was slow in Burkina Faso for most crops In general, average land product grew more quickly than average labor product, indicating increasing population density per square kilometer

Output of millet and sorghum (the main food crops) grew slowly, behind population growth, and average land product grew only around 1 percent yearly

Maize has bright production prospects but is still a minor part of food output, and its average land productivity is growing moderately, around 2 percent yearly

Output of cotton, the main cash crop, grew rapidly in the 1980s, as did its average land product, output growth has tapered off in the 1990s Area under cotton grew from 66,601 ha in 1973 to 74,948 ha in 1980 to 185,750 in 1991 to 176,900 ha in 1992, and average land productivity grew 3 8 percent yearly over 1961-1991

Pressure on arable land is already high in the unfavorable agroclimate zones (Sahelian and Sudanian zones) where two-thirds of the rural population lives, and moderate for now in the favorable agroclimate zone in the south (Guinean zone) But a World Bank study (Lallement 1990) shows that population is migrating quickly and pressure on land mounting in the south

Hence a major issue in Burkinabe agriculture is the need to move from "extensive" to "intensive" systems that involve much-increased land productivity through **sustainable intensification** as the "carrying capacity" of arable land is being undermined quickly by soil degradation and erosion of soil, soil conservation and water retention investments are needed (see e g Matlon and Adesina 1992, and Sanders et al 1994)

8 4 Our Findings Concerning Disaggregated Productivity Patterns

Among the coarse grains, maize has the highest average land productivity, followed by sorghum then millet The same pattern holds for labor productivity

The Guinean zone has from moderately to much higher (1 5-3 times) average land products than the other zones for all crops -- yet in good years millet yields, and to a lesser extent sorghum yields, can be similar across zones

Sorghum, maize, and cotton land and labor productivity are correlated with agroclimate (increase as go south), but the relationship is weaker for millet, especially in labor productivity, as it is relatively easy in the north to add land and thus protect labor yield (hence output per consumer)

Animal traction (AT) confers an advantage in land productivity in the case of maize and cotton in the Guinean zone, and a labor productivity advantage in cotton in the Guinean zone Cotton average land products on animal traction farms were 1 5 times those on manual farms

In general AT helps productivity in the case of crops that are relatively labor intensive

Land and labor yields fluctuate the most over years in the north, where rainfall fluctuates most For example, average land products changed sixfold between the good year of 1983 and the drought year of 1984 In general, maize land and labor productivity fluctuates more than that for the other crops because of its sensitivity to soil moisture This result points to the notorious riskiness of agriculture in

many areas, and to the sensitivity to beginning and ending points of longitudinal productivity analysis in WASAT

Labor yields tend to fluctuate more than land yields in the Sudanian and Guinean zones, partly because there appear to be land constraints (quality and quantity of land suitable to each type of crop), while this is not the case in the Sahelian zone where farmers can use more land (albeit of low quality) to augment labor

In the traction group, for both zones, the marginal value products of labor exceed the observed wage rates, suggesting a relative labor shortage

The marginal value products of labor for traction households exceed those for manual households, suggesting that animal traction makes labor more productive

In the traction group of the Guinean zone, the marginal value products of labor are almost equalized across crops, suggesting economic rationality in labor allocation This is not the case for manual farmers

In both zones, the average labor product is above the marginal labor product, again suggesting a labor constraint.

8.5 Determinants of Productivity General Findings

Our results reemphasized the importance of traditionally identified factors that determine productivity in farm management studies in the WASAT

- fertilizer
- manure
- animal traction

as well as land and labor But actual productivity effects varied substantially by location and farm household type Other country case studies also showed importance of access to improved seed (MSU studies of returns to agricultural research (Oehmke and Crawford, 1993) have also showed the pivotal role of effective seed distribution.)

Our study identified constraints on availability of fertilizer, equipment, operating capital, and good quality land. The study also showed unequal access to these inputs, and hence an unequal distribution of benefits from improved input use, partly because of unequal access to cash income (especially from nonfarm activities) and to credit.

Our study highlighted several determinants of productivity that have not traditionally been emphasized in Africa, that we believe are linked to the changes in the economic and physical context over the last few decades (discussed above) (1) nonfarm income generation often plays a key role in facilitating acquisition and use of productivity-enhancing inputs (2) market infrastructure, important to acquisition of inputs that drive productivity change

Other country case studies, whose results we feel are important for the Burkina case, but which our data did not allow us to confirm for Burkina Faso, highlighted the role of natural resource conservation in improving farm-level productivity Conversely, improving farm productivity helps conserve resources

8 6. Impacts of input use on productivity -- and patterns and determinants of input use

8.6.1 Fertilizer

We found fertilizer to have a positive impact on land productivity, but noise in the data appears to be the cause of its statistical insignificance Below we note that we found it an important determinant of output

Fertilizer use in Sub-Saharan Africa is low compared to world standards (9 kgs/ha in 1985 versus 58 5 in all LDCs) In Burkina (i) virtually no fertilizer was used in the Sahelian zone, (ii) an average of 11 kgs/ha in the Sudanian zone, and (iii) 39 kgs/ha in the Guinean zone

Availability and affordability are key issues in the use of fertilizer, in particular in the non-cotton areas Unfortunately, this is also where land is degraded and needs fertilization

Use varies alot over crops In the Guinean zone, use on cotton was 109 kgs/ha, followed by 46 kgs/ha on maize, and less than 5 kgs/ha on millet/sorghum

Fertilizer use is positively related to nonfarm income and accessibility as indicated by the proximity to a road in the Sudanian zone -- but not in the Guinean zone where the presence of SOFITEX (the cotton parastatal) makes fertilizer available to farmers regardless of village location and household cash sources

The elimination of credit and fertilizer subsidies and a switch from government to private sector distribution (reducing the area served), often associated with structural adjustment programs, have had a negative impact on fertilizer use, at least during the period of gradual removal of the subsidy, 1983-1987 Use has picked up again thereafter due apparently to intensification strategies on waning land of sufficient quality.

Hence, greatest fertilizer use (well above the African average) was in higher rainfall areas and on cash crops, where distribution, credit, and marketing/credit recovery were handled by a parastatal, or where households had more nonfarm income

8.6.2 Manure

Soils in Burkina Faso are known for their low organic matter content Soil amendment with manure and compost is needed to slow soil acidification

We found (1) manure increases land productivity of cotton and maize, (2) use of manure increases the output of maize, for both AT and manual farmers, in the Guinean zone, (3) cotton benefits from residual effects due to the rotation with maize

Manure use overall was only 150 kgs/ha in the Sahelian zone, then 411 in the Sudanian, and 995 in the Guinean zone In the Guinean zone, maize gets most manure (7384 kgs/ha) then cotton (1314) then sorghum (427) then millet (155)

8.6.3 Animal traction

In Africa, the main effect of AT shown to date has been to reduce field labor inputs and aid area expansion (especially on light soils), rather than to increase yields

We found AT have the following effects (relative to use of manual technology) (1) AT strongly improved land and labor productivity on cotton, and on labor productivity in millet, in the Guinean zone, (2) AT farms had greater supply responsiveness to price and nonprice incentives, (3) AT farms were more efficient in resource allocation, (4) AT farms used much more manure, (5) AT farms grew much more cotton, (6) AT farms were much bigger, (7) AT farms used only slightly less labor per hectare (overall)

The portion of households in the study zones that used AT in the study period was 9 percent in the Sahelian, 14 percent in the Sudanian, and 19 percent in the Guinean zone

Nonfarm income and farm size were important determinants of adoption of AT Nonfarm income (controlling for farm size) was particularly important in the Guinean zone, as credit was not generally available for it so the household's own liquidity sources -- mainly nonfarm income -- was crucial to that investment.

8.6.4 Land and labor

An increase in total farm land size has positive effects for all crops, with the bigger effect

accruing to millet which is the main beneficiary of land expansion

Wage increase decreases overall labor demand -- as off-farm opportunities increase, we expect that this will bid up farm wages, but with a land constraint, there will be a need for agrarian capital formation, mainly in form of AT investment

8 6 5 Nonfarm income

Nonfarm income can increase purchased input use or capital investments (thereby increasing productivity) where credit is unavailable or costly to use, or where other sources of cash income for loan repayment are lacking

Nonfarm activities smooth household income and help to reduce risk by diversifying the sources of household income

Within a given agroecological zone, the poor have less access to nonfarm income opportunities -- nonfarm income tends to make up a smaller share of total income for poor than for rich households, poor households are less able than rich households to participate in high-return nonfarm activities

There is generally a positive relationship between nonfarm income and improved input use (fertilizer in the Sudanian zone (where SOFITEX is not present to make it available to households regardless of their own-liquidity sources, and animal traction in the Guinean zone)

The combination of the above two points is worrisome because unequal access to nonfarm income translates into unequal access to farm inputs in the face of limited credit access

8.7 Determinants of Output Supply

8 7 1 Prices

The panel data allowed the isolation of the effects of prices on supply response The effects of prices are reinforced by those of non-price factors We found in general that (1) aggregate output responds positively to increases in the price of commercialized crops (cotton and maize) among AT households in the zone with the most favorable agroclimate, the Guinean zone -- thus averting the fear that price increases only lead to crop mix shifts (2) In response to policies increasing price to the farmer, cotton in the Guinean zone responded strongly to own price over the period of analysis A 10 percent increase in price led to the increase of supply by 256 kg for AT and 158 kg for manual farmers, from the mean (3) Millet and sorghum respond positively to own price changes, in the Guinean zone, with the response of millet larger, reflecting a land and/or an outlet constraint to expanding sorghum production

For the AT group, in the Guinean zone, we found (1) there is a complementarity, not a substitution in price between cotton and maize, reflecting cultural practices which rotate cotton and maize (2) Cotton is a substitute in price for the traditional cereals, millet and sorghum (3) For the manual group, in the Guinean zone, all cereal crops are in competition with cotton, reflecting a lower flexibility than AT households to reallocate resources to raise outputs simultaneously (4) The effects of prices are more limited in the less favorable Sudano-Sahelian zone, where only sorghum responds positively to own price, for the traction group

8.7.2 Fertilizer

An increase in the amount of fertilizer used by the households is associated with an increase in the output of cotton, in the Guinean zone, for both AT and manual farms Fertilizer has a positive effect on the output of maize for the traction households

8.7.3 Animal traction

Animal traction households had greater supply responsiveness to price

8.7.4 Markets

Well-functioning input and output markets facilitate the acquisition and use of productivity-increasing inputs by making inputs and market outlets available, and by reducing transactions costs and risks (e g , from imperfect information, or price volatility due to a thin market) Vertical integration and coordination functions (input supply, credit, output marketing) were assured effectively by a parastatal for cotton (This result coincides with Lele et al 1989

8.8 Relation of output supply and productivity

Incentive policies that increase cotton and maize production increase the output of crops that have higher land productivity – and thus are appropriate where land constraints are growing such as in the Guinean zone.

8.9 Modeling/theoretical findings

Modeling productivity and supply response in the context of an endogenous selectivity approach was shown to be appropriate in capturing the differences between traction and non-traction households and providing better parameter estimates than the use of an exogenous partition based on the usual

dummy variables approach

It is important for farm productivity analyses to incorporate directly or indirectly intersectoral effects (effects of nonfarm income) on investment and in turn on productivity

8 10 STRATEGIC, POLICY, AND PROGRAM IMPLICATIONS

1 **Sustainable intensification of farm production through use of improved inputs that raise and sustain increases in land productivity is a major food security issue in Burkina Faso,** given growing land constraints and soil degradation To get needed breakthroughs in farm productivity, farm input use -- such as fertilizer, organic inputs, animal traction, and conservation investments -- needs to rise substantially

In general we show that key elements of raising land productivity (and labor productivity) are fertilizer, manure, and animal traction These are especially useful in increasing yields in maize and cotton, which are the key crops that can usher in the new era of intensification of cropping and increase of yields The problem is that fertilizer, animal traction, and manure use are well below desirable levels and policies and programs need, even in this era of tight budgets, to encourage and enable farmers to use more of these inputs

2 **Strategies to raise farm productivity will need to differ, however, between favorable and unfavorable agroclimatic zones** With proper conditions, much increased productivity can be expected in the favorable zones (mainly the Guinean zone) Expectations for cropping intensification are more modest for the agroclimatically unfavorable and fragile zones (the Sahelian and Sudanian), and attention will need to be paid to alternative income sources off-farm in the latter zones This will promote food security in the agroclimatically unfavorable zones and increase effective demand for agricultural products from favorable zones

3 **Off-farm employment and the farm productivity agendas are linked. In many areas off-farm income is a critical means to pay for farm inputs and investments** Moreover, much of the growth of nonfarm activity is linked to growth of farm output Growth in off-farm employment opportunities in rural areas is essential to achieving food security and economic transformation in Burkina Faso

The liquidity constraint suggested by the significance of nonfarm income in farmers' decision must be addressed either through an appropriate credit policy, and/or through policies aimed at

developing income generating activities in rural areas The World Bank has already engaged in such activities in its food security component of the agricultural sector adjustment program in Burkina
But we worry about the long-term distributional effects of the importance of nonfarm income on productivity, particularly as we found that nonfarm income is not equitably distributed over households Programs that increase access to these sources of income are thus expected to in turn increase access to farm modern inputs by the poor

There are two implications of the importance of nonfarm income in the productivity equation

- Micro-enterprise promotion programs that provide rural employment while reducing the cost of farm inputs and increasing the off-farm multipliers from farm output growth are desirable
- New cropping technology proposed for farmer adoption must not only be financially and economically profitable, but also attractive relative to alternative uses of household resources (e g , livestock and nonfarm production)

4 Cash cropping programs spur productivity through providing cash to buy improved inputs, and depending on how they are organized, increase access from the supply side to improved inputs and to low-risk output marketing opportunities

When the technical conditions allow, the main cash crop (cotton) and the most productive food crop (maize) are complements not competitors (in cross-price terms), which runs counter to pessimism about cash cropping eroding food crop agriculture With appropriate technologies (animal traction) and incentives (guaranteed markets for the cash crop and strong support for maize) farmers in the Southwest of Burkina have expanded their cultivation of both cotton and maize This coincides with similar farm-level findings of complementarity in Mali (Dione 1989)

5 Sahel farmers respond to market mechanisms, but only on the condition that there is a propitious set of technologies, institutions, and physical conditions The institutional setting and policies appear to have promoted agricultural growth during the first half of the 1980s in Burkina, the government had placed greater emphasis on promoting the rural sector through incentive cotton prices (as well as rural organization and water retention technology development, not explored here) These policies appear to have contributed to agriculture performance above the norm during a time when other African countries in the semi-arid zone had negative agricultural growth

For policies such as the devaluation of the Franc CFA to have a positive impact on cash crop and aggregate supply response, policymakers should not ignore but rather reinforce sectoral programs such

as animal traction development and fertilizer distribution

6 **Animal traction programs are very important for Burkina Faso** -- in the 1960s and early 1970s, inexpensive packages were offered to farmers in a promotion program but adoption rates was low Since the cotton boom of the 1980s there appears to be much higher demand by farmers, but there are demand-side constraints (cash and credit constraints) to obtaining equipment Programs that make the equipment available widely and cheaply will help Rather than viewing AT as just a way to clear more land, we have underscored its role in raising land yields especially for cash crops in the southern zones As farm wages are bid up by increasing off-farm opportunities, and as land constraints increase, we expect agrarian capital formation to play an increasingly important role in intensification that is both labor and land saving

7 **Fertilizer was found to be important. Reduction of the fertilizer subsidy over the 1980s coincided with a decrease in its use. But fiscal constraints prohibit return to the days of massive fertilizer subsidies.** We need to seek a middle path, where programs and policies address the need to get fertilizer cheaper to farmers A key way to do this is to press hard on transport costs and the quantity/quality of rural infrastructure For example, the Premier Ministere (1993) study of potential impacts of devaluation shows that we can greatly lower fertilizer costs through improving the transport system and infrastructure

This middle path implies substantial public and private investment in agricultural research, human capital, and production and market infrastructure Policy reform alone (exchange and interest rate policy, market liberalization, privatization), while important, is not sufficient to spur higher agricultural productivity, resource, technology, and market constraints on agricultural growth must be tackled directly by allocating government and donor resources to overcoming them

Public investment should be such that it complements and spurs private investment on-farm, in the input distribution system, and in primary product processing It is essential that government and donors invest in understanding how to promote the economic use of the tools of sustainable intensification -- fertilizer, animal traction, organic inputs, and soil conservation investments

Thus the debate should be reopened on identifying cost-effective ways of increasing access to inputs, by improving the delivery of inputs and giving farmers the means to pay for them This effort is especially appropriate in West Africa FCFA zone whose macroeconomic environment has become more favorable through structural adjustment This should be a priority policy issue in the 1990s and beyond

REFERENCES

Adesina, A.A., K.K. Djato, and J.H. Pegatienan "Relative Efficiency of Rice Farms in Northern Cote d'Ivoire: Profit Function Analysis", mimeo, Selected Paper for the Annual Meeting of the American Association of Agricultural Economists, 7-10 August, 1994, San Diego.

Ball, E. "Output, Input, and Productivity Measurement in U.S Agriculture, 1948-1979", American Journal of Agricultural Economics, 67:475-486, 1985.

Barrett, V., G. Lassiter, D. Wilcock, D. Baker, and E. Crawford, Animal traction in Eastern Upper Volta: A Technical, Economic, and Institutional Analysis, Michigan State University International Development Paper No. 4, 1982.

Binswanger, H.P. "Determinants of Agricultural Supply and Adjustment Policies", in F. Heidhues and B. Knerr (eds.) Food and Agricultural Policies Under Structural Adjustment, Proceedings, Sept. 21-25, 1992, Hohenheim, Germany; 29th Seminar of the European Association of Agricultural Economics, Frankfurt: Peter Lang. 1994

Binswanger, H. and Pingali, P. "Technological Priorities for Farming in Sub-Saharan Africa", Research Observer, no. 1, World Bank January 1988.

Bourque, L., and Gagnon, J.-P., Statistiques Utiles Pour L'élaboration de Stratégies et de Politiques Alimentaires au Sahelian, Série Dossiers no. 5, Dec. 1988.

Bumb, B.L., "Fertilizer supply in Sub-Saharan Africa -- an analysis", in T.B. Tshibaka and C.A. Baanante (Editors), Workshop Proceedings, Fertilizer Policy in Tropical Africa, April 1988, Lomé, Togo. IFDC and IFPRI, 1988.

Carter, M.R., "The Impact of Credit on Peasant Productivity and Differentiation in Nicaragua", Journal of Development Economics 31:13-36. 1989

Chambers, R.G. Applied Production Analysis: A Dual Approach, Cambridge Univ. Press, 1988.

Chhibber, A., "The Aggregate Supply Response: A Survey", in S. Commander (ed.) Structural Adjustment and Agriculture: Theory & Practice in Africa and Latin America, Overseas Development Institute, London. 1989

Christensen, G., "Determinants of private investment in rural Burkina Faso", Ph.D. dissertation, Cornell University. 1989

Christensen, L.R. and D.W. Jorgenson,"U.S. Real Product and Real

Factor Input 1929-1967", Review of Income and Wealth, vol 16, no. 1, pp. 19-50. 1970

Clay, C. and T. Reardon, "Determinants of Farm-level Conservation Investments in Rwanda", in IAAE Occasional Paper no. 7. Contributed Paper for IAAE 22nd Congress (International association of agricultural economists) August 1994 in Harare

Cleaver, K.M., "A Strategy to Develop Agriculture in Sub-Saharan Africa and a Focus for the World Bank", World Bank Technical Paper No. 203. Washington, D.C.: World Bank. 1993

Diewert, W.E. "Exact and Superlative Index Numbers", Journal of Econometrics, 4:115-145, 1976

Dione, J. "Informing Food Security Policy in Mali: Interactions Between Technology, Institutions, and Market Reforms", Ph.D. Thesis, Michigan State University. 1989

Economist Intelligence Unit. Togo, Niger, Benin, Burkina. Country Report No. 3, 1994.

Economist Intelligence Unit. Togo, Niger, Benin, Burkina. Country Report No. 1, 1992.

Eicher, C.K. and D. Baker, "Research on Agricultural Development in Sub-Saharan Africa: A Critical Survey," MSU International Development Paper No. 1, 1982.

Ghai, D., and Radwan, S. (eds.) Agrarian Policies and Rural Poverty in Africa, ILO, Geneva, 1983.

Heckman, J. "Sample Selection Bias as a Specification Error", Econometrica 52(3):542-562. 1979

Higgins, G.M., Kassam, A.H, and Naiken, L., Potential Population Supporting Capacities of Lands in the Developing World. Technical Report of Project INT/75/P13. Rome: FAO. 1982

Hill, P. Dry Grain Farming Families, Cambridge University Press, 1982.

Hopkins, J. and T. Reardon. "Agricultural Price Policy Reform Impacts and Food Aid Targeting in Niger", Final Report submitted to USAID/Niger, April 1993.

Huffman, W.E. and R.E. Evenson, "Supply and Demand Functions for Multiproduct U.S. Cash Grain Farms: Biases Caused by Research and Other Policies", *American Journal of Agricultural Economics*, Vol. 71:761-773. 1989

International Fertilizer Development Center (IFDC), "Demande,

approvisionnement et commercialisation des engrais au Burkina Faso" IFDC-Afrique, Lomé, Togo. 1991

Jaeger, W. and P.J. Matlon, "Utilization, Profitability, and the Adoption of Animal Draft Power in West Africa", American Journal of Agricultural Economics, Vol. 72:35-48. 1990

Jorgenson, D.W. and L J. Lau, "Duality of Technology and Economic Behaviour", Review of Economic Studies, 41 (181-200). 1974

Kelly, V., T. Reardon, A. A. Fall, B. Diagana, L. McNeilly. "Final Report of IFPRI/ISRA Project on Consumption and Supply Impacts of Agricultural Price Policies in Senegal", December 1992.

Lallement, D., "Burkina Faso: Towards achieving food security", Agricultural Operations, Sahelian Department, Africa Region, draft (Washington: World Bank, 1990).

Lau, L.J., "A Characterization of the Normalized Restricted Profit Function", Journal of Economic Theory, 12 (131-163). 1976

Lele, U. and V. Bindlish, "How Important are the Relative Effects of Economy-wide and Sector-specific Policies in Explaining the Supply Response of Nigerian Agriculture?", The World Bank: MADIA Study. 1989

Lele, U., Stone, S., "Population Pressure, the Environment and Agricultural Intensification: Variations on the Boserup Hypothesis," MADIA Discussion Paper No. 4, World Bank, Washington, D.C. 1989

Lele, U., N. van de Walle, and M. Gbetibouo, Cotton in Africa: An analysis of differences in performance. MADIA Working Paper. Washington, D.C. World Bank. 1989.

Loveridge, S. "Les sources de revenu des ménages agricoles rwandais, les exportations et leur impact sur la disponibilité alimentaire en milieu rural (année agricole 1990), Publication DSA, no. 37, Ministere de l'Agriculture et de l'Elevage, Division des Statistiques Agricoles, July 1992.

Low, A. Agricultural Development in Southern Africa: Farm-household Economics and the Food Crisis. London: James Curry, 1986.

Marschak, J., and W.H. Andrews, "Random Simultaneous Equations and the Theory of Production", Econometrica 12: 143-206. 1944

Matlon, P.J., Income Distribution Among Farmers in Northern Nigeria: Empirical Results and Policy Implications. African Rural Economy Paper no. 18, Michigan State University. 1979

Matlon, P.J., "Improving Productivity in Sorghum and Pearl Millet in Semi-Arid Africa", Food Research Institute Studies Bulletin, Vol. XXII, No 1. 1990

Matlon, P.J., "The West African Semiarid Tropics", in Mellor, Delgado, and Blackie (eds), Accelerating Food Production in Sub-Saharan Africa, Johns Hopkins University Press. 1987

Matlon, P.J., The ICRISAT Burkina Faso Farm-Level Studies: Survey Methods and Data Files, ICRISAT, August 1988.

Matlon, P. and Adesina, A., "Agricultural Growth and Sustainability -- Prospects for Semi-Arid West Africa", in Vosti and Reardon (editors) Agricultural Sustainability, Growth, and Poverty Alleviation: Issues and Policies, 1994 manuscript; forthcoming, Johns Hopkins University Press.

McMillan, D. E., J. B. Nana and K. Savadogo, "Settlement and development in the River Blindness Control Zone. Case study: Burkina Faso". Technical Paper No. 200. World Bank. Washington, D. C. 1993

Norman, D.W., "Economic analysis of agricultural production and labor utilization among the Hausa in the North of Nigeria", African Rural Employment Paper No. 4, Dept. of Agricultural Economics, Michigan, State University, January. 1973

Norman, D.W., Newman, M.D., and Ouedraogo, I., Farm and Village Production Systems in the Semi-Arid Tropics of West Africa· An Interpretive Review of Research. ICRISAT, Research Bulletin No. 4, Vol. 1, October 1981.

Ogbu, O.M. and M. Gbetibouo, "Agricultural Supply Response in Sub-Saharan Africa: A Critical Review of the Literature", African Development Review, Vol. 2, no. 2, December. 1990

Ohm, H. and Nagy, J. (eds.), Appropriate Technologies for Farmers in Semi-Arid West Africa, Purdue University. 1985

Ouedraogo, I., "A Socioeconomic Analysis of Farmers' Food Grain Marketing Linkages and Behavior in Eastern Upper Volta", Ph.D. Thesis, (Michigan State University, 1983).

Place, F. and P. Hazell, "Productivity effects of indigenous land tenure systems in Sub-Saharan Africa," American Journal of Agricultural Economics, 75 (February): 10-19, 1993.

Poirier, D. J., "A Switching Simultaneous Equations Model for Physician Behavior in Ontario", in C.F. Manski and D. McFadden (eds.), Structural Analysis of Discrete Data with Econometric Applications. MIT Press, Cambridge. 1981

Premier Ministère, "L'impact probable de la dévaluation du Franc CFA sur l'économie du Burkina", mimeo, Ouagadougou, Burkina Faso. December 1993.

Prudencio, Y.C. "A Village Study of Soil Fertility Management and Food Crop Production in Upper Volta - Technical and Economic Analysis", unpublished Ph.D Thesis, University of Arizona, 1983.

Reardon, T. "Rural Household Consumption and Production Structures: Influences on Rural Consumption Survey Methodology", mimeo for IFPRI Coarse Grains Project Second Workshop, June 26, 1985, Ouagadougou.

Reardon, T., C. Delgado and P. Matlon, "Determinants and Effects of Income Diversification Amongst Farm Households in Burkina Faso", Journal of Development Studies, 28 (January): 264-296. 1992

Reardon, T., C. Delgado, and P. Matlon. "Farmer Marketing and the Composition of Cereals Consumption in Burkina Faso", IFPRI/ISRA Conference on Cereal Substition in West Africa, Dakar, July 1987, mimeo.

Rivers, D. and Q. H. Vuong, "Limited Information Estimators and Exogeneity Tests for Simultaneous Probit Models", Journal of Econometrics 39:347-366. 1988

Reardon, T., A.A. Fall, V. Kelly, C. Delgado, P. Matlon, J. Hopkins, and O. Badiane. "Agriculture-led Income Diversification in the West African Semi-Arid Tropics: Nature, Distribution, and Importance of Production-linkage Activities." In A. Atsain, S. Wangwe, and A. G. Drabek (eds.), African Economic Issues, manuscript, October 1993.

Reardon, T., V. Kelly, and P. Matlon. "The Effect of Non-Farm Income on Fertilizer Use in the West African Semi-Arid Tropics", mimeo, August 1990.

Reardon, T. and M. Mercado-Peters. "Self-financing of rural household cash expenditures in Burkina Faso: The case of net cereal buyers", in Cuevas and Benoit-Cattin (eds.), Finance and Rural Development in West Africa, proceedings of the 12th rural economy seminar (CIRAD, Ohio State University, CNCA, CEDRES, INERA) in Ouagadougou, October 21-25, 1991; CIRAD, Montpellier, 1993.

Reardon, T., T. Thiombiano, and C. Delgado, La Substitution des Céréales Locales par les Céréales Importées: La Consommation Alimentaire des Ménages à Ouagadougou, Burkina Faso, Research Report for IFPRI/CEDRES project, published by CEDRES, Université de Ouagadougou, Série des Résultats de Recherche, no. 002, June 1988.

Rochette, R.M. (ed) Le Sahel en lutte contre la desertification: leçons d'expériences, CILSS, PAC, Eschborn: GTZ, 1989.

Sanders, J H J.G. Nagy, S. Ramaswamy, "Developing New Agricultural Technologies for the Sahelian Countries: The Burkina Faso Case", Economic Development and Cultural Change, Oct 1990, vol. 39,no 1.
Sanders, J.H , S. Ramaswamy, and B.I. Shapiro, The Economics of Agricultural Technology in Semi-arid Sub-Saharan Africa, forthcoming Johns Hopkins University Press, manuscript 1994

Sanon, S., S. L. Millogo and S. J. Da, "Impact de la suppression de la subvention des engrais au Burkina Faso", mimeo Ministère de l'Agriculture et des Ressources Animales. Ouagadougou, Burkina Faso. September. 1993

Sargent, M., J. Lichte, P. Matlon, and R. Bloom, An Assessment of Animal Traction in Francophone West Africa, African Rural Economy Working Paper no. 34, Dept. of Agr. Econ., Michigan State University, 1981.

Savadogo, K., "Production systems in Southwestern Burkina Faso" Mimeo. University of Ouagadougou. 1990

Savadogo, K. and S. Lariviere, "Caractéristiques socio-démographiques et stratégies des ménages en matière de sécurité alimentaire dans la province du Passore", Projet CEDRES/Laval, Travaux de recherche no. 1. 1993

Savadogo, K., A. Slack and C. Delgado, "Long-Distance Transfer Costs of Agricultural Products in Burkina Faso", Paper presented at the ISRA/IFPRI seminar. Sally Portudal. Sénégal. 1992

Savadogo, K. and C. Wetta, "The Impact of a Self-Imposed Adjustment: The Case of Burkina Faso, 1983-89", in G.A. Cornia, R. van der Hoeven, and T. Mkandawire (eds) Africa's Recovery in the 1990s: From Stagnation and Adjustment to Human Development. MacMillan, London. 1992

Shehata, M., "Self-selection Bias and Economic Consequences of Accounting Regulation: An Application of Two-stage Switching Regression to SFAS No.2", The Accounting Review 66:768-787. 1991

Shumway, C. R., "Supply, Demand, and Technology in a Multiproduct Industry: Texas field Crops", American Journal of Agricultural Economics, Vol. 65, no. 4. November. 1983

Sidhu, S.S., "Relative Efficiency in Wheat Production in the Indian Punjab", American Economic Review, vol. 64 (4): 742-751. 1974

SOFITEX, "Rapport annuel", Burkina Faso, 1993.

Strauss, J. and D. Thomas "Health and Labor Productivity: Sorting out the Relationships", Invited paper for the 22nd International Conference of Agricultural Economists, Harare Zimbabwe, August, 1994.

USDA, "Africa and the Middle East", Situation and Outlook Series. Washington, D C 1994

Vierich, H. "A Guide to the ICRISAT Study Villages in Burkina Faso: An Historic and Ethnographic Introduction to the Village Level Studies in West Africa", draft mimeo, ICRISAT/Burkina, 1985.

Walker, T.S. et J.G. Ryan, Village and Household Economies in India's Semi-Arid Tropics, Baltimore: Johns Hopkins University Press. 1990

World Bank. World Development Report 1993.

World Bank Operations Evaluation Dept., Cotton Development Programs in Burkina Faso, Cote d'Ivoire, and Togo, 1988

Zerbo, D. and M. Le Moigne, "Problèmes posés par la mécanisation dans les pays membres du CILSS", CEEMAT, France 1977