Intensification of Sahelian farming systems: evidence from Niger

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Abstract

The general objective of this study was to trace the intensification process on sandy soils in the Birni N’Konni area of south central Niger and to identify the role of traditional and modern inputs. The primary hypothesis is that farmers intensify first using traditional inputs, such as traditional varieties, labor and manure, and turn to modern inputs, like inorganic fertilizer, improved varieties and pesticides, only when they have exhausted the potential of their traditional methods. The main reason hypothesized for the initial use of traditional inputs is their low capital requirement. The methodology uses a representative farm linear programming model with solutions at various land, labor and capital levels. The results indicate that intensification is a continuum, starting from traditional low plant density, extensive farming to using higher planting density and manure, and eventually to inorganic fertilizer, improved seed and pesticide. One implication of this research is that extension and development efforts should start with intensification of traditional inputs, instead of promoting use of modern inputs as the first step in intensification.

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1. Introduction

Traditionally, clearing additional land for cultivation was the primary way used by Nigerian farmers to increase agricultural production. Now, new cropland is becoming scarce (Charlick, 1991; Ramaswamy and Sanders, 1992). Land degradation by wind
and water erosion, combined with demographic pressure have reduced arable area per person. Niger has one of the highest population growth rates (3.3%) in the world and one of the lowest fertilizer use rates (0.27 kg/ha) (World Bank, 1997). Increased input use per hectare is needed to increase agricultural production to help feed this growing population. But which inputs should be intensified? Farmers can increase use of the traditional inputs of seed, labor and manure, or the modern inputs promoted by researchers and development projects (e.g. improved varieties, inorganic fertilizer, and pesticides)?

The general objective of this study was to trace the intensification process on sandy soils in the Birni N’Konni area of south central Niger and identify the role of traditional and modern inputs. The primary hypothesis was that farmers intensify first using traditional inputs, because they require less capital, but when they have exhausted the intensification potential of those traditional practices, they will adopt the so-called modern inputs. The methodology used a representative farm linear programming model with solutions at various land, labor and capital levels.

Niger is a landlocked country of about eight million people at the southern edge of the Sahara desert. Per capital gross national product in 1996 was about US$200. Over 90% of Nigerian adults depend on agriculture for their livelihood. Most of the cropland is in a 150-km-wide band along the southern border. Average annual rainfall in this area ranges from 300 to 800 mm. The main rainfed crops are millet, sorghum and cowpea. Less than 1% of the country’s crop land is irrigated. The average annual rainfall in the Birni N’Konni study area is about 400 mm.

Farming systems research in Africa has often focused on land and labor availability as constraints to intensification. The role of capital has been largely neglected. Most currently available intensification alternatives require some investment (cash and/or in-kind) in the off-season or at the beginning of the cropping season. Even the traditional alternatives require some cash or its equivalent. For instance, farmers need resources to compensate herders for corralling their livestock on a field as a source of manure, to have a donkey or bullock cart for transporting manure, and to acquire enough seed to increase planting density or increase the number of species in the intercropping system.

Capital is a very scarce resource for most Nigérien farmers. Formal sector credit is almost unknown in rural areas and informal sector credit is usually limited to urgent consumption needs. Because farmers have many potentially profitable non-crop investment opportunities, the opportunity costs of capital in West Africa are very high (Vijverberg, 1991; Lowenberg-DeBoer et al., 1994). To analyze the role of capital, the model used in this study allows farmers to choose between investment in crops, livestock and small-scale trade.

Farmers in Niger have been slow to adopt new agricultural technology (Charlick, 1991; Lowenberg-DeBoer et al., 1992a, b; Mazzucato and Ly, 1992). Most farmers use traditional crop varieties, low planting density and only a small amount of organic fertilizer. Mazzucato and Ly (1992) estimated that in 1990 only 5% of millet seed and less 1% of cowpea seed was of improved varieties. The National Agronomic Research Institute of Niger (INRAN) and the national extension services recommend inorganic fertilizers. They are available through non-governmental
organizations and private traders, but they are mostly applied to dryland cash crops and crops grown under irrigation (rice, cotton, wheat). Most crop activities are manual. Animal traction is used primarily on irrigated land and the small areas of heavy clay soils.

Commerce and artisanal activities have long been important for the people of southern Niger (e.g. Gregoire, 1992). In the Birni N’Konni area that importance is enhanced by their proximity to the Nigerian border. Reported annual rates of returns for this type of activity in West Africa range from 60% to over 1000% (Vijverberg, 1991; Lowenberg-DeBoer et al., 1994) for small investments ranging from 300 to 50,000 FCFA. At the time these data were collected in the early 1990s, the exchange rate was in the range of 250–300 FCFA/US$, so the investment levels ranged from US$1 to 200.

Boserup (1965) hypothesized that increasing population density will force farmers to adopt more intensive cropping systems. The Birni N’Konni region was chosen as a good candidate to test that hypothesis in Niger because it is one of the most densely populated rural areas in the country and that density is increasing. In this area, the average population density increased from 32.9/km$^2$ in 1977 to 47.7/km$^2$ in 1988 (République du Niger, 1991). In addition, on-farm trials in the region have indicated yield increases with fertilizer, improved varieties and pesticides (Lowenberg-DeBoer, 1990). The proximity to the Nigeria border creates trade opportunities, and an irrigated perimeter provides infrastructure, which results in a wide range of resource levels among farm families. The irrigated perimeter of Birni N’Konni is the largest in Niger and this potential competition for labor and capital can be important for dryland technology adoption (Maïkoréma, 1986; Ziyou et al., 1994).

1.1. Objectives and hypotheses

The general objective of this study was to identify, at the farm level, the potential for intensification of agricultural system using traditional versus modern inputs in the region of Birni N’Konni. Specifically, the objectives were:

1. to determine the effects of differences in resource endowments on the adoption of new agricultural methods;
2. to determine the effects of increased population pressure on adoption of inorganic fertilizer; and
3. to trace the agricultural intensification process in the Birni N’Konni area.

It was hypothesized that most farmers will choose traditional inputs as their first intensification option and that farmers with above-average resources will increase use of inorganic fertilizer, improved seed and pesticide as their capital increases.

Section 2 outlines the methodology, including a development of farmer resource categories and an overview of the modern crop technology alternatives. Section 3 provides the baseline results with traditional technologies and validation using data from a neighboring area. Section 4 gives results with introduction of modern technologies and sensitivity tests under changes in capital availability and increased population pressure. Section 5 discusses conclusions and implications of the research.
2. Methods

The analytical framework for this study was a deterministic linear programming model of representative farms with various resource levels. The model represents expected decisions in a long-term steady state situation after all adjustments are made. It maximizes the annual net revenue of the farm subject to resource constraints and food security level. To maximize revenue, the model chooses among crop, livestock and non-agricultural activities to allocate capital, labor and land available. Because animal traction use for field operations is not important in the region, the model considers only manual labor from family and hired labor. Abdoulaye (1995) documents the model in detail.

This model tried to strike a balance between adequate recognition of risk and parsimonious modeling. Risk was handled using a food security constraint. Food security is an important aspect for farmers in Niger, where food shortages are common. In a bad cropping season, having enough cereals to feed the family until next harvest is a top priority. The model had a minimum millet and sorghum production constraint, which required yields for chosen activities in bad crop seasons to be greater than or equal to the family’s subsistence cereal needs. The yields for each activity in a bad crop year were estimated at one standard deviation below the mean.

The analysis used data from a diagnostic survey conducted from 1989 to 1991 by INRAN’s Department of Rural Economics (INRAN/DECOR). A random sample of 20 farmers in three villages (Dagarka, Kaku, Ambouta) was used (for details on survey see Lowenberg-DeBoer, 1990). This was a cost-route survey with weekly data collection by observers based in the area. Using information from the survey, farmers were classified according to their resources. A representative household model was then built and adapted to each group’s resource availability. The intensification alternatives were introduced in the model for each resource category.

2.1. Farm categories

Farmers were classified according to their resource endowment. Ideally, the resource endowment of a given household should include all assets (physical and financial). Instead proxies were used here. Due to lack of information, livestock ownership and existence of irrigated cropping activities were used to differentiate among households. Data on farmers’ assets, particularly financial assets, are difficult to obtain. Farmers view researchers as part of the governmental system and suspect that data are collected for tax purposes. Livestock is the most common investment in rural Niger and in predominately Hausa areas like Birni N’Konni it is relatively easy for an observer to count cattle, sheep and goats as they enter the farm compound in the evening. The value of livestock is an objectively verifiable measure of the wealth of a household.

The other distinguishing factor used was presence of irrigated cropping activities in the household. In Niger as in other West African countries, markets for land do not truly exist. Legally in Niger, all rural land is property of the government, so land ownership can not be used as a measure of wealth. In the region of Birni N’Konni,
land is allocated to farmers by village chiefs. Once a piece of land is allocated to a farmer, he can use it and pass it to his sons, who can also pass on use rights without having the right to sell it. Most of the irrigated land in the region is located in the Birni N’Konni perimeter created by the government of Niger. Perimeter land was distributed without payment to farmers from surrounding villages as a function of family size. Farmers on the perimeter do not own the land or improvements, but they have access to the capital that it represents.

Four farm categories were identified in the sample (Table 1):

1. **The very poor.** This is the poorest segment of the population. They farm only a small area of dryland. Their only livestock is a few chickens or guinea fowl.
2. **The poor.** These households have a few sheep and goats but no cattle or irrigated crops.
3. **The average.** These households have some cattle, but the bulk of the livestock consists of small ruminants. They do not have irrigated cropping activities.
4. **The above average.** In the Birni N’Konni area the main difference between this category and the average category is that these households have irrigated crops.

In general, Nigerian rural households have at least a few sheep and goats. The study sample had 39% of each for poor and average categories and 17% in the above-average category. Survey data from the Maradi region showed that 27 and 26% of farmers had cattle in the villages of Maigué and Rigail Oubandawaki, respectively (INRAN/DECOR, unpublished data). Nationwide, the poor category is the largest among the groups identified here. The above-average group is the wealthiest and smallest segment of the rural population, because less than 1% of Nigerian farmers have access to government sponsored irrigation. In areas with no irrigated land, only village chiefs and a few other members of local elites are in this category.

The very poor group was omitted in this analysis. This group represents the poorest segment of society. They have very limited farming activities of their own. These people usually depend on wages earned working for wealthier farmers.

Table 1

<table>
<thead>
<tr>
<th>Household types</th>
<th>Poor</th>
<th>Average</th>
<th>Above average</th>
</tr>
</thead>
<tbody>
<tr>
<td>All crop land (ha)</td>
<td>3.8</td>
<td>4.5</td>
<td>2.9</td>
</tr>
<tr>
<td>Sandy</td>
<td>3.8</td>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td>Clay</td>
<td>0</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Irrigated</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Value of livestock (FCFA)</td>
<td>25 000</td>
<td>252 000</td>
<td>237 000</td>
</tr>
<tr>
<td>Labor (adult males)</td>
<td>1.6</td>
<td>2</td>
<td>1.8</td>
</tr>
<tr>
<td>Average investment in crops (FCFA/ha)</td>
<td>2603</td>
<td>5243</td>
<td>13 746</td>
</tr>
</tbody>
</table>

* Source: INRAN/DECOR, unpublished data.
Information on this group was hard to collect because their short planning horizon makes it unprofitable for them to work with researchers. They quickly lost interest when they found out that no reward was given for answering questions, unlike food-for-work and other development projects. There were four farmers in this category in the original survey sample, but three of them decided to stop cooperating after just 3 months.

Poor farmers have less dryland crop area than the average farmer group, but more than the above-average group (Table 1). The above-average group invests more per hectare than the other groups on dryland as well as irrigated areas. Investment per hectare was estimated using average expenses for seed, fertilizers, pesticides and pre-harvest hired labor for each household group. Investment by poor farmers was limited to seeds for low density planting. Livestock ownership was similar for the average and above-average groups. The wealthier households are larger, but the labor available for farming was similar for all three groups. Local custom limits women’s involvement in crop production to planting and cowpea harvest, so the number of adult males per household is a reasonable indicator of the agricultural labor force. The most critical labor bottleneck is weeding, which is done almost entirely by men.

2.2. Intensification alternatives

Agricultural system can be intensified using traditional inputs. Intensification options using traditional inputs included in this analysis used more labor per hectare because of higher planting density and/or higher number of crops in intercropping system compared to traditional extensive activities. Often in the region of Birni N’Konni farmers will switch from millet/cowpea intercrop to millet/cowpea/sorghum intercrop on a field with increased soil fertility. Manure and other crop-residues application to local crop varieties is also part of the traditional intensification strategies. Traditional intensification options are classified as:

- **Traditional 1**: This option includes all cropping systems using local varieties but requires more labor because of increased planting density and/or increased number of crops in the intercrop (more complex intercrop).
- **Traditional 2**: This option consists of applying manure and other organic matters to crops.
- **Traditional 3**: This option requires both increased labor and manure.

The new technologies being evaluated in this study are millet/cowpea intercropping technologies developed at INRAN. The technologies were tested during 5 years (1985–89) in on-farm trials using CIVT and TN-5-78 as new varieties of millet and cowpea, respectively. The millet/cowpea intercropping technologies developed at INRAN were aimed at improving traditional millet/cowpea intercropping yields and providing farmers with more options. These technologies were designed for sandy soils where farmers usually plant millet/cowpea (Lowenberg-DeBoer et al., 1992a).

Based on input requirements, the new technologies were classified into three intensification alternatives. These alternatives build up from a simple new variety
use to the total package, including inorganic fertilizer and pesticides. The modern intensification options evaluated in the paper are as follows:

**Option 1: New varieties.** This alternative uses improved millet and cowpea varieties at traditional low cowpea planting density (2000 hills per hectare).

**Option 2: Phosphate.** This option uses improved millet and cowpea varieties at high cowpea planting density (18,000 hills) and phosphate application. One-hundred kilograms of super simple phosphate (SSP) is applied per hectare before planting.

**Option 3: Total package.** This alternative uses improved millet and cowpea varieties at high cowpea planting density with 100 kg of SSP, 50 kg/ha of urea and two applications of insecticide on cowpea.

All modern intensification options use improved varieties. Options (2) and (3) use inorganic fertilizer. Option (3) uses pesticides. The new varieties alternative requires the same investment as the traditional method because both use the same seed quantity and improved variety seeds are valued at the same price as local varieties in the model. It has been the policy of governmental and non-governmental organizations (NGOs) in Niger to sell improved variety seed at the same price as traditional seed. Crop and seed prices were based on average market prices in the Birni N’Konni area from 1991 to 1993 (Table 2). The phosphate and the total package

### Table 2
Average crop prices at planting and harvest periods — Birni N’Konni 1989–93a

<table>
<thead>
<tr>
<th>Crops</th>
<th>Average prices (FCFA)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>June (planting)</td>
<td>October (harvest)</td>
<td></td>
</tr>
<tr>
<td>Millet</td>
<td>73</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>66</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Cowpea</td>
<td>135</td>
<td>103</td>
<td></td>
</tr>
</tbody>
</table>

*a Source: survey data and OPVN bulletins (OPVN, 1991–93).*

### Table 3
Gross margin (FCFA/ha) of traditional millet/cowpea intercropping and modern intensification options — Birni N’Konni

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Local extensive</th>
<th>New varieties</th>
<th>Phosphate</th>
<th>Total package</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross revenue (FCAF/ha)</td>
<td>21 197</td>
<td>26 082</td>
<td>43 667</td>
<td>58 069</td>
</tr>
<tr>
<td>Non-labor variable costs (FCFA/ha)</td>
<td>989</td>
<td>989</td>
<td>7699</td>
<td>16 589</td>
</tr>
<tr>
<td>Gross margin (FCFA/ha)</td>
<td>20 208</td>
<td>25 093</td>
<td>36 058</td>
<td>41 480</td>
</tr>
</tbody>
</table>

*a Source: Abdoulaye (1995). Local extensive: this is traditional millet and cowpea intercropped at traditional low cowpea planting density of 2000 hills/ha using local unimproved varieties.*
options cost more to implement than traditional methods or the new varieties options but have higher gross margins than the others (Table 3).

Yields for the traditional and intensified traditional activities were estimated from the survey data, which included the whole range of traditional input use levels. Regression was used to estimate yield as a linear function of planting density, soil type, planting date, first weeding date, manure application and an intercept. Labor requirements were estimated from survey data as a function of planting density. Manure is available either through livestock ownership or through purchase in the form of corralling. In the region, farmers often contract with herders to get manure. In such a contract, it is usually agreed that the herder will corral the herd on the farmer’s field for a specified number of days. The animals will graze on the crop residues and manure the field. Based on average herd size and length of stay, the model used an estimated cost of 1365 FCFA/ha as the cost of corralling.

3. Baseline results and validation

The baseline results are model solutions with only traditional activities and initial resources levels (Table 4). The model solutions showed that all households engage in the non-agricultural activity, small-scale commerce. The solution for the above-average group had intensive traditional activities — higher planting density intercropping with manure (100%). This group has enough resources to pay for the additional seed, manure and weeding labor. The poor group had mainly extensive

<table>
<thead>
<tr>
<th>Table 4</th>
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<tbody>
<tr>
<td>Activities choices and shadow prices of constraining resources by household type — model resultsa</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Poor</th>
<th>Average</th>
<th>Above average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monocrop — low planting density (% of sandy crop area)</strong></td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td><strong>Intercrop — low planting density (% of sandy crop area)</strong></td>
<td>54</td>
<td>56</td>
</tr>
<tr>
<td><strong>Intercrop — higher planting density with manure, traditional 3 (% of sandy crop area)</strong></td>
<td>35</td>
<td>44</td>
</tr>
<tr>
<td><strong>Non-agricultural activity</strong></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Livestock activities</strong></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Shadow prices</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital (%)</td>
<td>70</td>
<td>48</td>
</tr>
<tr>
<td>Labor for weeding (FCFA/day)</td>
<td>1277</td>
<td>1113</td>
</tr>
<tr>
<td>Sandy land (FCFA/ha)</td>
<td>107</td>
<td>384</td>
</tr>
</tbody>
</table>

a Source: Abdoulaye (1995). Number for each cropping system represents the percentage of cropping land allocated to that system by the given resource group. ‘Yes’ means the activity was included in the optimal model solution and ‘No’ indicates the activity was not chosen as part of the optimal model solution. Shadow prices represent the opportunity cost for each resource (land, labor, capital) as suggested by model results.
low planting density activities (65%), which require only seed as investment. This group is the only one to allocate land to low planting density monocrop millet activities (11%). With this kind of activity the out-of-pocket expenses are almost zero because farmers often conserve their own cereal seeds. The poor household group chose intensive traditional activities for only 33% of their cropping area. With the choice of low planting density activity, this group is able to keep crop investment within its capabilities. The average group was in between the two extremes with all its land allocated to intercropping, but only 45% of its cropping area allocated to manured higher planting density activities.

The food security constraint was binding for poor and average household categories. To satisfy the food security requirement, even low productivity activities are chosen, which drives down the shadow value of land. The above-average household group easily satisfies the food security requirement because of irrigated cropping activities. The low shadow value of land reflects both scarcity of quality land and relative abundance of sandy soils to these resource categories. Labor opportunity costs were comparable to observed hired labor cost of 800 to 1000 FCFA plus a meal.

3.1. Validation

In order to be useful for policy or new technologies adoption analysis, the model must represent the actual practices of the area. Therefore, model solutions were compared to survey data for Guidan Ider, 20 km north of Birni N’Konni (Abdoulaye et al., 1992). The Guidan Ider survey classified farmers according to animal traction use. Three groups were identified, bovine traction users, asine traction users and those who do not use animal traction. In terms of capital requirements, these categories correspond roughly to the above-average, average and poor categories, respectively, in the Birni N’Konni data. The model was solved for resource levels of Guidan Ider farmer categories.

Sandy soil crop allocation in model solutions was very similar to that found in the Guidan Ider’s survey data. Millet, sorghum and cowpea were the crops grown in both cases. Both model and survey results show the preference for intercropping by farmers in the region. The non-agricultural activity was in the solution for all models and exists in all categories of the Guidan Ider data. For poorest group in Guidan Ider, the no animal traction category, land allocation to intercropping and monocropping was the same in both survey and model results.

For animal traction users the model results included slightly more monocropping (5–7%) than the survey results indicate (0–2%). The areas allocated to monocropping by the model are sorghum on clay soils. Because of relatively high sorghum yield, the model was choosing mono-crop sorghum as the best activity on clay soils.

For livestock activities the models seemed to overestimate small ruminants and under estimate cattle activities. Large animals ownership does have a prestige dimension to it, which was not accounted for in the model. This can explain why the model was underestimating the number of large animals owned by the household. In general the model did a good job of mimicking the dryland cropping choices of the Guidan Ider farmers.
4. Introduction of modern intensification alternatives

New technologies entered the solution for all resources categories (Table 5). For each household type, results suggested different combinations of technologies depending on the resources available. With introduction of new technologies, the food security constraint was no longer binding for poor and average resource farmers. Adoption of new technologies increases food security because of lower variability in millet yields. Constraints for land, capital, and weeding labor were still binding.

Farm incomes increased with the introduction of new technologies. Poor and average resource household groups benefited more than the above average from the introduction of new technologies. Income increases were 22 and 26% for poor and average categories, respectively, while it was only 7% for the third. This is similar to the 20% increase in income with adoption of new technologies in western Niger estimated by Shapiro (1990). The above-average group receives most of its crop income from irrigated activities, which are not directly affected by the new technology introduced.

Introduction of new technologies in the system caused some important changes in the land allocation. For poor farmers land allocated to traditional intensive (manured) activities was reduced by 5% because of higher cowpea production by the new variety. The new cowpea variety, TN-5-78, has higher average grain yield than local cowpea varieties. The model chose to produce more cowpea as a cash crop when the food security constraint was eased by the higher cereal yields of new technologies.

Results showed the importance of the capital constraint for the type of technology adopted. The average and above-average resource categories, those with higher resource levels, allocated (68 and 89%, respectively) land to the technologies with inorganic fertilizers while the low resource category (poor group) allocated its land to new varieties with no fertilizer (Table 5). Furthermore, the average resource households invested in the phosphate technology, while the above-average household category invested in the total package, with both nitrogen and phosphate. Poor farmers used low capital cost manure as their source of fertilizer, while the average and above-average categories chose inorganic fertilizer sources (Table 5). Model

<table>
<thead>
<tr>
<th>Activities</th>
<th>Percent of sandy soils</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>Intercrop — higher planting density with manure (Traditional 3)</td>
<td>28</td>
</tr>
<tr>
<td>New varieties</td>
<td>72</td>
</tr>
<tr>
<td>Phosphate</td>
<td>0</td>
</tr>
<tr>
<td>Total package</td>
<td>0</td>
</tr>
</tbody>
</table>

solutions for higher resource categories do not include any manured activities. Due to lack of data, activities which combine traditional and modern inputs (e.g., new varieties with manure application) were not included in the model. This type of mixed activities could be optimal at some higher resource levels.

In model solutions poor farmers did not apply any inorganic fertilizer. This was consistent with observed practices in Niger. Average resource farmers applied 66 kg of SSP per hectare on sandy soil and no nitrogen in model results. This was consistent with use of phosphate fertilizer and almost no nitrogen by in INRAN/DECOR adoption surveys conducted in villages near Maradi, where on-farm trials had been conducted (Lowenberg-DeBoer et al., 1992b). The above-average category applied 90 kg of SSP per hectare and 45 kg per hectare of urea on sandy soils. The solution for the above-average group was close to the application rates of 100 kg of SSP and 50 kg of urea recommended by extension in Niger.

4.1. Increased capital availability

An increase in capital can occur if a family member who is working temporarily or permanently in the city sends some cash or if the value of agricultural production increases. Credit is another possibility for capital availability to increase. Increased capital endowment is simulated in this section to compare how the different types of households react to higher capital availability.

Capital endowment was increased by 10% for poor farmers and 44 and 36% increase for average and above-average categories, respectively. These increases represent levels for changes in solution for each household type. The increase in capital caused land allocated to new technologies to increase for all resource categories. The marginal increase in the capital endowments caused a small increase in cowpea production by poor farmers through increase in land allocated to new varieties without fertilizer. Both average and above-average farmers increased land allocated to technologies using inorganic fertilizer (Table 6).

4.2. Population pressure

Given the current rate of population increase in Niger, an increase in population pressure will be one of the most important structural changes in the region. This scenario analyzed the effect of increased population by resource category. It assumed a decrease in cropping area per household available due to increase in population. The test here was to analyze how a decrease in cropping area due to population growth will change land allocation to new technologies using inorganic fertilizer.

This comparison focuses on sandy soils because they are much closer to living areas and easier to transform into home sites than clay soils. Clay soils are located in low lands, which flood after heavy rains and hence are not suitable for housing construction. Therefore, the analysis of land reduction focused on sandy soils only. In addition, new technologies in the model were introduced only on sandy soils. As was the case with capital change, changes in land area available were also made at levels where the optimal solution changes for each household type. Sandy soils
availability was reduced by about 10% for all household types. New land endowments were 3.73 ha of sandy soils for poor farmers and 3.97 and 1.54 ha for average farmers and the above average group, respectively.

The effect of a land decrease was an increase in relative area allocated to new technologies in the solutions for all resource categories. Because the decrease in land endowments increases capital available per unit of land, the effect of increased population pressure on model solutions was the same as an increase in capital. Decreases in land caused the system to become more intensive as the demand for soil fertility increased. With the new technologies all farmer categories exceeded subsistence consumption requirements, so subsistence requirements did not drive solutions. Low resource farmers still did not allocate land to inorganic fertilizer technologies, because intensification via traditional inputs remained more profitable for them. Both average and above-average farmers increased land allocated to inorganic fertilizer technologies (Table 7).

4.3. Intensification process

This section analyses the potential intensification process for poor farmers with a gradual increase in capital endowments. The test consisted of model solutions at different capital levels for low resource farmers. The starting capital level (7550 FCFA) was the average initial investment required for non-agricultural activity in the region (Lowenberg-Deboer, 1990).

At low capital levels, the solution contained mainly unmanured low planting density activities (Fig. 1). Initially as capital increases land allocated to manured, traditional activities is increased. At higher capital levels new technologies using inorganic fertilizer became more profitable than traditional manured activities. New technologies with inorganic fertilizer entered the solution at 37,750 FCFA capital level and land allocated to new technologies increased to 40% of the dryland area at 60,400 FCFA capital level.

As expected, at low capital levels, the optimal solution contained only traditional low planting density activities as capital is very limited and part of it was invested in the non-agricultural activity. Because of the consumption constraint, investment in non-

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Table 6
Land allocation in model solutions with marginal increase in capital availability by household type — model results

<table>
<thead>
<tr>
<th>Activities</th>
<th>Percent of sandy soils</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>Traditional 2</td>
<td>24</td>
</tr>
<tr>
<td>New varieties</td>
<td>76</td>
</tr>
<tr>
<td>Phosphate</td>
<td>0</td>
</tr>
<tr>
<td>Total package</td>
<td>0</td>
</tr>
</tbody>
</table>

*Source: Abdoulaye (1995). Traditional 2 is the traditional intensification option 2. It includes here manure application to low planting density intercropping.
agricultural activity was reduced to allocate capital to crops. When capital is increased, the system begins to intensify using traditional manured cropping activities (high planting density and manure). Area allocated to extensive traditional activity was reduced and area allocated to more intensive traditional activities (with manure) increased as capital increases. Area allocated to traditional manured activities reached its maximum as all sources of manure are exhausted given capital available. In order to increase manure production, a large investment in livestock was necessary, but given capital available more livestock could not be purchased. Thus, the intensification process shifted to new technologies using inorganic fertilizer. Poor farmers will intensify their farming practices if more capital is available to them. The process starts by using traditional inputs (labor and manure) then it shifts to more productive modern inputs (inorganic fertilizers, pesticides, improved varieties) as more capital is available for their purchase.

Table 7
Land allocation with marginal decrease in per capita sandy soil availability by household type — model results

<table>
<thead>
<tr>
<th>Activities</th>
<th>Percent of sandy soils</th>
<th>Poor</th>
<th>Average</th>
<th>Above average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional 2</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>New varieties</td>
<td>75</td>
<td>33</td>
<td>5</td>
<td>95</td>
</tr>
<tr>
<td>Phosphate</td>
<td>0</td>
<td>67</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total package</td>
<td>0</td>
<td>0</td>
<td>95</td>
<td></td>
</tr>
</tbody>
</table>

a Source: Abdoulaye (1995). Traditional 2 is the traditional intensification option 2. It includes here manure application to low planting density intercropping.

Fig. 1. Intensification of crop activities in Birni N’Konni model at various capital levels. Source: Abdoulaye (1995). Extensive: local varieties in monocrop and/or a two-crop intercrop at low planting density without manure or inorganic fertilizer. Intensive Traditional (either of the three traditional intensification options): intensive crop activities using traditional inputs (manure and labor and/or more complex intercropping). Intensive Modern (either of the three modern intensification options): intensive crop activities using modern inputs (new varieties, inorganic fertilizer and/or pesticides).
5. Conclusions and implications

This analysis suggests that agricultural intensification in southern Niger is a continuum, starting with intensification using traditional inputs and eventually leading to use of improved seed, fertilizer and pesticide. As the amount of capital per hectare increases cropping intensity increases. The effect on technology choice is the same if the capital increase is a result of capital accumulation or a reduction in land availability due to population pressure. When new technologies are available all farmers groups can satisfy subsistence requirements, even in reduced land scenarios; intensification is not driven by subsistence food requirements. This analysis suggests that one of the primary reasons for starting with traditional intensification using higher planting density on traditional varieties, more complex intercrops and manure is the lower capital requirement.

One of the implications of this research is that extension and rural development efforts in southern Niger should start with intensification of traditional cropping strategies. In the past, extension and development projects in Niger have put more emphasis on the so-called modern inputs, improved seed, fertilizer and pesticide, and little attention paid the potential for traditional intensification (except for some localized efforts by some NGOs). They have tried to bypass a step in the intensification process. The low adoption rate of modern technologies may be because the potential of traditional, low capital intensification has not yet been exhausted. Model results suggest that programs targeting small farmers will be more successful if they include technologies improving the use of traditional inputs (traditional varieties, labor, manure) as a transitional strategy, rather than relying on modern purchased crop inputs as initial intensification strategy.

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