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Predicting the Impact of New Cropping Practices upon Subsistence Farming: A Farm Level Analysis in Brazil

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An analysis is done on the potential effects of several improved cropping practices in a subsistence agricultural farming system along with analyses of other development options. The farming system is modeled as a linear programming model. The problem involves mixture of perennials and annuals, sharecropping provisions and risk. The practices are found to have differential effects on the distribution of income between the landlords and tenants, marketable surplus and on farm employment.

The transformation of traditional agriculture into a self-sustaining and broadly-based modern agriculture is often a key element in economic development. Many feel that the introduction of new production practices will transform traditional agriculture (Schultz; Hayami and Ruttan), starting a chain reaction which stimulates development. However, the implementation of useful new practices is difficult. Often technically well designed practices are not widely adopted because of economic and social factors. For example, farm level profitability, consistency of the practice with both the farming resources and the farming system, and consistency with the social and governmental institutions are important. Designers of new practices can find it useful to pretest practices for "adoptability."

The present study constitutes such a pretest. An analysis is done on new cropping practices for small farms within a poverty stricken region of northeast Brazil (Goodwin *et al.*; Sanders and Dias; and Kutcher and Scandizzo, 1981, present related analyses). The general objective involves the prediction of the potential effects of new cropping practices on farm income, income distribution, marketable surplus and employment. Results of such a study could be used to establish research and extension priorities, to design/redesign practices, and to discover desirable traits of new practices.

The overall area of inquiry in this study is farming systems research—FSR (Byerlee *et al.*). FSR proponents commonly call for detailed farm level trial evaluation of new practices. However, because of time and money constraints, we will not follow these procedures. Rather we incorporate data from a number of such studies in our analytical framework. We follow an analytical modeling procedure, as discussed in Anderson and Hardaker, which allows us to explore many possibilities in an eco-

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nomical, timely fashion. Thus, our methodology predicts the consequences of technological change through modeling. Model analyses will also be done comparing technological change against other possible development policies (alterations in the land holding pattern, rural credit programs, and tenure reform).

When studying subsistence agriculture, one often finds many potential institutional or behavioral "barriers" to practice adoption. In this study the farming system contained tenure arrangements, risk characteristics, and subsistence behavior which could influence adoption. These will be captured within a linear programming model. The model will incorporate risk, perennials, livestock, subsistence requirements, labor exchange-share cropping arrangements, and decision making by two parties, along with the usual farm level resource restrictions and activities.

Study Region Background

The study is set in the Canindé region in Ceara state, northeast Brazil. Introduction of new cropping practices into this region is complicated by adverse climatic conditions and by land tenure arrangements. Northeast Brazil possesses a semiarid climate. Rainfall tends to be concentrated in a short period within any year and also is subject to large year-to-year variations. The basis of the production system is a long-staple perennial cotton (called Moco). Although low-yielding on average, this crop produces output even under the most adverse conditions. Moco cotton is generally interplanted with subsistence crops, primarily corn and cowpeas. Cattle are also an element within the production system, and graze crop residues.

Sharecropping is common in the region. The concentration of land-holdings is highly skewed, with a small number of large farmers owning the majority of the land interspersed with a large number of small farmers (Johnson, 1971). The small farmers are either self-contained subsistence farmers or are farmers who utilize sharecropped land. The sharecropping arrangements, described locally as *regime du subjeicao* (regime of subjection), are somewhat unique. A tenant receives the use of land in exchange for both an output share and a commitment to work for the landlord at a reduced wage rate. This system, although often criticized because of the embodied dependency relations, provides the land-abundant owner with needed labor, and the tenant with a minimum income and land for use. (For background see Johnson, 1971; or Kutcher and Scandizzo, 1981). The tenancy arrangement is also a risk sharing mechanism.

The region has experienced little agricultural modernization. Productivity has been stagnant and per capita incomes remain low.[1] Production practices have been proposed which conceivably could aid regional development. At the time of this study (1977), little research had been directed toward the economic viability of the new production practices and whether the peculiar tenure arrangements of the region inhibit the adoption of new practices. This research provides tentative answers to these questions for a select group of practices.

Cropping Practices Background

Four cropping practices were analyzed: traditional, animal traction, *Bosque Denso*, and *Bosque Denso* with sorghum. The animal traction practice is not greatly different from the traditional practice. The two remaining new practices are considered "potential" because they do not correspond to actual farm production situations. A brief definition of each practice follows.

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[1] Labor has flowed out of the region for more than 30 years, and within the northeast there has been substantial rural-urban migration.

Traditional Practice

Moco (long staple) cotton is planted in consortium with cowpeas and corn during the first year of a five-year production cycle. In the remaining four years, the Moco cotton is left on the field and cultivated alone. All farming activities are done manually.

Animal Traction

The animal traction practice contains the rotational and cultural characteristics of the traditional practice. However, weeding is done with an animal-drawn cultivator. This results in a substantial reduction in labor requirements.

Bosque Denso

The *Bosque Denso* practice embodies a change in the way crops are planted. Cowpeas and corn are planted in consortium between the Moco cotton rows throughout the life of the cotton crop. In the first year, all land is prepared, planted, and managed as with the traditional practice. During the following four years, the land between the cotton rows is annually prepared and planted to cowpea-corn consortium. After five years, a rotation of crops occurs such that, during the next production cycle, the rows where cotton was planted will be planted to the cowpea-corn consortium and vice versa, so that there is actually a land rotation system on the field.

Bosque Denso with Sorghum

The *Bosque Denso*-sorghum practice involves the substitution of grain sorghum into the *Bosque Denso* system as a replacement for corn. Sorghum has not been widely used in the region; consequently there could be difficulty with farmer acceptance. In particular subsistence farmers must substitute sorghum in their dietary pattern (Johnson, 1978). In spite of this, for modeling purposes, it was assumed that sorghum would be accepted as a substitute for corn in the diet.

Model Structure

The farm level economic impacts of these four alternative practices were tested using a linear programming representative farm model. The model is a MOTAD, risk linear program (following Hazell). However, the features involving perennials and sharecropping are nonstandard.

Perennials

Moco cotton is a perennial crop and is included along with annual crops within the linear programming model. Livestock are also a multiple year enterprise. This section discusses the assumptions involved in the simultaneous inclusion of multiple year enterprises with annuals in a one year model. Throsby presents a similar development. We will use moco cotton in the discussion.

Moco cotton has a five year economic life within the study region. Assuming that the technical data characteristics (yields, input usage, etc.) are dependent on elapsed age of crop, then total cotton yield, land and nonland resource use in year t is

$$YLD_t = \sum_{k=1}^{5} Y_t X_{t,k}$$

$$L_t = \sum_{k=1}^{5} X_{t,k}$$

$$RU_{i,t} = \sum_{k=1}^{5} R_{i,k} X_{t,k}$$

where

YLD_t = Yield in year t from all cotton plantings

$X_{t,k}$ = Land area of cotton which is k years old in year t

Y_k = Per land unit yield of cotton which is k years old

L_t = Land use in year t from all cotton plantings
$R_{i,k}$ = Per land unit use of resource i by cotton which is k years old
$RU_{i,t}$ = Use of resource i in year t by all cotton plantings.

These equations may be rewritten by observing that the cotton acreage which is k years old in year t must have been one year old in year t − k + 1. Thus, the yield equation becomes

$$YLD_t = \sum_{k=1}^{5} Y_k X_{t-k+1,1}.$$

Now assume that the farm is in a stationary state, i.e., that an equal amount of cotton land is planted every year. Thus, a five year rotation is present and in each year an equal acreage of the cotton at each stage of its life is present. Consequently, the year of planting subscript on X may be dropped and the following equations result:

$$YLD = \sum_{k=1}^{5} Y_k X_1 = X_1 \sum_{k=1}^{5} Y_k$$

$$L = \sum_{k=1}^{5} X_1 = 5X_1$$

$$RU_i = \sum_{k=1}^{5} R_{i,k} X_1 = X_1 = X_1 \sum_{k=1}^{5} R_{i,k}.$$

Thus, in any year the yield produced will equal the sum of the yields across each year of the crop's life; using five times the cotton land area newly planted (X_1); and the resources summed over all years of the crop's life. Normalizing to one land unit, the cotton may be then represented as a single linear programming activity which supplies the average yield ($\sum_{k=1}^{5} Y_k/5$), using the average amount of resources ($\sum_{k=1}^{5} R_{i,k}/5$) and one unit of land. The perennial activities may then be entered into the model along with the annuals, using the assumption that the farm is in a stationary state—continuous rotation—with one fifth of the total cotton land acreage planted each year.[2] A similar approach was used to develop the cattle activities.

Sharecropping

The sharecropping system involves labor and yield exchanged in return for wages and land. The landlord provides land to the sharecropper and pays a prespecified wage rate for labor services received from the tenant. The sharecropper provides the landowner with one-half the cotton harvested, part of the other crops harvested, and dedicates a given number of labor hours per week to the landlord.

Under the sharecropping regime the landlord determines the quantity of land to exchange for labor and vice versa. Thus, the model includes an activity (the tenancy contract) which transfers land and wages from the landlord to the tenant, in turn, transferring labor and yield to the landlord. However, the quantity of land traded depends upon a mutually negotiated agreement. This was modeled by incorporating two linear programming matrices, one for each party, then developing a multiple objective formulation (see Charnes and Cooper for a recent review) where the two individual objective functions (i.e., the landlord's and the tenant's) were weighted into a single objective using empirically determined weights. This represented the negotiation process. Thus, the sharecropping portion of the model is unlike previous studies (Kutcher and Scandizzo, 1976; Cheung; Bardham). Simultaneous optimization of weighted total income of the two parties is assumed. The weights will be empirically discovered by determining which weights give the "best" correspondence with observed behavior.[3]

[2] This development provides the underlying assumptions when one develops a linear program with regional average budgets for multiple year crops.

[3] There are a number of other approaches that could

Composite Model

The overall structure of the linear programming model is portrayed in Table 1.[4] The landowner and sharecropper models are structurally identical and consist of activities for:

a) Crop production—production of cotton, cowpeas, corn, and sorghum under the various cropping systems. These activities are disaggregated by time period. The timing of the production activities is represented by the x's in Table 2. A production activity uses land, labor in several time periods, and capital; produces crops; enters the risk balance; and contributes cost to the farm net income.
b) Livestock production—production of cattle. These activities use land, labor in several time periods, and capital; consume crops; produce livestock products; and contribute cost to the objective function.
c) Crop sale—sale of crops to market. These activities remove crops from the yield balance, and contribute revenue to farm net income.
d) Crop consumption on-farm—consumption of crops grown on the farm for subsistence or livestock feeding. These activities remove crops from the farm balance and supply them to the on-farm minimum consumption rows for use by the farm household and by livestock.
e) Risk bearing—negative deviations from the expected value of net income (developed as in Hazell and implemented as in Brink and McCarl). Coefficients are derived using seven years of data and a standard deviation of income approximation. These activities enter the risk row and a risk aversion coefficient[5] enters the farm net income row.
f) Crop purchase—purchase of crops for household consumption or livestock. These activities provide crops for on-farm consumption and contribute cost to the farm net income.
g) Livestock sale—sale of livestock products. These activities remove products from the livestock product balance row and provide revenue to farm net income.
h) Labor reservation—sale of excess labor to the marketplace. These activities use labor, and provide a return in the objective function. The labor reservation activity is implemented as alternative employment for labor at one-half the prevailing wage rates. This was done following the arguments presented in other development models (Norton and Solis). These activities provide a floor on labor price (at one half the prevailing wage rate) below which labor goes into other uses—handicraft, off farm industry, work on other farms, or leisure.
i) Labor hiring—acquisition of extra labor for farming. These activities supply labor to the labor balance and enter the cost of hiring into farm net income.
j) Income—a variable which gives the numerical value of the risk adjusted farm net income for the sharecropper and landowner. These activities are weighted in the composite objective function by the weights λ_1 for

have been utilized (Cheung; Candler *et al.*; Holmstrom). The particular approach used was chosen because of the authors' familiarity with it, its simplicity, a feeling that there is negotiation involved in the establishment of share contracts, and time-complexity constraints on the research project.

[4] The model structure is abstracted below. Each party's model had 54 variables and 26 constraints. The total model had 109 variables and 52 constraints.

[5] The constant transforms the model so that the risk measure is standard error, as discussed in Hazell, and Brink and McCarl.

TABLE 1. Linear Programming Model Schematic.[a]

	Landlord's Activities									
	Crop Production	Livestock Production	Crop Sale	Crop On-Farm Consumption	Risk Bearing	Crop Purchase	Livestock Sale	Labor Reservation	Labor Hiring	Income
Overall Objective										1
Landlord										
Land	+	+								
Labor	+	+						+	−	
Crop Product Balance	−		+	+						
Livestock Product Balance		−					+			
Risk Balance	+				+					
	−									
Capital	+	+								
On-Farm Consumption Needs		+		−		−				
Net Income	−	−	+		−	−	+	+	−	−
Sharecropper										
Land										
Labor										
Crop Product Balance										
Livestock Product Balance										
Risk Balance										
Capital										
On-Farm Consumption Needs										
Net Income										

[a] Pluses and minuses refer to signs of coefficients in cells.

the landowner and λ_2 for the tenant, as in multiobjective programming.

Sets of the above activities are defined both for the landlord and the tenant (as portrayed in Table 1). In addition an activity is entered which depicts the tenancy contract. This activity transfers land and income from the landlord's balances into the tenant's, simultaneously transferring cotton, cowpeas, corn or sorghum, and labor to the landlord.

These activities operate within the context of constraints on each party. The constraints represent the availability of land, labor during 9 annual periods and capital; product balances; risk rows (as in Hazell's negative deviation version of MOTAD); on-farm consumption requirements; and individual, risk-adjusted net farm income. An overall objective maximizes the summed, differentially weighted, risk adjusted, net farm income of the two parties.

Model Specification

Details on the exact model equations and their numerical specification are presented in Brandao. The majority of the data were drawn from the project "De-

TABLE 1. Extended.

Sharecropper's Activities											
Crop Production	Livestock production	Crop Sale	Crop On-Farm Consumption	Risk Bearing	Crop Purchase	Livestock Sale	Labor Reservation	Labor Hiring	Income	Tenancy Contract	RH5
									2		
											+
										+	+
										−	
											0
										−	
											0
											0
											+
											−
										−	=0
+	+									−	+
+	+						+	−		+	+
−		+	+							+	0
	−					+					0
+				+							0
−											
+	+										+
	+		−		−						−
−	−	+		−	−	+	+	−	−	+	=0

velopment Alternatives for Low-Income Groups in Brazilian Agriculture" (Singh *et al.*). Data were also drawn from reports by the Banco do Nordeste do Brazil; Patrick and Carvallo; and Teixeira. Risk aversion parameters applicable to an approximation of the standard deviation of income (as in Brink and McCarl) for the landlord (1.2) and the tenant (0.9) were drawn from Dillon and Mesquita. In addition, data on new cropping practices were drawn from Dias and Sanders 1976, 1979; Sanders and Dias; and Sanders *et al.* The technical data for the landlord and sharecropper are mostly identical; how-

TABLE 2. Landlord's and Tenant's Incomes with Different Income Weights (in Cruzeiros).[a]

Relative Weights		Landlord's Income	Tenant's Income	Total Income
λ_1[b]	λ_2[c]			
0.0001	0.999	3,749	5,373	9,122
.33	.67	4,984	3,984	8,968
.5	.5	6,430	3,079	9,509
.56	.44	6,469	3,031	9,500
.67	.33	6,486	3,009	9,496
.999	0.001	5,374	2,258	7,632

[a] These results were generated using the traditional technology data and zero risk aversion coefficients.
[b] λ_1 = relative income weight for the landowner.
[c] λ_2 = relative income weight for the sharecropper.

TABLE 3. Results of Practice Experiments.

	Traditional	Animal Traction	*Bosque Denso*	*Bosque Denso-* Sorghum
Landlord				
Income (CR $)	5,317	8,094	7,536	6,343
Livestock (Animal Units)	3.33	0	4.6	6
Land Cultivated (Hectares)	7.14	19.57	1.76	0
On-Farm Use of Own Labor (Man/Days)	276	448	192	91
Tenant				
Income (CR $)	2,498	3,381	1,446	3,258
Livestock (Animal Units)	0	0	0	0
Land Cultivated (Hectares)	7.78	11.98	6.8	1.41
On-Farm Use of Own Labor (Man/Days)	324	421	594	67

ever, the prices for crops were lower for the tenant because of timing of crop sales (caused by a need to repay credit at harvest).

Model Experiments

Three sets of experiments were performed. The first set consisted of calibration experiments, to establish the values of the objective function weights for the two parties (λ_1 and λ_2, in Table 1). The second set of experiments constituted the technological appraisal. The third set of experiments dealt with sensitivity to selected parameter changes.

Calibration Experiments

The calibration experiments involve systematic alteration of the landlord's (λ_1) and tenant's (λ_2) relative objective function weights (Table 2). The results were compared with sample data and past experience to develop appropriate weights for further experimentation. The weights selected were those that yielded the amount of land sharecropped and the associated cropping patterns which most closely matched sample data and the researchers' expectations utilizing the method given in Brink and McCarl (alternative methods are reviewed in Barnett *et al.*). Values of 0.56 for the landlord and 0.44 for the tenant were chosen. Thus, in all further experimentation the landlord's income was treated as 25 percent more important than the sharecropper's income.

Cropping Practice Experiments

The second set of experiments involved investigation of the alternative cropping practices. A model solution was generated for each of the four practices (Table 3).

Under *traditional* practices the total income was CR $7,815,[6] with 68 percent accruing to the landlord and 32 percent to the tenant. The landlord allocates 53 percent of his land holding to raising livestock, 23 percent to crops, while 24 percent is sharecropped by the tenant who grows all crops. Cotton was the only crop sold to the market. The other crops were grown entirely for on-farm consumption. In addition, the tenant purchased cowpeas and corn in order to satisfy minimum levels that were not fulfilled with farm production. Most of the available capital was idle for both farmers. The results indicate that the landlord reserves (seeks off farm employment with) 76 percent of family labor, while the sharecropper reserves 55 percent of family labor. This proportion does not include the labor the tenant exchanges for the land sharecropped.

[6] In 1977, 1 CR = 0.0623 U.S. $.

Under the *animal traction* practice, total income was CR $11,475. The landowner received 71 percent of this income, and the sharecropper 29 percent. Livestock were not raised, all the land was used for crops. The landlord rented 28 percent of his land to the tenant, and sold a quantity of all three crops. The tenant was able to sell small quantities of cowpeas and a greater quantity of cotton than under the traditional practice, but still needed to purchase corn for consumption. The capital stock was used more intensively than under traditional practices, but was not a binding resource. The results indicated that the landlord reserved 47 percent of his family labor while the sharecropper reserved 45 percent.

In the *Bosque Denso* practice, where cowpeas and corn are planted along with cotton, the total income was CR $8,982. The landlord received 84 percent of the income and the tenant 16 percent. The landlord used 73 percent of available land for raising livestock, 6 percent for crops, and cropshared 22 percent. The landlord and the tenant both sold quantities of all three crops to the market. Once again, part of the capital stock was idle for both farmers. The results indicated that the landlord reserved 87 percent of his family labor. On the other hand, the tenant needed to hire 112 units of labor in period 9 (cotton harvest), while reserving 22 percent of his available family labor in other periods.

Under the *Bosque Denso* practice with sorghum the total income was CR $9,601. The landlord's income was 66 percent of the total and the tenant's 34 percent. The landlord did not cultivate any crops, allocating 96 percent of available land to raising livestock, with the remaining 4 percent rented to the tenant. The quantity of crops the tenant produced satisfied both parties' consumption requirements. The landlord received more sorghum than required for consumption and sold the surplus. Both farms sold cotton. Since the landlord only raised livestock, most of his capital stock was idle. All of the landlord's family labor was reserved for off farm use. The tenant's labor was exchanged under the sharecropping arrangement and used to care for livestock. The tenant reserved 83 percent of his family labor.

Cropping System Comparisons

Assuming that the four basic models and their embodied parameters represent the farmer's behavior and constraints reasonably well, the animal traction practice leads to the greatest collective total income increase. However, another technology may be superior from a distribution of income perspective. The *Bosque Denso*-sorghum practice narrows the difference between landlord and sharecropper incomes while still providing increased income for all; i.e., a Pareto welfare improvement (Just *et al.*). However, this narrowing of income disparities comes at the expense of the overall level of income, and the income of both parties relative to the animal traction practice. (Thus, this is confirmed by the findings of Sanders and associates which also show benefits from sorghum adoption although they did not consider *Bosque Denso*.)

The choice between the technologies possesses an interesting dimension when one regards the amount of food produced and the level of on-farm employment. Animal traction appears to be the best technology for food production and employment as it induces the largest a) acreage of crops, b) marketable surplus and c) employment. The practices other than animal traction had the interesting effect of increasing the efficiency of cropping, allowing the farms to shift resources out of cropping into livestock. Further, animal traction provides the greatest amount of on farm employment. This is an important point to be considered since there are not many opportunities to work off the farm within this region. Animal traction

TABLE 4. Results of Policy Motivated Experiments.

	Land Availability				Tenant Land Availability	Price Equalization	Labor Regime Elimination
	31.56 ha (Base)	35 ha	40 ha	65 ha			
Landlord							
Income (CR $)	5,317	5,651	6,137	8,564	5,317	5,326	5,349
Livestock (Animal Units)	3.33	3.99	4.96	9.81	3.33	3.35	2.13
Land Cultivated (Hectares)	7.14	7.14	7.14	6.88	7.14	6.47	11.37
On-Farm Use of Own Labor (Man/Days)	276	275	274	268	276	266	323
Tenant							
Income (CR $)	2,498	2,493	2,486	2,450	3,198	2,608	2,469
Livestock (Animal Units)	0	0	0	0	2.24	0	0
Land Cultivated (Hectares)	7.78	7.91	8.10	9.07	2.94	8.26	13.54
On-Farm Use of Own Labor (Man/Days)[a]	324	331	342	373	166	350	376

[a] Includes labor exchanged to landlord.

also led to both the landlord and tenant selling crops in the market (i.e., creating a marketable surplus). This is significant because an important role of agriculture in the development process involves supplying food for the nonfarm sector.

Sensitivity Experiments

As an alternative means of increasing the incomes of landowners and sharecroppers, a number of sensitivity runs were conducted which were constructed to be suggestive of development policies (Table 4). The first set of runs contained experiments suggestive of alterations in land holdings. These included a number of changes in the endowment of land. An increase in the availability of the landlord's land had the effect of increasing total income as well as the landlord's income. But the tenant's income decreased slightly with each change. Income for the landlord was less than the income under animal traction until the landowner's plot was equal to 65 hectares (more than double the size assumed in the model). The effect of "giving" land to the tenant (i.e., land reform) was also examined. Seven hectares (an amount approximately equal to the amount rented under the traditional practice) of land were added to the tenant's land area without change in the landlord's endowment. This increased the tenant's income from CR $2,498 to CR $3,197, while the landlord's income remained constant. The tenant still sharecropped land, while substantially increasing the quantity of livestock reared. Compared to animal traction, the landlord's income was substantially smaller, but the tenant's income was almost as large. Total income, however, was smaller. Hence, technology appears to have a larger effect than land reform. (These results are not entirely consistent with those of Kutcher and Scandizzo, 1981.)

Another means of increasing income

(mainly the tenant's) involves the equalization of crop prices. The landlord received relatively higher prices than the tenants. This was because the tenants generally sold crops at depressed harvest season prices because they faced cash flow problems. Prices could be equalized by a number of policy means, for example, credit policies. When tenant prices were the same as the landlord's, the tenant's income increased by four percent while the landlord's remained approximately constant.

Finally, an elimination of the labor exchange under the sharecropping system was analyzed. Thus, the landlord hired the tenant at the full wage when extra labor was needed. In this experiment, the landlord sharecropped slightly more land. However, very little change occurred (less than 5%) in total income.

Conclusions

Conclusions regarding several issues may be drawn from the above analysis. These include: a) the impact of new cropping practices, and the identification of the "best" practice; b) the desirability of new practices versus other methods for regional development; c) the welfare costs of the sharecropping *regime de subjeicao.*

The analysis points out, assuming the model is adequate, that new cropping practices are a means of increasing incomes in the study area (as also argued in the papers by Sanders and associates). The results, however, are somewhat counter intuitive. Improved cropping patterns (i.e., *Bosque Denso*) do not lead to income improvement through cropping (unlike the results by Sanders and associates); rather, resources were moved from cropping into livestock. The improved cropping patterns made the farmers more efficient producers of subsistence crops, releasing resources to livestock, where income gains were realized. If this occurred (arguments could be mounted that it occurred in this case because the livestock returns data were too high), the adoption characteristics of the new practice would be unusual in that adoption led to a reduction in cropped acreage. This, if accurate, shows the benefit of farming systems analyses as opposed to cropping system analyses.

Income distributional implications of the practices are also important. The most striking distributional change came from the animal traction technology. Income of both parties, marketable surplus, and labor use all increased. Simultaneously, however, the skewness of income distribution shifted. The results under the various technologies suggest that a more favorable income distribution technology results from *Bosque Denso*-sorghum. This and the animal traction result seem to indicate the potential attractiveness of a new cropping practice which would combine animal traction and *Bosque Denso*-sorghum. (This would need to be developed by farm level research.) Another interesting aspect of the results involves the differential effects of the practices on income. *Bosque Denso* showed increased total income but decreased sharecropper income. Each of the alternatives resulted in different gains to the different parties. These results demonstrate that careful attention needs to be paid to distributional concerns when implementing new practices in this region.

Switching now to the alternative development strategies, two experiments were done which are suggestive of other development policies. The sensitivity experiments involving "giving" land are suggestive of a land redistribution scheme. These experiments exhibited a smaller impact on income than did the technology experiments (in contrast to the findings of Kutcher and Scandizzo, 1981). Second, the sensitivity experiments eliminating the price differentials between the landowner and the sharecropper are suggestive of rural credit policies which would alleviate the need to sell at harvest; programs leading to increased market information; and/or grain price stabilization programs. These results indicate that such policies could be successful in increasing rural incomes. New practices, however, led to larger increases in rural income than either of these types of policies.

Regarding the welfare effects of the *regime du subjeicao*, the sensitivity experiments indicate that land redistribution, accompanied by a removal (in the model) of this regime, leaves income to both parties essentially unchanged. This suggests that this regime has minimal welfare costs.

Finally, in closing, we should note that linear programming evaluations such as this one have been criticized for being hypothetical, overly simplistic and/or generally inaccurate (see the discussion in Anderson and Hardaker). In particular, this is a farm level analysis and as such is dependent upon the price and other assumptions made. As noted by O'Mara, the price assumptions may be very critical in the face of a major expansion in production (e.g., we do not consider the change in prices which could result from expansion in production of livestock or crops). Consideration of market effects may lead to very different prices which would require further analysis. However, we agree with Shaner *et al.* who prominently mention linear programming stating ". . . that searching through a range of feasible solutions is generally complex and time consuming. Instead some form of modeling is usually required . . . linear programming . . . such studies are long range approaches that when integrated with . . . on farm research, help in setting the directions of future research" [p. 126]. We use linear programming modeling here to do a) comparative budgeting-projection of consequences; b) comparisons with alternative development strategies; c) identification of important issues. We feel that the benefits of such an exercise outweigh its drawbacks.

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