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The Village Level Impact of Machine Threshing and Implications for Technology Development in Semi-Arid Tropical India

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The Village Level Impact of Machine Threshing and Implications for Technology Development in Semi-Arid Tropical India

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Should research institutions in the public sector invest scarce resources in the evaluation and design of threshing technologies for the Semi-Arid Tropics (SAT) of India? This question is multifaceted, but it can be simplified into two dimensions--consequences and comparative advantage.

Consequences ultimately relate to who gains, who loses, and by how much from the adoption and diffusion of new threshing technologies. At best, new threshing technologies may directly increase productivity and have a beneficial impact on employment by breaking labor bottlenecks that constrain sequential cropping. At worst, mechanical threshers may have a slight advantage in cost reduction compared to traditional techniques, a negligible impact on output, a sharp labor-displacing effect, and a pronounced tendency to widen disparities in income.

Comparative advantage refers to who does the research and development on mechanical technologies: the private or public sector. Historically, most mechanical inventions and resulting innovations in agriculture have been designed by tinkers, other village artisans, and small-scale industrial entrepreneurs. If there was a demand for new mechanical technology the private sector has responded with a supply of innovations. Some would argue that the market for mechanical technologies in developing countries does not function efficiently (Duff 1980; Johnston 1980). A lack of incentives and infrastructure constrain the ingenuity of inventors and innovators; therefore, public sector research has an important role to play in the design and evaluation of mechanical technologies.

In order to make a sound case for public sector research in threshing and related postharvest technology, one first has to show that the market for mechanical innovations does not function properly and document why. Secondly, the need for new technologies has to be demonstrated so that we are assured that these technologies have a reasonable chance of adoption and that when they are accepted by farmers they will have a beneficial impact on society.

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This study looks at the second or "consequences" condition and measures the effects on cost, output, and employment from the introduction of mechanical threshers at the village level in SAT India. The study relies on data from the ICRISAT Village Level Studies (VLS) (Binswanger and Jodha 1978). The VLS data are ideally suited for impact analysis because they can furnish a "before and after" evaluation along with a "with and without" comparison. Most other impact statements draw inferences exclusively from a "with and without" comparison which is vulnerable to multiple confounding effects of uncontrolled variables that are positively correlated with mechanization over time. Most other studies have analyzed mechanical threshing of irrigated wheat or rice; this research focuses on the prospects for and impact of mechanically threshing rainfed sorghum which is a staple food crop in SAT India.

After a brief review of innovations in mechanical threshing in India, several conceptual issues that condition consequences in SAT India are outlined. This outline provides a framework for taking microscopic snapshots of the village level consequences of the diffusion of threshers over time. Because direct output effects from new threshing technologies are likely to be small, the private profitability of machine threshers and the size of cost reduction vis-à-vis traditional techniques are central themes for analysis. Particular attention is given to price determination for machine hiring within the village economy. The paper concludes with comments on implications for research policy on potential threshing technologies in SAT India.

RECENT INDIAN EXPERIENCE WITH THRESHERS
AND PROSPECTS FOR SAT INDIA

The demand for threshers has rapidly expanded in India over the last 15 years. Most of the growth in demand was sparked by the introduction of high yielding wheat varieties in the Punjab, Haryana, and Uttar Pradesh. The early maturing, high-yielding varieties, together with a rising investment in tubewells expanded the opportunities for double cropping and stimulated the demand for seasonal threshing labor which in turn precipitated rapidly rising seasonal wages. Higher wages made threshers a decidedly attractive investment, and the changing economic conditions did not go unnoticed by agricultural engineers and researchers. In 1966 "in recognition of its great importance, the Indian Council of Agricultural Research (ICAR) offered a prize award for the best prototype design of a low horsepower thresher (Roy 1970, p. 541)." The private sector rapidly responded to rising demand by designing simple threshing innovations. Indicative of this response was the finding that the number of mechanical threshers per 100 farmers in four sampled districts of the

High-Yielding Varieties Program in the Indian Punjab increased from 2.50 in 1965 to 25.75 in 1970 (Lockwood, 1972).[1]

In contrast to the highly productive irrigated regions, diffusion of threshers in the SAT of India has not been widespread. For example, by 1972 the density of threshers per 1,000 cultivated hectares was 16.3 for the Indian Punjab compared to .65 for predominantly rainfed Maharashtra. Between 1972 and 1977 the number of threshers increased from about 75,000 to approximately 215,000 in Uttar Pradesh, while comparable estimates for Maharashtra show an expansion from about 1,000 to 5,000 (Directorate of Economics and Statistics 1980). The vast majority of threshers in use are designed for the threshing of wheat and rice.

Several characteristics unique to SAT agriculture in India dampen the demand for new threshing technologies. Before analyzing these characteristics it is worthwhile to examine the ways in which threshers directly or indirectly increase productivity. Increased productivity can be partitioned into reduced cost, increased output, and higher price effects. In SAT India, any advantage in cost reduction is dampened by prevailing low real wages for agricultural labor. In the immediate future, sharply rising real wages are unlikely; therefore, relative costs are not apt to change quickly. Threshers may directly affect output by decreasing turnaround time from harvesting to threshing. Improved timeliness can decrease the risk of postharvest losses due to inclement weather. New threshing technologies can indirectly enhance output by breaking labor bottlenecks that limit cropping intensity. They can also be instrumental in stimulating the diffusion of "latent" technologies such as high-yielding cultivars that are difficult to thresh (Singhal and Thierstein, 1979). A more efficient technique may also produce grain that commands a higher market price because it is cleaner with a lower percentage of brokens (ICRISAT 1980, p. 193). Some threshers can also chaff cereal straw into a finer quality fodder that fetches a higher price than unthreshed straw. Most of these benefits can be measured economically in a producer-consumer surplus framework (Currie et al. 1971), but first they have to be documented and evaluated in a specific socioeconomic and agroclimatic context.

Profitability of mechanically powered threshers in the SAT is further restricted by yield risk. In less assured rainfall environments, yield uncertainty means that a "lumpy" capital investment like a thresher has an uncertain utilization rate and benefit stream. In poor years, depressed

1. Even in the Punjab under the best of circumstances with the rapid expansion in irrigation and introduction of seed-fertilizer technology, machine threshing was not an innovation that benefited all segments of the population (Ladejinsky 1969). Mechanical threshing is a prime candidate why wages to landless laborers and to migrants from other states did not keep pace with rising profits to farmers and with spiralling land prices. The impact of mechanical innovation on migration is a neglected area of research

output is synonymous with lower utilization and reduced profitability. Because the majority of farmers in the SAT are small landholders, many potential owners will have to hire out their threshers in order to amortize cost. Hiring out has many positive features but it means that in years of adverse weather the owners of threshers cannot compensate for low yields by charging a higher price. Bullock treading and hand beating, the most common traditional methods, are substitutes for machine threshing and provide an effective price ceiling on what owners of machine threshers can charge.[2]

In contrast to irrigated agriculture, cropping intensity in the SAT is low and barely exceeds 100 (Jodha 1980). Although new technologies may increase cropping intensity in the SAT, potential cropping intensity in dryland agriculture does not approach what can be obtained with irrigation. Thus, there is less economic incentive for breaking seasonal labor bottlenecks to promote double cropping.

In summary, we would expect that the demand for threshers is limited in SAT India by revenue uncertainty, low wages, and the scarcity of double cropping opportunities. These hypotheses are examined in the village level study described in the next section.

VILLAGE LEVEL ADOPTION OF MECHANICAL THRESHERS

Typical of much of SAT India, the traditional mode of threshing cereals and pulses in Kanzara is by bullock power and human labor. Kanzara is located in Akola district in the rainfed Vertisol, cotton-growing region of Maharashtra. Cotton is generally row intercropped with local sorghum and pigeonpea in the rainy season. Hybrid sorghum (mainly CSH-1) is sole cropped at the start of the monsoon. Other pulses are also grown and threshed in the village. Threshing begins after the harvest of mung bean (green gram) in September and ends after the harvest of irrigated wheat in March. Threshing activity intensifies in October, December, and March after the harvests of hybrid sorghum, local sorghum, and wheat respectively

Most threshing in Kanzara takes place on the gothan or common cattle pasture and corral area, which is located on government land near the village. A central location for threshing has a number of advantages. The gothan is located in an open area where higher wind velocity aids winnowing. A central location also facilitates information exchange on bullock and labor availability in the village.

2. This observation assumes that mechanization has been selective and has not precipitated the selling off of draft power. For the village under study, both the observation and assumption are valid.

Each farmer prepares a circular threshing yard on the gothan. A wooden pole is placed in the center of the yard and is used to tie bullocks while threshing. Grain is threshed by the trampling of bullocks; bullock carts are seldom used for threshing in Kanzara.

Introduction and Diffusion of Threshing Technologies

The first thresher was introduced into the village in 1976. By 1980 five threshers owned by different villagers had been purchased.[3] In 1980 four threshers were operating, two in the village and two outside the village.

The threshers run on diesel or electric motors ranging from 5-10 hp and are designed for threshing wheat.[4] The threshers are manufactured by two firms in Punjab and are distributed through dealers located about 60 kilometers from Kanzara. The investment cost of the machines with motor and attachments ranges between Rs. 6,000 and Rs. 10,000. Few farmers have production sufficient to make threshers a remunerative investment without hiring out their machines. In order to increase the utilization of machines, some owners have taken their threshers outside the village. Since the threshers are portable, they can also thresh grain in a farmer's field.

The most salient feature about threshing in Kanzara is the rate structure that owners of threshers have adopted to promote increased utilization of thresher capacity over the season. For sorghum, regardless of the size of output, they retain 4% of production as a payment for threshing. The first owner in 1976 appears to have skillfully calculated what the market would bear when he introduced the 4% charge which has not changed in the last five years. Machine owners have not attempted to increase their rate of utilization by underpricing their competition through lowering the in-kind fee for threshing.

Threshing technology rapidly diffused throughout the village. With the time series of VLS data, one can track the use of threshing technologies for a sample of 30 farmers in Kanzara over the last five years. By any measure of adoption presented in Tables 1 and 2, mechanical threshing has rapidly displaced traditional methods. By 1978-79, about 99% of

3. Four of the five owners are large farmers and belong to higher castes in the village. The fifth purchaser is a close relative of one of these owners. The five owners have on average nine years of schooling; the village average for male heads of household is three years.

4. Only one owner has used his thresher motor as a prime mover for other mechanical operations such as chaff cutting. The other four owners have used their machines exclusively for threshing.

Table 1. Method of threshing hybrid sorghum (CSH-1) in Kanzara by output, number of plots, and respondents.

Method of threshing	Cropping year				
	1975-76	1976-77	1977-78	1978-79	1979-80
	-- percent of output --				
Hand	18	1	16	1	0
Bullock	82	29	3	0	7
Machine	0	71	82	99	93
Output (Kgs)	14243	20224	19867	9412	16800
	-- percent of plots --				
Hand	47	4	17	22	5
Bullock	53	23	3	6	9
Machine	0	73	80	72	86
No. of plots	19	26	30	18	22
	-- percent of respondents[a] --				
Hand	44	6	9	27	6
Bullock	56	12	5	7	11
Machine	0	88	91	73	89
No. of respondents	16	17	22	15	18

a. Column totals may sum to more than 100 because some farmers use more than one threshing method.

Table 2. Method of threshing local sorghum in Kanzara by output, plots, and respondents.

Method of threshing	Cropping year				
	1975-76	1976-77	1977-78	1978-79	1979-80
	-- percent of output --				
Hand	28	14	14	17	27
Bullock	72	27	4	17	21
Machine	0	59	82	66	52
Total output (kgs)	14353	12865	5494	5346	8067
	-- percent of plots --				
Hand	43	41	35	50	57
Bullock	57	20	2	14	15
Machine	0	39	63	36	28
Total No. of plots	49	59	49	50	68
	-- percent of respondents[a] --				
Hand	48	52	45	76	83
Bullock	65	12	5	12	21
Machine	0	52	60	24	29
No. of respondents	23	25	20	25	24

a. Column totals may sum to more than 100 because some farmers use more than one threshing method.

hybrid sorghum was threshed mechanically (Table 1). Mechanical threshing of local sorghum reached a peak in 1977-78 at about 82 percent of threshed output (Table 2). By 1979-80, all farmers in the sample had relied on mechanical threshers to thresh at least a part of their produce. Moreover, by 1977-78 all wheat produced by farmers in the Kanzara sample was threshed by machine. Other crops were not mechanically threshed.

The data in Tables 1 and 2 also suggest that mechanical threshing has not strictly dominated traditional techniques. Many farmers in 1979-80 reverted back to traditional techniques.

Access to Mechanical Threshers

Farmers in the village had relatively equal access to the new threshing technology. Because of land fragmentation, plot size is small. For all production levels above 50 kgs, machines displaced both traditional methods of threshing (Table 3). The produce from about 80% of small plots yielding 50 to 200 kgs of hybrid sorghum was threshed by machine from 1975-76 to 1979-80 (Table 3).

The in-kind payment charged for mechanical threshing effectively eliminated any potential purchasing power constraints or liquidity problems facing low-income farmers. The term of payment at a fixed percentage of threshed output stimulated an effective demand for the new technology and transformed a lumpy capital investment into a highly divisible input. Mechanical threshing was probably a particularly attractive alternative for low-income farmers who did not own bullocks or who incurred substantial transactions cost for hiring bullocks. One can also speculate that an in-kind fixed percentage payment also maximized utilization and developed in response to the operational farm structure in Kanzara where many farmers seasonally produce small quantities of cereals.

COST REDUCTION, PROFITABILITY AND
PRICE DETERMINATION

The widespread use of threshers in Kanzara indicates that it was profitable to thresh with machines. Direct economic superiority may stem from a reduced per unit cost of converting harvested produce into threshed grain, decreased threshing losses or a higher output price reflecting cleaner grain or a lower percentage of brokens. Survey evidence suggests that threshing losses and output price do not vary significantly by threshing technique. Therefore, it is assumed that direct benefits attributed to mechanical threshing must result from a lower per unit cost.

Table 3. Distribution of size of output by threshing method by cultivar from 1975-76 to 1979-80.

Size of threshed output per plot in kgs	Sorghum cultivar and method of threshing					
	Local[a]			Hybrid[a]		
	Hand	Bullock	Machine	Hand	Bullock	Machine
	--Percent of plots threshed in each size category--					
20 - 50	77	10	13	50	16	33
51 - 100	41	22	37	20	0	80
101 - 200	35	24	41	21	0	79
201 - 500	20	34	46	36	22	47
501 - 1000	0	30	70	11	39	36
1001 - 2000	0	0	100	7	27	66
2001 - 4000	-	-	-	0	25	75

a. Row totals by cultivar may not sum to 100% because of rounding.

Cost Savings with Mechanical Threshers

Costs are compared for the three techniques by first calculating average input-output coefficients based on the assumption of a fixed-coefficient production function where constant returns to scale and input combinations in fixed proportions are assumed. These coefficients are presented in Table 4 and represent the average number of hours taken to thresh one quintal of sorghum. They are estimated from data on all 367 sorghum plots in the Kanzara sample from 1975-76 to 1979-80.[5] For both hybrid and local cultivars and for the three threshing methods, male hired labor is the largest component of input. On average, hybrid CSH-1 was easier to thresh than local varieties. CSH-1 generally has more grain per head and this may be the reason for the differences in bullock and human labor intensity between hybrids and locals.

The choice of threshing technique by the farmers in Kanzara is a function of bullock hire prices, hired male wages in the casual labor market, the opportunity cost of male family labor, and the expected price of sorghum. Higher bullock hire and male wage rates, and lower output prices, favor machine threshing. As the sorghum:hired labor and sorghum: bullock price ratios rise, traditional methods become more economically attractive.

Comparative cost data in Tables 5 and 6 reveal that the direct cost savings attributable to threshers are not large. The estimates in Table 5 are obtained by multiplying the coefficients in Table 4 by the average annual yearly price and wage data in Appendix Table 1 (Asokan 1980). The same wage rates were used for family and hired labor. Mechanical threshing of local sorghum had a slight edge over bullock treading and hand beating from 1976-77 to 1979-80. Although the relative savings in cost was on the order of 20%, the absolute cost savings was only one to two Rs. per quintal which generates a small, almost negligible, savings in value of production. For hybrid sorghum over the same period, machine threshing does not have a clear-cut advantage over bullock treading (Table 5). Because different farmers have different price expectations and opportunity costs of family labor, we should not be surprised to see all three techniques being used in the village in the same year.

Profitability of Mechanical Threshing

The profitability of mechanical threshing is directly tied to cereal production in the village. A few calculations highlight this point. Suppose all sorghum and wheat harvested in Kanzara is threshed by machine. Under

5. Because farmers sometimes mix produce from different plots before threshing the number of observations is less than 367.

Table 4. Labor and bullock inputs required to thresh and winnow one quintal of sorghum by cultivar and method from 1975-76 to 1979-80 in Kanzara.

	Hybrid			Local		
	Hand	Bullock	Machine[b]	Hand	Bullock	Machine[b]
	-- Hours per threshed quintal --					
Male family	2.74	0.39	0.48	3.98	2.46	0.83
Female family	0.00	0.09	0.12	3.01	0.11	0.07
Male hired	5.48	4.16	1.09	6.15	4.07	1.38
Female hired	3.44	0.25	0.03	2.72	0.02	0.00
Total human labor	11.66	4.89	1.72	15.86	6.66	2.28
Bullocks owned[a]	-	1.18	-	-	1.82	-
Bullocks hired[a]	-	0.21	-	-	0.27	-
Total bullock labor	-	1.39	-	-	2.09	-

a. Refers to a bullock pair.

b. Refers to the requirements of the farmer who hires the machine.

Table 5. Cost of threshing Hybrid Sorghum by method and cropping year in Rupees per quintal and in percent of value of output.

Cropping year	Technique					
	Hand	Bullock	Machine	Hand	Bullock	Machine
	--Rupees per quintal--			--Percent value of output--		
1975-76	5.16	4.23	-	5.38	4.41	-
1976-77	4.61	3.70	4.68	4.70	3.78	4.77
1977-78	5.95	4.77	4.52	6.68	5.36	5.08
1978-79	5.50	4.20	4.89	5.50	4.20	4.89
1979-80	5.92	4.64	5.57	5.14	4.04	4.85

Table 6. Cost of threshing local sorghum by method and cropping year in Rupees per quintal and percent value of output.

Cropping year	Technique					
	Hand	Bullock	Machine	Hand	Bullock	Machine
	--Rupees per quintal--			--Percent value of output--		
1975-76	6.75	6.12	-	6.49	5.88	-
1976-77	6.04	5.33	4.42	7.18	6.34	5.26
1977-78	7.83	6.86	5.34	7.83	6.86	5.34
1978-79	7.26	6.03	5.22	7.26	6.03	5.22
1979-80	7.76	6.67	5.80	6.74	6.07	5.23

some reasonable assumptions[6] based on the VLS data and Singhal and Thierstein (1979), we estimate an internal rate of return to management and capital of over 100% when one machine of 300 kilograms per-hour capacity threshes all available produce. If another thresher of the same capacity is brought into the village and the two machines divide equally the harvest, expected profitability on each thresher falls to 30%. Introduction of a third machine of identical vintage results in a 13% return, while the addition of a fourth thresher cuts the internal rate of returns on investment to an unprofitable 4%.

Unless cereal productivity increases sharply, the purchase of additional machines over and above replacement will erode the profitability of existing machines. Lower profitability will in turn curtail investment demand for low horsepower threshers. What happens to the rental rate for threshing as the supply of threshers increases in the village is analyzed in the next section.

Price Determination and the Diffusion of Machine Threshing

The data in Tables 5 and 6 do not make a compelling case for mechanical threshing. In order to explain the absence of a significant cost advantage, we have to answer two questions. Why did the first machine owner charge 4% and why has this percentage piece rate fee remained intact over the last six years despite the entry of other machines into the village? With the aid of hindsight, it is possible to draw on microeconomic theory to suggest answers to these questions and to add insight to the diffusion of mechanical threshing in Kanzara. We focus on the village and the peak period demand for and supply of threshing resources. The demand schedule (DD) in Figure 1(a) applies to the short-run, perhaps a two-week peak threshing period for hybrid or local sorghum. Demand is totally inelastic and is given by the size of the crop. The upward sloping supply schedule (SS) indexes the availability of bullock and human threshing labor for changes in their hiring rates (in rupees per quintal threshed). The supply of traditional threshing resources is determined by supply and demand conditions in the bullock and labor markets in the village and in neighboring villages. It is assumed that a hiring market for bullocks and labor exists

6 We assume that multiplying the sampled farmers' production by the inverse of the sampling fraction (27%) gives total production in the village from 1975-76 to 1979-80. Assumptions on the machine are an initial purchase price of Rs. 6,500, an operating cost of Rs. 15.38 per 8-hour day, a labor charge of one man-day to the machine owner, no maintenance expense, a useful life of six years, a zero salvage value, nontransferibility of machine parts such as the motor, and a fixed 4% in-kind payment of threshed grain. Sorghum and wheat are priced at Rs. 100 and 145 per quintal. These assumptions approximate 1975-76 when the first thresher was purchased in Kanzara.

Before mechanical threshing is introduced into the village, output Q_t is threshed with traditional resources at price P_0 [Figure 1(a)]. The area PBL under SS and to the left of DD represents payments to bullock owners and labor. Because some farmers employ their own bullocks and family labor for threshing, PBL is distributed to hired labor, owners of hired bullocks, and farmers who use family labor and bullocks for threshing.

One enterprising person in the village buys a thresher and faces the decision of what price to charge. Suppose he picks P_m, the intercept of the supply schedule SS with the price axis [Figure 1(b)]. We assume that mechanical threshing is a fixed coefficient technology; therefore, a machine can only thresh a fixed quantity (Q_1) of sorghum during the two-week threshing period. We further assume that at full utilization of capacity the thresher can thresh only a part of the village produce Q_t during the peak demand period. Thus, with the machine thresher, SS flattens out along its initial section, shifts to the right and is converted into S'S'. Q_1 is threshed by machine at price P_m; (Q_t-Q_1) is threshed by traditional methods at price P_0'. Farmers who hire the machine have to supply their own labor; therefore, the total cost of machine threshing to these farmers is P_f, which includes the payment to machine threshing labor MTL. P_f represents the variable nonlabor cost per quintal threshed for operating the machine. Payments to fuel and other variable inputs are reflected in TVC.

Machine threshing generates cost savings to producers of CSP. The size of CSP represents the magnitude of direct benefits to society due to the introduction of the thresher. PBL shrinks as profits and return on investment (PTO) accrue to the owner of the thresher.

It is in the interest of the thresher owner to charge a price that maximizes his return on investment PTO. If our owner had perfect knowledge of DD and S'S', he would have established P_m' as his revenue maximizing price [Figure 1(c)]. Under our assumptions, this is the highest price he can charge without losing some of his business to his traditional threshing competitors. At price P_m' he still threshes an amount (Q_t-Q_1') that equals Q_1. Because he threshes the same quantity as before, PBL, TVC, and MTL do not change. Profits to the owner expand at the expense of CSP, which is greatly reduced. The prices P_f' and P_0' facing farmers who machine hire and those who thresh with traditional techniques are the same. APTO represents an additional payment for perfect foresight.

Figure 1 illuminates many aspects of the thresher owner's pricing decision. His ceiling prices is P_m'. Any price above P_m' results in a loss of output to traditional threshing methods. P_f or nonlabor variable costs per unit of output threshed establishes the floor price. Assuming mechanical threshing is profitable, some price in the vicinity of P_c is probably a competitive price that provides an equitable return on

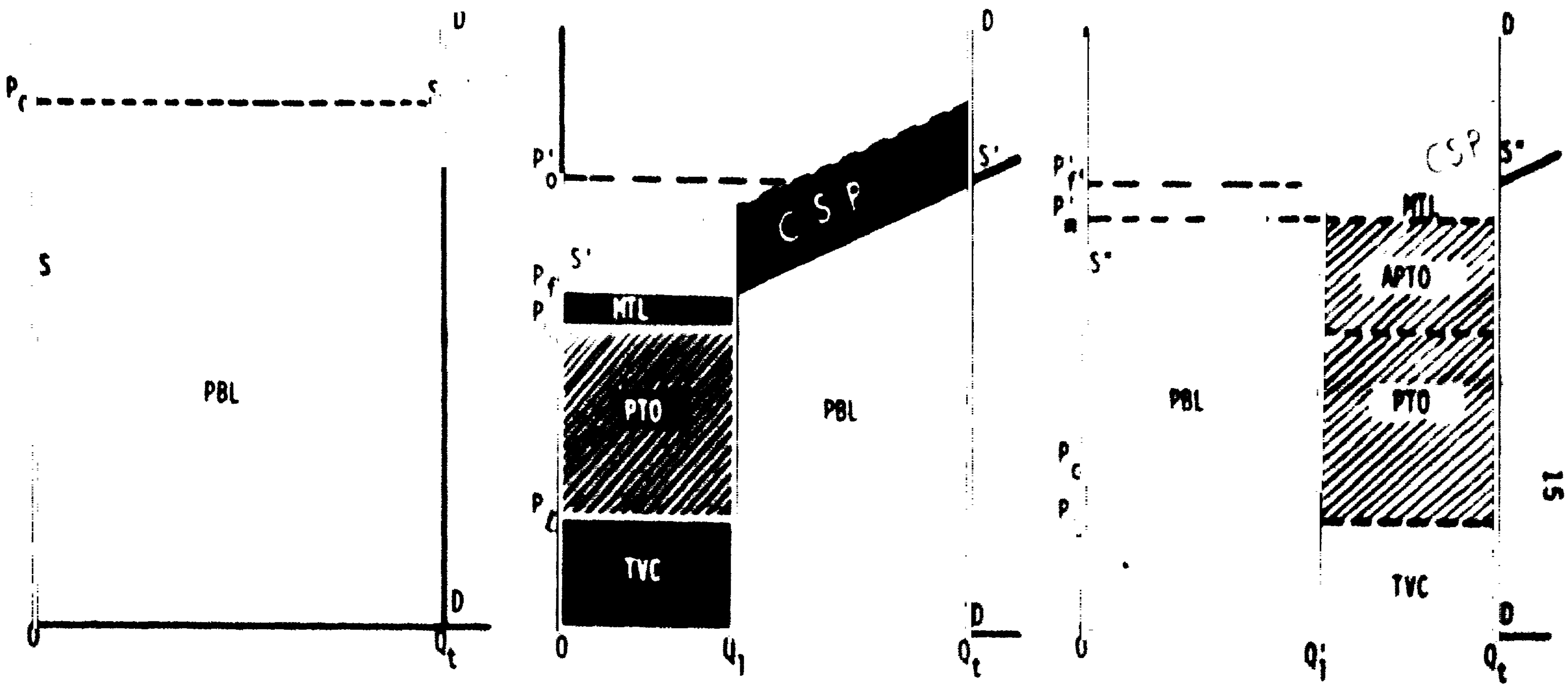

Figure 1(a)   Figure 1(b)   Figure 1(c)

Figure 1. Supply of and Demand for Threshing Resources at the Village Level.

investment. P_m' is probably too high a price to charge. In some years, village output may fall considerably short of Q_t. For example, if demand shifted to Q_1' and the owner opted for P_m' his returns would be nil; he would be forced to revise his price downwards.

The owner has to take a longer view when he forms expectations on OD and [illegible]. For the case depicted in Figure 1(c), his chosen price should fall between P_m' and P_c. As the price approaches P_m', direct benefits to society diminish and profits to the owner increase. If the owner chooses a price close to P_m' we should not see a significant difference between the per unit cost of threshing for mechanized and traditional techniques.

With the increasing entry of mechanical threshers into the village elementary economics would suggest that P_m would fall. Figure 2(a) describes the case where one thresher operates in the village and charges a piece rate price P_m. Q_1 is threshed by the single thresher and $(Q_t - Q_1)$ is threshed by traditional methods. Returns (PTO) on investment are large and may entice another resident in the village to purchase a thresher. The addition of a second thresher of identical vintage into the village translates into a reduced market share and decreased revenues to the first owner [Figure 2(b)]. The total quantity Q_t of unthreshed grain is not sufficient to maintain both machines at full capacity. In order to increase revenue and eliminate excess capacity, both owners are motivated to search for unthreshed grain outside the village. A strong external demand would likely attract one machine to move outside the village, and the returns to the other owner would be restored to the original position in Figure 2(a).

Suppose threshing resources in neighboring villages are abundant and/or demand is weak. Because external hiring out is not a highly profitable option, the only strategy available to the first owner to recover his market share is to change his price. Demand schedules facing each owner are drawn in Figure 2(c). Depending on the importance of timeliness and on the supply of traditional resources, prices above P_m will result in large decreases in quantity demanded and falling revenues. There appears to be some scope to increase revenues and machine utilization if the first owner unilaterally lowers his price to P_s on demand schedule OD'. As the first owner initially cuts his price in Figure 2(c) he will regain his market share at the expense of the second owner who naturally will react by matching the price of the first owner. As both decrease their price the size of PTO will shrink, and both will be worse off than before.

Demand schedule OD' is drawn on the assumption that the second owner will not react when the first owner changes his price. The first owner is not so myopic to think that he faces demand schedule OD'. He will realize the interdependency depicted in OD in the firm demand schedules; hence, there is no incentive to lower prices. Initial price P_m is the best that either owner can do to maximize revenue.

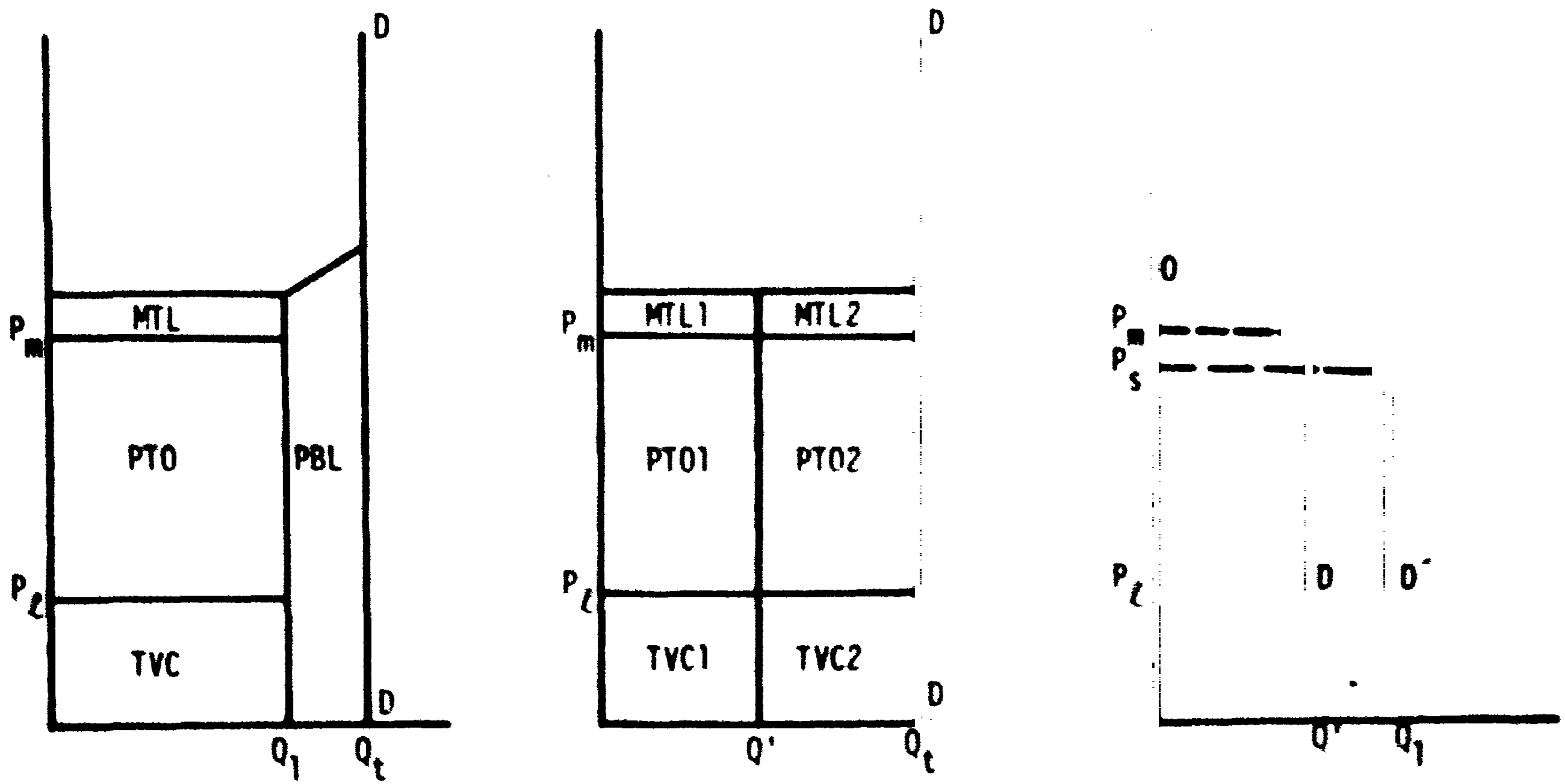

Figure 2(a)   Figure 2(b)   Figure 2(c)

Figure 2. Entry and Price Competition in the Village Threshing Market.

Even with the entry of more threshers into the village, it is not surprising to learn that the price for threshing has not changed in the last six years in Kanzara. We would expect the constancy of the piece rate payment to hold for other crops such as wheat. Although the spatial oligopsony, kinked-demand curve scenario illustrated in Figure 2 may not strictly apply to the rest of SAT India it explains some salient facts about the threshing market for cereals in Kanzara.[7]

SEASONALITY IN LABOR DEMAND
AND TIMELINESS

The wage data in the cost analysis in Tables 5 and 6 is based on annual averages by operation and may mask the importance of seasonal variables in threshing. Seasonality in the demand for threshing labor is hinted at by comparing the data in Tables 5 and 6 (which suggest that the cost advantage of machine threshing is greater for local varieties than for hybrids) with the diffusion data in Table 1 and 2, which clearly show that more hybrid sorghum is threshed by machine. Because threshing takes place during October for hybrids and December for local varieties, seasonality in daily wage rates and in the opportunity cost of labor could explain the differences in the use of mechanical threshing by cultivar type.

7. The pictures depicted in Figures 1 and 2 on price determination and on too many machines chasing too little demand is also supported by some isolated facts and observations. In Gujarat where wage rates for daily agricultural labor are higher than in Kanzara, owners of low horsepower threshers in the two VLS villages charge 5% (unpublished VLS data). During the 1980-81 season, the two owners operating threshers in Kanzara were extremely reluctant to have a third machine which was operating outside, return to the village. Singhal (1981) recently reported that when a private thresher owner heard about an ICRISAT test of a new design near his home village in Western Maharashtra "he rushed to the village... worrying about his business (1981, p.2)".

In March 1978, one of the thresher owners from Kanzara took his machine about 25 kms to a village for wheat threshing. In this village, the traditional payment was 16 kgs per 3 threshed quintals to hired labor with the farmer supplying his own bullocks for treading. This works out to a threshing cost of about 5.33 percent plus the opportunity cost of the farmer's bullocks. Not surprisingly, the thresher owner set his price at 16 kgs per 3 threshed quintals. He hired four laborers for machine threshing, gave them 4 kgs, and retained 12 kgs for himself. Farmers were motivated to machine thresh because they could use their bullocks for other activities

Table 7 sheds some light on possible explanations.[8] If we compare the two most important fortnights for threshing local and hybrid cultivars from 1975-76 to 1979-80, daily wages are higher for both male and female landless laborers during fortnights 21 and 22 when hybrids are threshed compared with fortnights 25 and 26 when local threshing activity reaches a peak. Another way to measure labor seasonality is to analyze the variation in the fortnightly opportunity cost of labor, which reflects the daily wage weighted by the probability of employment. Opportunity cost comparisons do not point to differences in labor demand seasonality by varietal type. Male opportunity costs for peak threshing fortnights are the same for both local varieties and hybrids (column 7, Table 7). Female opportunity costs are lower during the threshing of local sorghum, but estimates corrected for seasonality reveal that human labor costs for threshing are about 25% higher for local sorghum.[9] The incidence of seasonality in the demand for labor from September to February is not particularly strong because other cropping operations occur at the same time as threshing.

The timeliness of farming operations has long been recognized as a factor contributing to mechanization. Although the benefits to timeliness are usually difficult to quantify, farmers are rarely left speechless when asked why they need to finish operations as quickly as possible.[10] In sorghum, improved timeliness in threshing can diminish the incidence of postharvest losses due to inclement weather. Preharvest grain mold and postharvest storage fungi can be severe problems in rainy season sorghum. Speedy threshing per se does not reduce the likelihood of disease or insect damage, but it may enhance the chances of escaping pest-conducive environments. Assuming that postharvest storage is adequate, benefits derived from timely threshing are largely determined by the risk of an adverse environment, which can be measured as the probability of a wet week in the last column of Table 7. The probability of rainfall is much higher during the threshing of hybrids than local

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8. Data on the daily wages and [illegible] are taken from Ryan et al. (1979) and are estimated for 1975-76. It is assumed that these estimates are representative for other cropping years.

9. Seasonally adjusted human labor costs are estimated by weighting daily wages and opportunity costs by the incidence of sorghum threshing by cultivar in columns (3) and (4) of Table 7. These wage and opportunity cost estimates are then multiplied by the labor requirements given in Table 4 for each threshing technique.

10. In a penetrating analysis, Fisher (1953) conceptually has shown how it is in the interest of farmers—but not workers—to hire the maximum amount of labor to harvest crops in the shortest span of time.

Table 7. Seasonal distribution of sorghum threshing, daily wages, opportunity cost of labor, and the incidence of rainfall in Kanzara.

Fortnight number	Date	Sorghum threshing in percent by cultivar		Daily wage in Rs. per day		Opportunity cost in Rs. per day		Average probability of a wet week
		Local	Hybrid	Male	Female	Male	Female	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
20	Sep 24-Oct 7	0	4	3.81	1.91	2.52	1.34	.43
21	Oct 8-Oct 21	0	42	3.79	2.60	2.88	2.19	.24
22	Oct 22-Nov 4	1	40	4.00	2.84	3.35	2.34	.08
23	Nov 5-Nov 18	1	14	3.58	2.38	2.87	2.13	.08
24	Nov 19-Dec 2	12	0	4.33	2.42	3.76	2.24	.10
25	Dec 3-Dec 16	34	0	3.77	2.06	3.35	1.91	.05
26	Dec 17-Dec 31	42	0	3.16	2.09	2.89	1.88	.07
1	Jan 1-Jan 14	6	0	3.09	2.37	2.75	2.16	.15
2	Jan 15-Jan 28	3	0	4.01	1.67	3.46	3.46	.03
3	Jan 29-Feb 12	2	0	3.59	1.95	2.97	1.54	.03

Sources: Constructed from Ryan, Ghodake, and Sarin (1979); Virmani, Sivakumar, and Reddy (1978).

varieties. The average probability of a wet week is about .24 during the peak period of hybrid threshing from October 8-21. Expectations of post-harvest damage from rainfall undoubtedly condition the choice of threshing technique and probably contribute to why machine threshing is favored for hybrids. Although this is plausible explanation, we can also see that the expected probability of a wet week for most of the threshing season is not large.

CROPPING INTENSITY

Threshers can break seasonal labor bottlenecks and stimulate an increase in cropping intensity. The machine threshing of hybrid sorghum in Kanzara can release family and bullock labor for sequential cropping in the post-rainy season. The most common postrainy season crops are irrigated wheat and chickpeas. Wheat is planted on small plots irrigated by wells, and chickpeas are sown in low lying areas in fields. Thus seasonal rainfall and access to well irrigation are important determinants of the potential for double cropping.

In order to test the hypothesis that threshers have increased cropping intensity, two types of comparisons are made in Table 8. The first two columns record the percent area and farmers in Kanzara planting different crop combinations during the rainy and postrainy seasons. If the cropping intensity hypothesis is valid, we would expect that more farmers allocated more land to sequential cropping and/or cropped more fallow land or leased-in land during the postrainy season; that is, we would expect more land in the latter two categories during the last three years compared with 1975-76 before machine threshers were introduced.

The data in Table 8 do not suggest a sharp change in cropping pattern Sequential and postrainy season cropping on rainy-season fallow land have not appreciably replaced intercropping. Nevertheless, a Wilcoxon matched pair signed-ranks test, which is suited to statistically test the changes in cropping pattern for 19 farmers who switched to mechanical threshers in 1976-77 indicates that sequential cropping in 1976-77 and postrainy season cropping on leased-in or rainy season fallow land in 1977-78 was significantly greater than in 1975-76. The other before-and-after comparisons do not yield statistically significant results at the 5 percent level.

The small but statistically significant increase in postrainy season cropping could be due to other variables such as rainfall. Total rainfall received in Kanzara in 1975-76 was slightly above 400 mm. In contrast, more than 800 mm fell annually from 1976-77 to 1978-79. Wetter years favor more sequential cropping particularly in low lying areas where chickpeas are grown.

Table 8. Cropping pattern by village from 1975-76 to 1978-79 in percent of cultivated area and number of farmers.

Cropping pattern and season		Village			
		Kanzara		Kinkheda	
		Percent area	Percent farmers	Percent area	Percent farmers
Rainy season intercropping	1975-76	71	89	86	100
	1976-77	73	100	83	100
	1977-78	77	100	88	93
	1978-79	72	100	76	75
Rainy season sole cropping	1975-76	25	74	7	25
	1976-77	21	79	5	36
	1977-78	16	63	5	25
	1978-79	18	68	17	32*
Rainy season sequential cropping	1975-76	2	32	3	18
	1976-77*	6	53	8	43
	1977-78	3	37	4	29
	1978-79	7	32	3	18
Postrainy season cropping on rainy season fallow or leased-in land	1975-76	2	16	3	11
	1976-77	0	5	4	18
	1977-78*+	5	47	3	18
	1978-79	3	32	3	14

* Statistically significant at the 5% level in the before-and-after comparison.

\+ Statistically significant at the 5% level in the with-and-without comparison.

One way to control for the confounding effects of weather is to compare the cropping pattern in Kanzara with a neighboring village. In the VLS, one village in each area has been left as a control for such comparisons. Fortunately for our purposes, from 1976-77 to 1979-80 machines were not used to thresh sorghum in Kinkheda. Contrasting the cropping pattern in Kanzara to that of Kinkheda establishes a with-and-without evaluation of the impact of mechanical threshing.

The influence of weather is readily detected in the last two columns of Table 8. For the 31 farmers who planted sorghum in Kinkheda from 1975-76 to 1979-80, the percent sequential cropping jumped from 18% in 1975 to 43% in 1976-77. Both villages received more than 800 mm of rainfall in 1976-77, and a Mann-Whitney U test shows that the distribution of sequential cropping is not significantly different for the two villages A similar test on differences in postrainy season cropping in 1977-78 leads one to reject the null hypothesis that the two samples are drawn from the same population--more farmers allocated more land to postrainy season cropping in Kanzara than in Kinkheda.

Overall the evidence that the introduction of mechanical threshing in and of itself caused a favorable impact on cropping intensity is extremely weak. In only one year has there been a significant increases in postrainy season cropping in Kanzara on rainy season fallow or leased-in land; and in that year postrainy season cropping accounted for only 5% of total cultivated area.

EMPLOYMENT

The marked decrease in labor hiring for threshing between 1975-76 and 1978-79 is yet another indication of the speed with which mechanical harvesting technology diffused throughout Kanzara (Table 9). The number of observations where members of VLS landless labor and small farmer households were hired for post-harvest work, mainly sorghum threshing, totaled 40 in 1975-76.[11] By 1978-79 only two observations of labor hired for post-harvest threshing were recorded in the VLS sample.[12]

11. In the VLS manual, postharvest operations include drying, husking, threshing, winnowing, and cleaning (Binswanger and Jodha 1978).

12. To some limited extent, the reduction in numbers in Table 9 could be attributed to fewer rounds or interviews in the later crop years. The frequency of rounds during the sorghum threshing season declined from 8, 7,5, and 4 from 1975-76, 1976-77, 1977-78, and 1978-79 respectively.

In order to gauge the impact of mechanical threshers on employment, two questions are asked: (1) what was the level of involuntary unemployment for hired laborers in the VLS sample threshing sorghum during the peak threshing season from 1975-76 to 1977-78, and (2) what was the rate of labor market participation and level of involuntary unemployment in 1978-79 for laborers who threshed sorghum during the previous three seasons? In other words, did the introduction of mechanical threshers lead to increased unemployment for laborers participating in the threshing operation and did workers who had previously participated in threshing find alternative employment opportunities in 1978-79?[13]

The answer to the first question appears to be affirmative. The rate of involuntary unemployment rose sharply from 1975-76 to 1977-78 (Table 10). Before mechanical threshing in 1975-76, the estimated rate was only 7% during the threshing season; by 1977-78 the five workers who were still threshing sorghum "lost" one day in five to involuntary unemployment. The average levels of involuntary unemployment are statistically different at the 5% level between 1977-78 and the two earlier cropping years.[14]

Workers who were potentially displaced by mechanical threshers were generally able to find other employment in Kanzara. Twenty five household members in the sample threshed sorghum in one or more cropping seasons from 1975-76 to 1977-78. Employment histories are available on 20 of these workers who remained in the sample during the peak sorghum threshing periods in 1978-79.[15] These data reveal that six obtained monthly regular farm work, five entered the daily agricultural labor market, four secured off-farm employment, three did not participate in the labor market and worked on their own farms, and two benefited from government employment. For the five daily agricultural wage laborers, the rate of involuntary unemployment was about 30% during sorghum threshing in October and December. Despite this high percentage, we conclude that the majority of agricultural workers previously engaged in threshing were able to find

13. Only two rounds of employment data were taken in Kinkheda during 1977-78; therefore, it is not possible to carry out a with-and-without employment comparison for the two villages. Nevertheless, for 1975-76 and 1976-77, 14 and 8 sorghum daily wage threshing observations were reported in Kinkheda, and the rate of involuntary unemployment was 6% for 1975-76 and 0% for 1976-77. The latter rate is significantly less than that reported for Kanzara in Table 10 for the same crop year.

14. To the extent that the least productive workers are left behind, selectivity in the daily agricultural labor market could partially explain the increase in involuntary unemployment with the decline in numbers.

15. Four members left their households in the village and one died.

Table 9. Wages for and frequency of post-harvest labor in Kanzara from 1975-76 to 1978-79.

Crop year[a]	Male labor		Female labor	
	Rupees per hour	No. of observations	Rupees per hour	No. of observations
1975-76	.50	30	.25	10
1976-77	.42	33	.26	7
1977-78	.59	17	.45	12
1978-79	.64	2	-	0

Source: Asokan (1980).

a. Data on time allocation by operation were not collected for 1979-80.

Table 10. Involuntary unemployment for laborers in Kanzara hired for threshing hybrid and local sorghum from 1975-76 to 1977-78.

Crop year	Involuntary unemployment in percent	No. of observations
1975-76	7	19
1976-77	11	26
1977-78	20	5

alternative regular employment. This finding confirms other results (Binswanger et al. 1979) that the labor market in Kanzara is buoyant and operates efficiently for males who are the primary source of labor for sorghum threshing.

Summing up, the introduction of threshers increased the unemployment rate for those daily agricultural workers who remained in the market and threshed sorghum, but the costs of potential displacement was minimized by the ease with which threshing labor found other employment opportunities in Kanzara in 1978-79. Because of the small sample size, these results are only indicative of what can happen with the introduction of selective mechanization and further point to the need for larger samples and explicitly designed labor market studies to document the impact of mechanization on employment. Moreover, sorghum threshing in the diversified agriculture of Kanzara is not a sufficiently large source of employment that one would expect a pronounced repercussion on the labor market from the introduction of machines. This finding may not hold for other SAT villages, particularly rainy season fallow areas where postrainy season sorghum is sole cropped and is the dominant crop.

TECHNICAL INNOVATIONS IN THRESHING AND THEIR IMPLICATIONS

There are several possible ways to improve thresher performance (Singhal and Thierstein, 1979). One type of improved machine would increase threshed grain output per hour. Our findings suggest that the main implication of such a technology would be to reduce the quantity of grain available for threshing by less efficient machines. The utilization and resulting profitability of older models would diminish. For example, assume we increase the capacity of one machine by 50% to 450 kilograms per hour. If we have both a smaller and a larger capacity machine threshing in the village, the profitability of the smaller machine is reduced by 33%, from 30 to 20 percent. Thus a higher capacity thresher would have a negative impact on the owners of existing machines as we would expect to see fewer threshers per village. This type of innovation in and of itself would have a negligible impact on society because the benefits from increased capacity would not flow to producers and consumers.

The second kind of improvement would focus on the development of a multicrop thresher to take advantage of the diversified cropping pattern in SAT India. Such a multipurpose machine would increase utilization and smooth out seasonality in peak-periods of threshing demand. In Kanzara, one could envisage a machine that would thresh sorghum, wheat, and grain legumes such as pigeonpea, mung bean, and black gram which are grown in considerable quantities by many farmers.

For grain legumes, the social desirability of mechanical threshing is more tenuous than for sorghum. Unlike sorghum, most pulses are threshed almost exclusively by hand beating. Pulse threshing in Kanzara is intensive in its demand for female labor (Table 11).

Such a multicrop machine therefore has the potential to displace significant quantities of female labor. Women are discriminated against in the labor market, and it is unlikely that they could find alternative employment as readily as men (Binswanger et al., 1979 and Ryan et al., 1979). This prediction applies especially to pigeonpea threshing during February and March before the slack months of April and May. The probability of females from landless labor households getting a job reaches an annual low of .20 during April (Ryan et al., 1979). This high rate of involuntary unemployment results in an opportunity cost wage of less than one rupee for the same time period. Mechanical threshing may release women to spend more time on household activities, but it is questionable that the value of such activities could compensate for lost wages.

Performance could also be improved by introducing a mechanical thresher that produces cleaner grain with lower percentage brokens and with fewer separation losses. Broken and unthreshed grain command lower market prices than threshed grain; therefore, there may be some scope for increasing benefits to society by improving cleaning efficiency and decreasing the percentage brokens.[16] Such an improvement must be evaluated relative to other threshers and traditional methods. Singhal and Thierstein (1979) show that for sorghum hybrid CSH-6, hand beating gave the same level of threshing and cleaning efficiency as machine threshing. Threshing by bullock treading was not tested. The same study reported wide variation in threshing efficiency among different mechanical models. If we assume that the present machines are inefficient in Kanzara we have to ask the question: why would farmers thresh with machines when the cost advantage is so narrow over traditional methods? Assuming our cost data reflect the real situation, the most plausible answer is that existing models are not that inefficient and do not have high enough separation losses and percentage brokens to lead to a significant reduction in market price. The efficiency hypothesis needs to be tested under on-farm conditions but it is doubtful that a more efficient thresher will have a significant impact on boosting the production of clean, whole grain for many sorghum cultivars.

16. In a marketing study of CSH-6, percent brokens from 4 to 10% depressed price from 1 to 6%, while unthreshed grain from 1 to 10% was lineraly and inversely correlated with price (ICRISAT, 1980).

Table 11. Average amount of labor required to thresh by hand one quintal of pulses in Kanzara and Kinkheda from 1975-76 to 1978-79.

Pulses	Labor type				No. of observations
	Family male	Family female	Hired male	Hired female	
	--hours per threshed quintal--				
Mung Bean	2.35	2.92	3.23	3.60	132
Black Gram	2.73	7.79	1.81	6.53	161
Pigeon Pea	5.03	4.12	5.74	12.71	202

CONCLUDING COMMENTS

Because of few confounding effects, Kanzara offered an excellent vantage point to evaluate the consequences of mechanical threshing. The general results from the study strongly suggest that the introduction and widespread diffusion of machine threshing did not significantly reduce costs, increase cropping intensity, or displace labor. In and of itself, mechanical threshing has not had much impact in the village.

These findings have to be placed in perspective, as the results from one impact study in only one village cannot be expected to apply to all of SAT India. But they do provide a reference point for analysis of the likely consequences of machine threshing in other socioeconomic and agroclimatic settings.

One major finding that is widely applicable is that a diversified output mix limits the scope for and conditions the impact of mechanical threshing technologies in SAT India. Crop diversity and low production encourage machine hiring as few farmers have enough produce to afford a lumpy investment like a thresher. Based on our assumptions, two machines of current vintage can profitably thresh all the sorghum and wheat produced in the village. Addition of a third thresher makes mechanical threshing a far less attractive investment opportunity--the expected rate of return for each machine drops from 30 to 13%.

Although we usually think that mechanical threshing is an apt example of selective mechanization, machine threshing in Kanzara was anything but selective in terms of access to technology. Hiring out and the need for high rates of machine utilization made mechanical threshing readily accessible to all farmers in the village. Under such conditions, mechanical threshing may respond particularly to the needs of small farmers who do not own bullocks or who have limited access to draft power.

A buoyant male labor market in Kanzara insulated daily workers from the potential labor displacing effects of mechanical threshing. Daily agricultural workers who threshed sorghum during the introduction and diffusion of machine threshers in 1976-77 and 1977-78 experienced significantly higher rates of unemployment compared with 1975-76, but they were able to find alternative employment in 1978-79. Because cotton is the principal crop in Kanzara, we should not expect to see a high level of labor displacement from machine threshing of sorghum. This benign expectation may not hold for rainy season fallow-postrainy season sorghum areas, nor would it apply to new multicrop machines capable of threshing grain legumes that traditionally require a large amount of female labor in the threshing operation.

Cultivation of nonthreshable longer growing season crops like cotton greatly diminishes the potential for mechanical threshing. Because cotton seems to have been the dominant crop in the Kanzara area during at least the last 100 years (Binswanger et al. 1979), we could, likewise, not attribute an increase in cropping intensity to mechanical threshers. Increased sequential cropping is not documented in either before-and-after and with-and-without comparisons. For other areas of the SAT, the argument that machine threshers may break labor bottlenecks that constrain multiple cropping may still apply, but the validity of the argument is diminished by the multiplicity of cropping patterns in dryland agriculture. Illustrative calculations on one potential sequential cropping pattern, while instructive, may greatly overestimate and disguise the nature of seasonal labor bottlenecks. Unless new technology dramatically increases the profitability of specific cropping systems and leads to specialization, it is unlikely that even under the best of conditions farmers in given regions of SAT India will all adopt the same sequential cropping pattern; hence, seasonal labor constraints estimated for prospective new technologies may be more imaginary than real.

Our results show that mechanical threshers have not significantly reduced threshing costs. Certainly, the 4% in-kind fee charged by thresher owners has not been exorbitant, but the spatial oligopsony nature of the village threshing market suggests that the cost reducing potential of mechanical threshing has only partially been realized. The dynamics of diffusion of mechanical threshers point to the same conclusion. The 4% price of mechanical threshing has not changed--even with the gradual introduction of more machines--in the last five years in Kanzara.

With present levels of cereal production in SAT India, only a few machines per village are economically feasible. A few machines per village do not lead to competitive pricing. Under these conditions, it is questionable whether potential benefits from reduced costs due to new threshing technologies will be passed on to producers and consumers.

The demand for improved threshing technologies could increase _if_ investment in irrigation opened up more opportunities for multiple cropping, _if_ short-duration, mold-resistant rainy season sorghum cultivars were developed to enhance the potential for sequential cropping, and _if_ hulling characteristics of high-yielding, difficult-to-thresh sorghum cultivars could not be upgraded through plant breeding. Moreover, _if_ there were tremendous scope for enhancing the field performance of machines supplied by the private sector, public research could yield dividends. Thus the payoff from public investment in research on mechanical threshing is an extremely "iffy" proposition in dryland agriculture. There should be less problematic investment alternatives than mechanical threshing research and development to directly increase production in Semi-Arid Tropical India.

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Appendix Table 1. Prices used in cost calculations.

Crop year	Hybrid sorghum October price (Rs. per Qt.)	Local sorghum December price (Rs. per Qt.)	Threshing male labor (Rs./hr)	Threshing female labor (Rs./hr)	Bullock rental (Rs./hr per pair)
75/76	96	104	.52	.26	1.28
76/77	98	84	.46	.24	1.10
77/78	89	100	.58	.34	1.45
78/79	100	100	.53	.33	1.21
79/80	115	111	.59	.31	1.33

Source: Asokan, (1980).