ECONOMICS OF TECHNOLOGY OPTIONS FOR DEEP VERTISOLS IN THE RELATIVELY ASSURED RAINFALL REGIONS OF THE INDIAN SEMI-ARID TROPICS

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SEMINAR ON MANAGEMENT OF DEEP BLACK SOILS

New Delhi, 21 May 1981

Sponsored by the Indian Ministry of Agriculture, the Indian Council of Agricultural Research and the International Crops Research Institute for the Semi-Arid Tropics

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James G. Ryan and R. Sarin*

INTRODUCTION

Since 1976 research has been conducted at ICRISAT Center, Patancheru on operational-scale deep Vertisol watersheds and subwatersheds of from 1 to 5 ha. One of the primary objectives has been to develop improved soil, water, and crop management technology options which would enable profitable crops to be grown both in the rainy and postrainy seasons. In many of the deep Vertisol regions of India the land is left fallowed in the rainy season and cropped only in the postrainy season to crops such as sorghum, chickpea, wheat, and safflower (Figure 1).[1] These crops occupy an area of approximately 14.8 million ha in the six states represented at this seminar (Table 1)

States which have the largest areas of kharif fallowing are Madhya Pradesh, Maharashtra, and Andhra Pradesh (Table 2). Among them they have almost 12.3 million ha of land left fallow in the rainy season. This is 26% of their current net sown area. Malone (1974) earlier estimated that some 26.2 million ha of rainy-season fallow existed in India. Of this we estimate some 12 million ha are in the Vertisols of the semi-arid tropics (SAT) If a 2 tonnes/ha food-grain crop could be grown on these rainy-season Vertisol fallows it would add some 24 million tonnes to India's food-grain production. This would represent almost a 20% increase. In addition, the crop cover provided by rainy-season crops on these Vertisols could reduce soil erosion by approximately 80% (Binswanger et al. 1980b, p.34).

Results from research at ICRISAT Center suggest that there is potential for food-grain production increases of more than 3 tonnes/ha on the deep Vertisols. This can be achieved by.

- improving field drainage,
- dry-sowing ahead of the monsoon,
- use of HYVs, and fertilizers,
- using improved seed and fertilizer drills to ensure proper placement and stand,
- appropriate plant protection,
- timely harvesting,
- postharvest cultivation.

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*The authors are grateful to their colleagues J.A. Kampen, B.A. Krantz, S.K. Sharma, S.M. Miranda, S.V.R. Shetty, G.E. Thierstein, G. Michaels, and their assistants, who were responsible for the much of the research on which this analysis is based. The comments of V.S. Doherty, J.S. Kanwar, and K.L. Srivastava on an earlier draft are appreciated. The authors alone are responsible for the content that remains.

1. The graph was compiled by G. Michaels, previously Research Scholar in the Economics Program at ICRISAT.

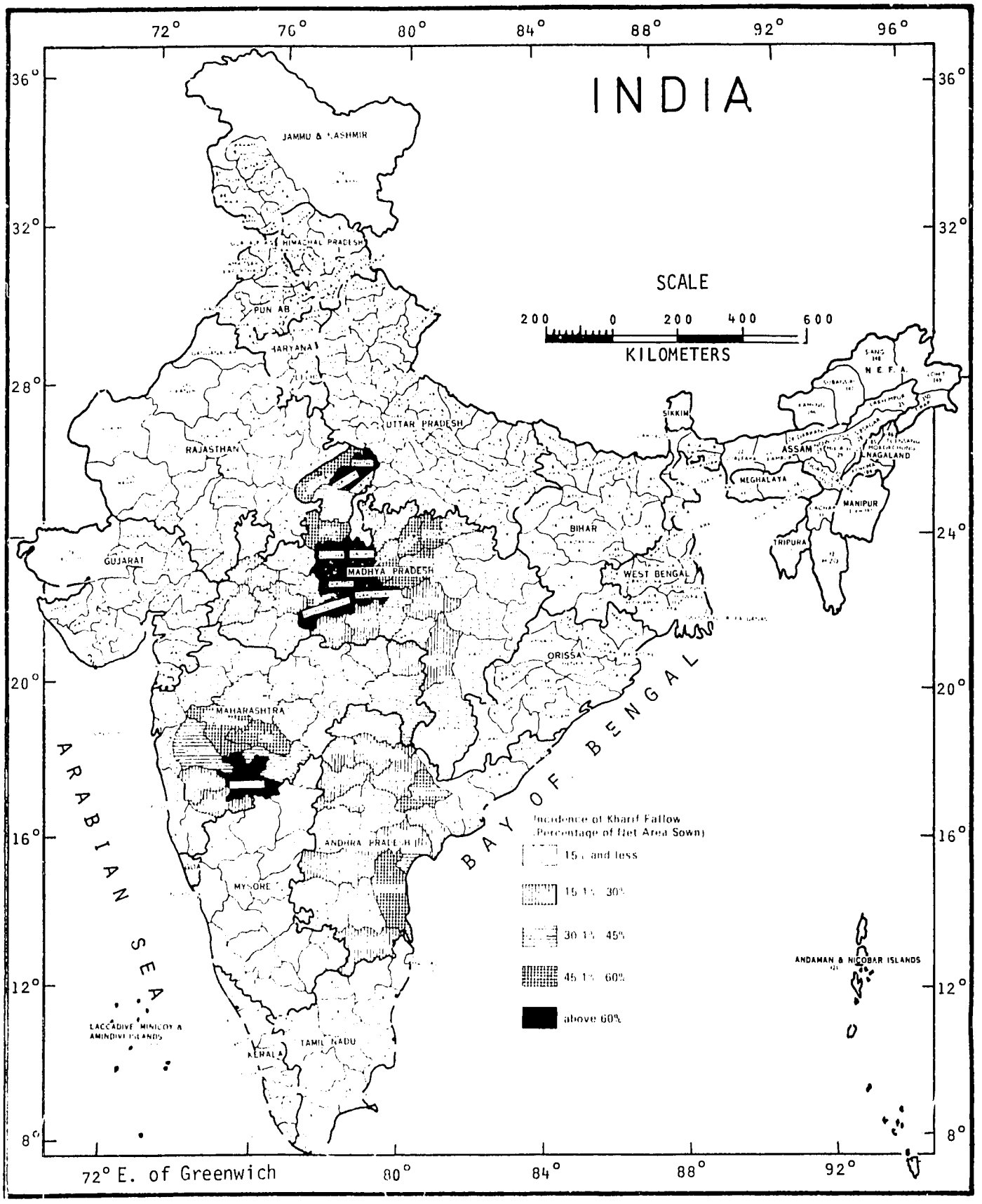

Figure 1. Extent of rainy-season fallows in selected areas of India. (Data are not available for the unshaded areas.)

Table 1. Average annual area of postrainy-season crops in six Indian states 1975-78 ('000 ha).

Crops	STATES						
	Andhra Pradesh	Gujarat	Karnataka	Madhya Pradesh	Maharashtra	Tamil Nadu	TOTAL
Sorghum	1088	168	1037	18	3373	156	5840
Wheat	27	699	378	3244	1195	2	5545
Chickpea	83	75	173	1982	452	11	2776
Safflower	16	0	168	1	499	0	684
TOTAL	1214	942	1756	5245	5519	169	14845

Source: Directorate of Economics and Statistics (1979).

Table 2. Estimates of extent of rainy-season fallow in India.

State	Years	Average annual area of rainy-season fallow ('000 ha)	% of net sown area fallowed in rainy-season
Madhya Pradesh	1971-78	5378	29
Maharashtra	1971-75	4642	27
Andhra Pradesh	1972-78	2253	20
Total 3 states	--	12273	26
India	1970-71	26200	19

Sources: Compiled by G. Michaels from data in Directorate of Agriculture (various years), Bureau of Economics (various years) and Government of Maharashtra (various years) and Malone (1974).

All deep Vertisol regions in India will not be suitable for this type of technology. It is possible only in the relatively high (>750 mm/yr) and assured rainfall areas with deep Vertisols. S.M. Virmani and his colleagues at ICRISAT have mapped the regions where this technology is likely to have most promise.

In this paper we discuss the economics of the improved technologies that have been evolving from research at ICRISAT Center and in villages aimed at enabling crops to be grown in deep Vertisols in the rainy-season.

PROFITS FROM IMPROVED TECHNOLOGY

Joint research of the Farming Systems and Economics Programs from 1976 to 1981 has shown that such an improved watershed-based technology based on maize intercropped with pigeonpea can increase profits by about 600% compared with a traditional system based on rainy-season fallow followed by postrainy-season sorghum and chickpea. This improved system utilizing graded broadbeds and furrows has generated profits averaging Rs. 3650/ha/year over 5 years. This compares with a figure of only Rs. 500/ha/year from the traditional system (Table 3). These profits represent a return to land, capital, and management, as the costs of all human and animal labor, fertilizers, seeds, and implements have been deducted. For an extra annual cost of about Rs. 1200/ha a farmer changing from the traditional system could earn an additional profit of about Rs. 3100/ha. This represents a rate of return on the increased working expenditure of about 250% - a most attractive figure.

The capital cost of a wheeled tool carrier with a full set of attachments is Rs. 8000 - 10000. This implement permits the formation of the graded broadbeds and furrows and greatly facilitates the improved placement and distribution of seeds and fertilizers. Our estimates are that one unit could effectively serve 12-15 ha. Based on these figures the extra profits from the new system could pay for the wheeled tool carrier in 1 year provided it was utilized along with the improved technology on at least 4 ha.

On the deep Vertisols at ICRISAT Center the data in Table 3 show that the graded broadbeds and furrows increase profits by about 30% compared with a flat cultivation system using a maize/pigeonpea intercrop. With the maize-chickpea sequential system the graded broadbeds and furrows have a 20% profit advantage. If farmers were able to achieve improved placement of seed and fertilizers with their traditional implements, these results suggest that the wheeled tool carrier would still be profitable for forming the broadbeds and furrows. With additions to profits of Rs. 500-800/ha, the wheeled tool carrier could be paid for in 1-2 years from the extra income generated by the broadbeds and furrows.

Table 3. Economics of improved technology on deep Vertisols at ICRISAT Center: annual averages 1976-81.

Crops	Soil and crop management	Gross returns	Costs[b]	Gross profits
		Rs/ha		
1. Maize/pigeonpea intercrop	Broadbeds and furrows, HYVs[a], chemical fertilizers, wheeled tool carrier, plant protection	5380	1730	3650 (975)[c]
2. "	Flat cultivation, HYVs[a], chemical fertilizers, wheeled tool carrier, plant protection	4607	1771	2836 (606)
3. Maize-chickpea sequence	Broadbeds and furrows, HYVs[a], chemical fertilizers, wheeled tool carrier, plant protection	5304	2241	3063 (1527)
4. "	Flat cultivation, HYVs[a], chemical fertilizers, wheeled tool carrier, plant protection	4811	2254	2557 (1469)
5. Rainy-season fallow, postrainy-season sorghum and chickpea	Flat cultivation, local varieties, farmyard manure, local implements	1083	589	494 (270)

[a] A variety of cultivars have been used: maize - Deccan Hybrid 101, SB23, 51-54, Vitthal; pigeonpea - Sharada, ICP-1; chickpea - local.

[b] Costs include all materials, human and animal labor, and annual costs of implements.

[c] Figures in parentheses are the standard deviations of gross profits. They are based on 15 observations for the improved broadbed technologies, and 7 for all others.

If for some reason broadbeds and furrows were not used, but all other components of the improved technology were, profits could still be increased by more than 400% compared with the traditional system (Table 3).

The improved technologies do not seem to increase risk compared with the traditional practice if we define risk as the ratio of standard deviation of profits as a percentage of average profits (CV). The standard deviation of profits rises from Rs. 270 to Rs. 975/ha with the improved technology, but the coefficient of variation (CV) falls from 55% for the traditional to 27% for the improved maize/pigeonpea intercrop system based on broadbeds and furrows. Besides being more profitable, the improved maize/pigeonpea intercrop systems also have involved much lower level of profit risk (CVs of 21, 27%) than the improved maize-chickpea sequence (50, 57%). This helps explain why most semi-arid tropical farmers in India practice intercropping extensively.

HUMAN LABOR USE WITH IMPROVED TECHNOLOGY

The improved technology results in a greatly increased demand for human and bullock labor. This is desirable because it will allow landless laborers and cultivators who rely on wage earnings for a substantial part of their income to share in the additional income streams that the improved technology can generate.

The improved technologies can imply an increase in human labor use of more than 250% (Table 4). The traditional rainy-season fallow, postrainy-season cropped fields at ICRISAT Center used a little more than 300 man-equivalent hours/ha. This compares well with the figure of 268 derived from our village-level studies in the Sholapur region (Ryan et al. 1980). The improved intercrop technologies could increase this to more than 1000 man-equivalent hours/ha.

The operations where much of the increased human labor demand would be required are threshing, harvesting, weeding, and sowing (Figures 2 and 3). The substantial labor peaks which could result would tend to put upward pressure on agricultural wages, which could be of benefit to laborers. However, as we have observed in some village-level studies, pressure on wages will encourage selective mechanization such as the use of threshing machines. Hence these peaks may be dampened in practice by such developments. Also it is unlikely that single-cropping patterns, such as are illustrated in Figures 2 and 3, would be maintained in villages. In practice farmers would be likely to grow a range of crops in different cropping patterns. The extent to which they do so would mean a further dampening of the projected labor peaks.

Table 4. Human and animal labor use with improved technology on deep Vertisols at ICRISAT Center, 1976-81.

Crops	Soil and crop management	Bullock pair hours per net sown ha	Human labor hours per net sown ha[a]	
			Excluding threshing	Including threshing
1. Maize/pigeonpea intercrop	Broadbeds and furrows, HYVs, chemical fertilizers, wheeled tool carrier, plant protection	81	604	1220
2. "	Flat cultivation, HYVs, chemical fertilizers, wheeled tool carrier, plant protection	76	537	1041
3. Maize-chickpea sequence	Broadbeds and furrows, HYVs, chemical fertilizers, wheeled tool carrier, plant protection	90	701	1140
4. "	Flat cultivation, HYVs, chemical fertilizers, wheeled tool carrier, plant protection	89	732	1203
5. Rainy-season fallow, postrainy-season sorghum and chickpea	Flat cultivation, local varieties, farmyard manure, local implements	53	193	317

[a] Expressed in terms of male-equivalent hours.

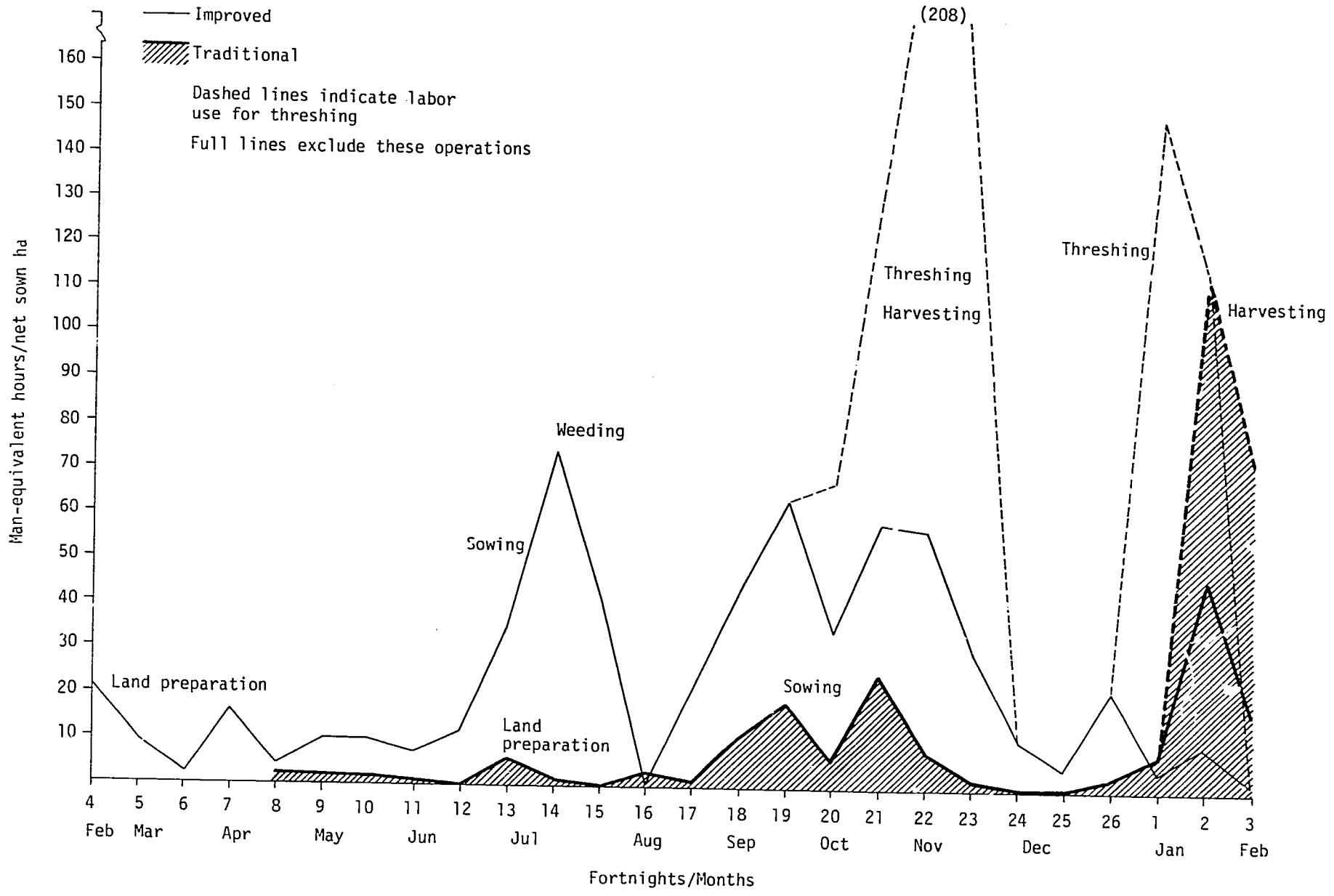

Figure 2. Average seasonal use of human labor with improved maize/pigeonpea intercrop versus traditional rainy-season fallow with postrainy-season sorghum and chickpea on deep Vertisols at ICRISAT Center, 1976-81.

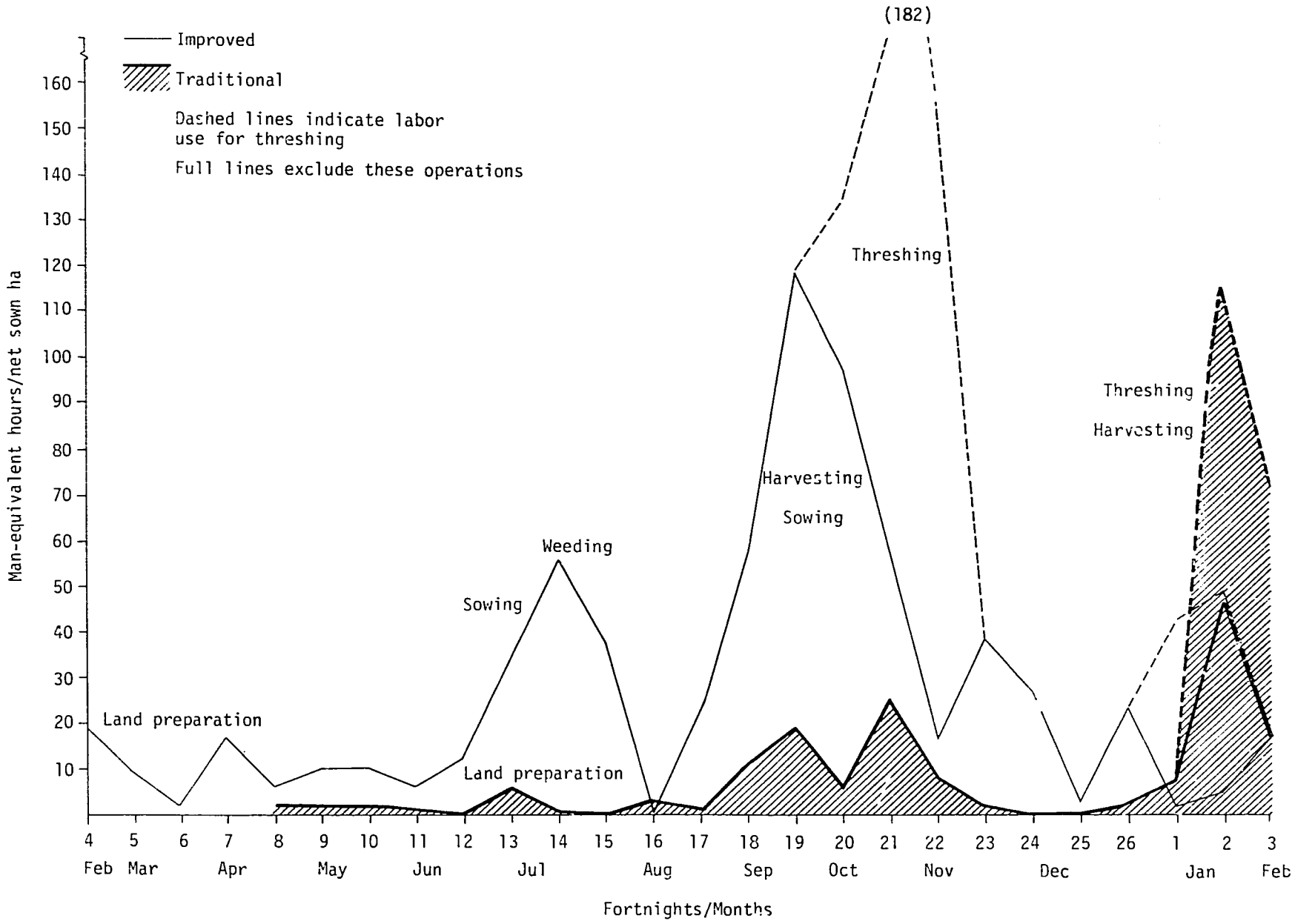

Figure 3. Average seasonal use of human labor with improved maize-chickpea sequence versus traditional rainy-season fallow with postrainy-season sorghum and chickpea on deep Vertisols at ICRISAT Center, 1976-81.

BULLOCK LABOR USE WITH IMPROVED TECHNOLOGY

The improved technology can mean an increased use of bullocks by 50% on average, if it is based on an intercrop system, and by 70% if a sequential crop system is employed (Table 4). The main reasons for the increased use of bullocks are (a) the additional land preparation, including initial smoothing of fields, plowing, forming and maintaining broadbeds and furrows,[2] and (b) the sowing of an additional crop in the case of the sequential system.

The seasonal pattern of bullock power utilization is substantially altered with the intercrop or double-crop system (Figures 4 and 5). 70-80% of the bullock labor occurs between February and May with the improved broadbed-and-furrow systems, whereas 85% of it occurs after June with the traditional systems. As a result it is likely that the availability of fodder for animals may be more of a constraint with the improved systems, particularly in the hot season from March to May. However, the improved systems would generate increased quantities of fodder, so the major problem would be in the initial year when watersheds are being developed, using bullock power, but before additional fodder has been produced.

The wheeled tool carrier can perform operations at a rate 2-3 times more quickly than that of traditional implements. That is primarily because of the greater width of the tool carrier. For some operations, such as bed forming, ridging, and interculture, two operators are usually required with the tool carrier, whereas only one is required for such traditional operations as cultivating, harrowing, and interculture. Our experience in the villages where we have been experimenting with improved technology is that in the 1st year (1979-80) in the Vertisols the total bullock requirements for the improved system were about double those of the traditional system (Table 5). This is mostly because of development operations. This average of 132 hours is inflated by the fact that traditional implements were used for most of the development operations in Kanzara village in Akola District. If we look at the figures for Shirapur village in Sholapur District, where the wheeled tool carrier was used for development, the total bullock requirements were only 91 hours in the 1st year. Even so, this figure was almost 90% higher than the traditional bullock labor use of 48 pair hours/ha.[3]

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2. The time taken for such initial capital development activities have been prorated over the 5-year period in Table 4 and Figures 4 and 5.

3. Note that none of the village experiments in Table 4 compares improved double cropping or intercropping with postrainy-season cropping as in Table 4. In Table 5 all comparisons are for similar cropping patterns.

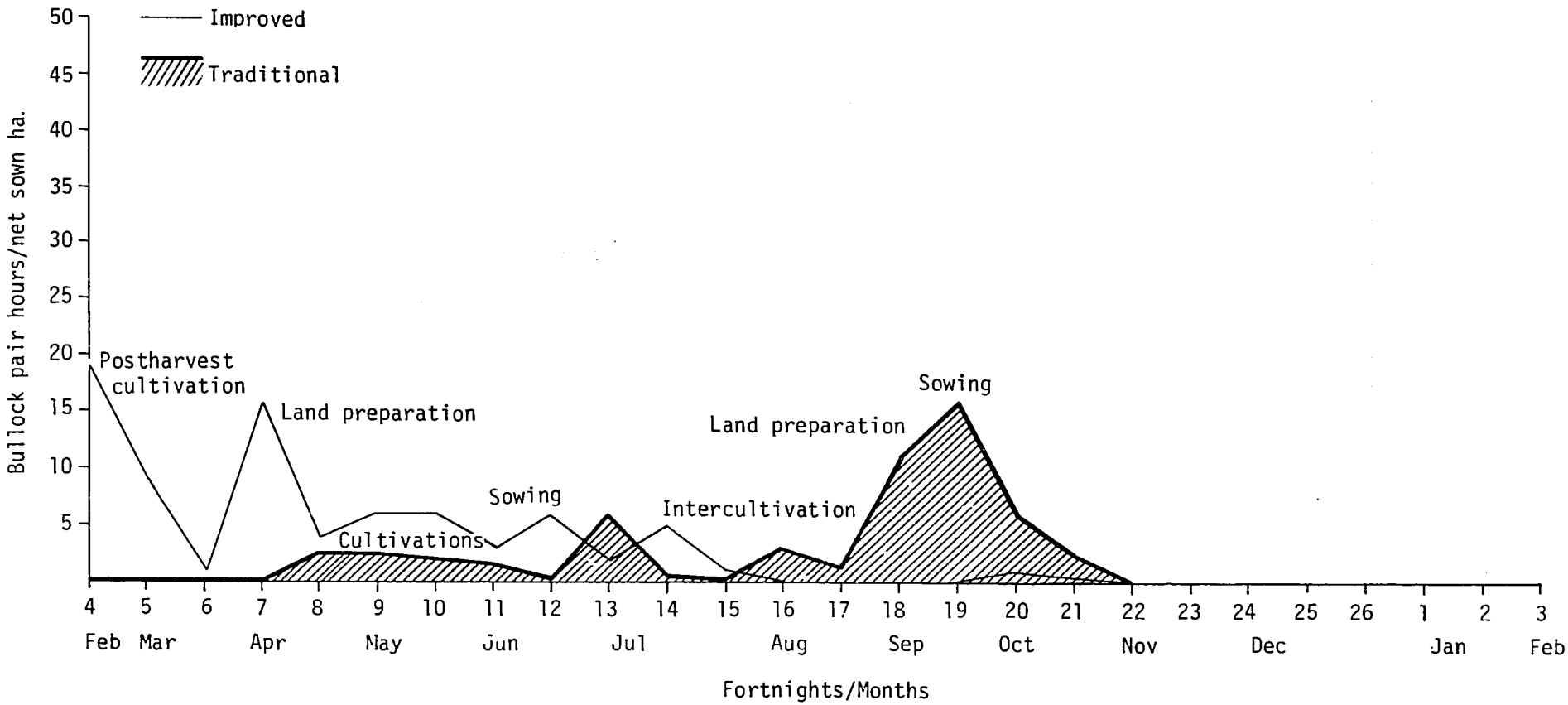

Figure 4. Average seasonal use of bullock labor with improved maize/pigeonpea intercrop versus traditional rainy-season fallow with postrainy-season sorghum and chickpea on deep Vertisols at ICRISAT Center, 1976-81.

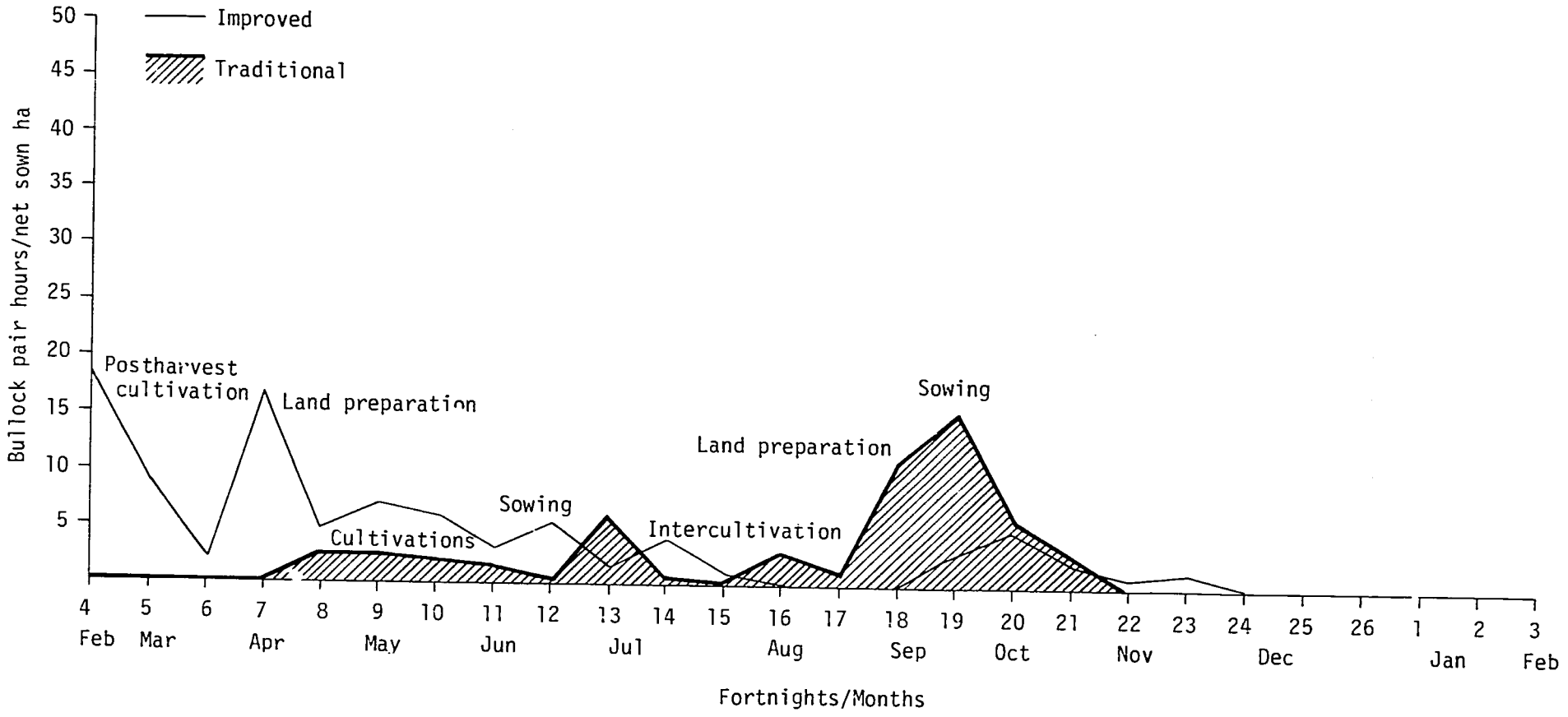

Figure 5. Average seasonal use of bullock labor with improved maize-chickpea sequence versus traditional rainy-season fallow with postrainy-season sorghum and chickpea on deep vertisols at ICRISAT Center, 1979-81.

Table 5. Use of bullock labor in village operational-scale experiments.[a]

District/Village/Crop	Technology: Improved with wheeled tool carrier, 1st year 1979-80	Improved with wheeled tool carrier, 2nd year 1980-81	Traditional with local implements 1975-78	Ratio of improved/traditional 1975-78: 1979-80	Ratio of improved/traditional 1975-78: 1980-81
	Bullock pair hours/ha				
		VERTISOLS			
Sholapur/Shirapur					
Postrainy-season sorghum	91	63	48	1.89	1.31
Akola/Kanzara					
Groundnut	154[b]	42	70	2.22	0.60
Cotton/sorghum/pigeonpea	139[b]	42	79	1.77	0.53
HYV sorghum/pigeonpea	145[b]	47	68	2.13	0.69
Average for Vertisols	132	49	66	2.00	0.74
		ALFISOLS			
Mahbubnagar/Aurepalle					
Groundnut	59	51	200	0.29	0.26
Sorghum intercrop mixture	54	46	80	0.67	0.58
Castor	73	61	108	0.80	0.56
Average for Alfisols	62	53	129	0.51	0.47

[a] See footnote 3 in the text.

[b] All development operations prior to bed formation in Akola were carried out with local implements. This explains the much higher figures.

In the 2nd year (1980-81) in Shirapur bullock labor use fell by 15% but was still 30% higher than the traditional figure. In Kanzara in the 2nd year of the improved technology bullock requirements fell dramatically. From being double traditional levels of use in the 1st year they declined to a figure of around 60%. The contrasting results in Shirapur and Kanzara suggest that the extent to which the development operations of plowing, chiseling, harrowing, ridging, and bed-forming have to be repeated after a number of years may mean that overall average bullock requirements might not be much less with the improved system. Recent experience in the Vertisol villages suggests that weed control under broadbeds and furrows may be more difficult to achieve than in traditional systems, particularly in the dry-season. This was the case especially in Shirapur. It may be necessary to completely cultivate over the broadbeds each year and reform them in order to control weeds properly.

We have recently commenced a cooperative project with the Andhra Pradesh Department of Agriculture, the All India Co-ordinated Research Project for Dryland Agriculture (AICRPDA), and Andhra Pradesh Agricultural University (APAU), in Tadthanpally village, Medak District. The aim is to introduce the broadbed-and-furrow system on a small deep Vertisol watershed of about 15.5 ha involving 13 farmers. Traditionally most of this area is fallowed in the rainy season and such crops as sorghum, chickpea, chillies, and safflower are grown in the postrainy season. Farmers intend to double-crop under the improved system, utilizing both rainy and postrainy seasons, planting a range of crops suited to their individual preferences. Among the cropping patterns are sorghum or maize intercropped with pigeonpea, sorghum or maize followed by chickpea or safflower, and mungbean followed by chillies.

Development activities began in February 1981 with surveying and design. Field development operations have not yet been completed, but up to 2 May 1981 have involved 19 bullock pair hours/ha and 27 man-hours. Total development costs so far (excluding surveying and design) amount to Rs. 85/ha. The development work is not yet completed because more ridging and bed-forming are required, along with the construction of drains and grassed waterways. Total costs are expected to range between Rs. 300 and Rs. 500/ha.

PROSPECTS FOR OTHER REGIONS

The ICRISAT Center Vertisol research supports the results achieved by AICRPDA in the Indo-British Project at Indore in Madhya Pradesh. AICRPDA has amply demonstrated that by improving the drainage of the deep Vertisols in that region it is possible to grow crops in the rainy season and substantially increase profits. It is in the higher rainfall areas with deep Vertisols and a relatively assured monsoon that the potential for

greatly increasing cropping intensity lies. Districts such as Raisen, Vidisha, Hoshangabad, Sagar, Damoh, Jabalpur, Indore, and Narsinghpur in Madhya Pradesh seem to have such potential (Table 6).

AICRPDA and ICRISAT experience in Sholapur suggests that the monsoon rains are too uncertain to sustain rainy-season crops there. As hypothesized, we have been unable to grow rainy-season crops successfully in Shirapur village of Sholapur District in 2 of the last 3 years due to inadequate soil moisture. This experience supports the conclusions from the rainfall analysis of Binswanger et al. (1980b), which shows that, although average annual rainfall in Sholapur is almost the same as that of Hyderabad, the probability of adequate moisture for rainy-season cropping in Sholapur is much less. However, we have been able to demonstrate substantial increases in yields (170%) and profits (140%) from the use of improved technology on the postrainy-season crops in the same village (Figure 6).[4] We could not demonstrate large increases in either yields (0-30%) or profits (20%) in Kanzara village in Akola District, where at present such crops as cotton, sorghum, and pigeonpea are mostly grown in the rainy season on medium-deep Vertisols. Neither was there substantial extra profit from the improved technology in the Alfisol and uncertain rainfall village of Aurepalle in Andhra Pradesh in 1979-80. We have been able to achieve yields which were 2-4 times higher than those on traditional fields in Aurepalle, but extra costs of labor, seeds, and fertilizers have largely offset these yield gains.

POLICY ISSUES

The most promising areas for the technology outlined in this paper are where rains are assured and exceed an annual average of about 750 mm and where there are deep Vertisols. However, before this promise can be called a real potential there are some policy questions which arise.

1. Availability of bullock power. In the 1st year when the improved drainage and broadbeds and furrows are being introduced, there will be an increased demand for bullock power compared with present utilization patterns. While evidence from our village studies suggests small farmers have about the same average number of bullocks per operated hec-

4. In an analysis of yields and returns of postrainy-season sorghum in traditional fields in Shirapur from 1975-76 to 1979-80, T.S. Walker found the mean gross profit to be only Rs. 280/ha. The mode was -Rs. 50, indicating a strong positive skewness in the yield and profit distributions. During the same period R.P. Singh and M. Asokan have calculated that the average net income per net sown hectare from all crops ranged from a low of Rs. 243 on small farms in Aurepalle village in Andhra Pradesh to a high of Rs. 1004 on large farms in Dokur in Andhra Pradesh. Net incomes of small and large farmers from the Vertisol villages in Maharashtra were between these extremes, ranging from Rs. 293 to Rs. 604 per net sown hectare.

Table 6. Examples of areas with high and low potential for improved rainy-season crop technology in deep Vertisols.

Districts	Average area of rainy-season fallow ('000 ha)	Rainy-season fallow as % of net sown area
High potential in Madhya Pradesh (due to high and assured rainfall)		
Raisen	319	81
Vidisha	382	77
Sagar	355	70
Damoh	164	59
Jabalpur	229	50
Indore	114	45
Narsinghpur	173	64
Low potential in Maharashtra (due to low and uncertain rainfall)		
Sholapur	773	73
Osmanabad	322	30
Bhir	336	46
Ahmadnagar	680	57
Aurangabad	475	40
Sangli	130	23

Source: G. Michaels, using data from Directorate of Agriculture (various years) and Government of Maharashtra (various years).

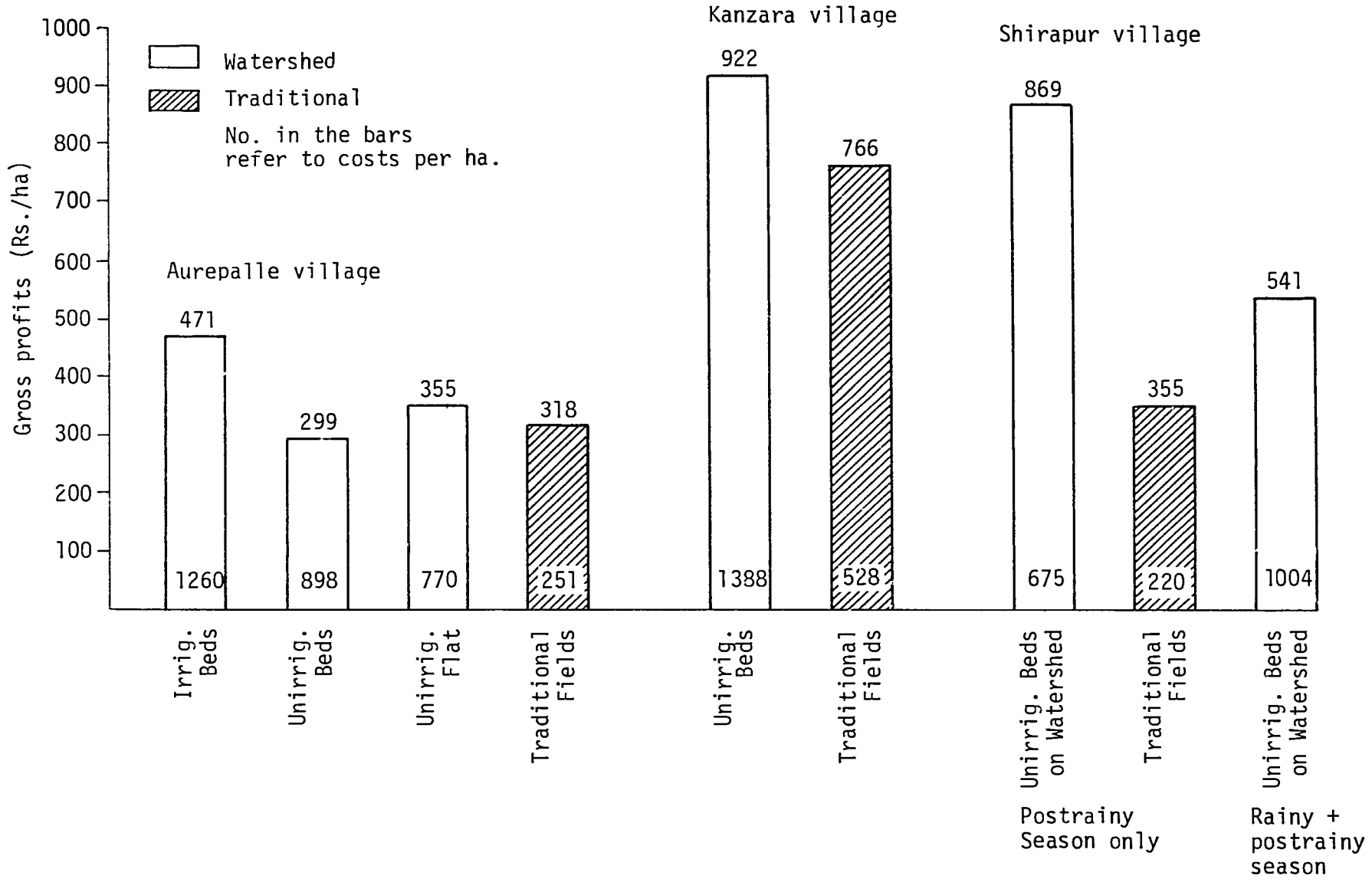

Figure 6. Gross profits from various systems in village on-farm watershed experiments, 1979-80.

tare as large farmers, bullock availability for small farmers varies much more from year to year than it does for large farmers (Table 7). Also, in most cases small farmers have lower-valued and less sturdy bullocks than large farmers. If this is true in the high potential areas, the data suggest that particular attention will have to be paid to draft power availability for small farmers. In a number of the high-potential areas in Madhya Pradesh tractor numbers have been increasing. In 1974-75 our estimates are that there were nearly 0.60 bullocks per net sown hectare in these areas. In addition tractors provided the equivalent of 0.30 bullocks per ha, a much higher figure than for all M.P. (0.04) [5] This suggests that draft availability in the high-potential regions may be much greater than in some of the areas where we have been working (Table 7). However, this needs to be more fully investigated to ensure that small farmers are able to gain access to the required draft power to implement the technology. If banks presently do not provide loans for the custom-hiring of animals or machines, policies may be required to enable this to be done

2. Community works. To effect improved drainage it is almost always necessary to improve existing field drains or to construct new ones. When such drains are within a farmer's own field, our experience so far in Tadthanpally is that they may be willing to construct them themselves. However, where drains are outside their fields and/or involve drainage flows of many farmers, it probably will be necessary to pay farmers and laborers to construct them. The question arises of how to finance such works? In Andhra Pradesh the soil conservation program has some provision for such work, but it is not clear whether there are sufficient resources to mount a large-scale program under the soil conservation programs in high-potential areas. The Food for Work and National Rural Employment Progr ms could be utilized. However, they are mostly for drought-prone areas, and the high-potential regions for the technology described in this paper are in the high and relatively assured rainfall zones. Hence there may be need to consider some special programs for these regions in order to effect the community works

3 Farmer loans. Many farmers may not be in a position to provide their own labor and bullocks to effect land improvements required by the technology, even on their own farms. They may need the income they presently earn from wages off their farms to sustain them during the dry season. In such cases it may prove difficult to implement the technology without payment to farmers. Perhaps these payments could be given as a Soil Conservation loan to be repaid in the same manner as the regular loans for bunding, etc. Recall that the rainy-season crop cover which the improved technology allows has a substantial effect in reducing soil erosion.

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5. Assuming one bullock pair is equivalent to one horse power.

Table 7. Average annual availability of bullock power in six SAT villages in south India, 1975-78.

Item	District/Village			
	Mahbubnagar		Sholapur	Akola
	Aurepalle	Dokur		
Bullocks (no.)/ha				
Small farmers:				
Lowest year	0.22	0.29	0.07	0.21
Mean	0.36	0.43	0.13	0.26
Highest year	0.50	0.64	0.21	0.30
Large farmers:				
Lowest year	0.32	0.30	0.14	0.24
Mean	0.34	0.34	0.14	0.24
Highest year	0.37	0.40	0.15	0.25
Value of bullocks (Rs.)/ha				
Small farmers:				
Lowest year	132	87	28	77
Mean	186	184	98	93
Highest year	302	279	187	115
Large farmers:				
Lowest year	157	214	117	140
Mean	174	235	129	145
Highest year	208	264	150	148

4. Infrastructure and fertilizer supplies. One of the key elements in the improved technology is increased use of fertilizers on unirrigated crops. Currently the bulk of fertilizer consumption in India is concentrated in irrigated areas. Jha and Sarin (1980, p.4) estimated that in 1977-79 those districts in the Indian SAT with more than 25% irrigation used an average of 57.5 kg/gross cropped ha/year of ($N + P_2O_5 + K_2O$). This compared with a figure of 18.5 for those SAT districts with less than 25% of irrigation. Our calculations from Jha and Sarin's original data show that those areas with the largest extent of rainy-season fallow in the states of Madhya Pradesh, Maharashtra, and Andhra Pradesh have levels of fertilizer use (Table 8) much below the national average of 28 kg/gross cropped ha/year. Madhya Pradesh and Maharashtra have little irrigation and their consumption figures are well below the 18.5 figure for the less irrigated SAT districts. All this suggests there seems to be considerable potential for increasing the use of fertilizers in the high-potential SAT areas. This will require investments in improving fertilizer distribution networks in the dryland Vertisol regions. Experience shows that unless fertilizer of the desired type is physically available and accessible to dryland farmers, they will not use it.

Table 8. Average annual fertilizer use per gross cropped ha in three states of India, 1975-77. (kg/ha)

State	% of rainy-season fallow[a]		
	< 15	15.1 - 45	> 45
Madhya Pradesh	6.2	5.3	7.0
Maharashtra	21.7	13.2	12.1
Andhra Pradesh	28.1	31.0	21.2

[a] Districts in each of the three states were classified according to the three ranges of fallow extent and their fertilizer consumption averaged.

5. New cropping patterns. There may be a need for farmers to grow new crops for the technology to express itself For example, the AICRPDA experience with maize at Indore, and ICRISAT's similar experience at Patancheru, suggest this crop could find a prominent place in new cropping patterns. Soybeans is another possibility. The market for maize is somewhat limited at present in many areas. Consideration needs to be given to marketing policies that may be required to

ensure the additional produce can be sold at attractive prices, although ICRISAT experience suggests that the improved system could still be highly attractive even if prices fell 50%. If maize prices could be contained by large increases in production this might give considerable impetus to dairy and poultry production in India. Milch buffaloes and cows, and poultry birds, could utilize increased maize grain provided prices were reasonable. Bullocks could also be fed maize grain to improve their draft capabilities.

In many of the high-potential areas wheat is the dominant crop in the postrainy season following the rainy-season fallow. More research is required on cropping systems that would enable a rainy season crop to be grown and harvested without adversely affecting the wheat crop. It is unlikely that a cereal crop such as sorghum could fill that role. It is more likely to be a legume crop such as soybeans. Perhaps sorghum with a pigeonpea intercrop or sorghum followed by chickpea would be more profitable than fallow followed by wheat in any case?

6. Wheeled tool carrier. The wheeled tool carrier offers promise in improving seed and fertilizer placement, making broadbeds and furrows, saving bullock power, and in providing a more efficient form of transport. However, it is expensive (Rs 8000 - 10000) and probably beyond the reach of individual small farmers. Entrepreneurs who would custom-hire the tool carrier may have to be encouraged by appropriate policies. One possibility would be extension of the Educated Unemployed Schemes to include financing the purchase of tool carriers by diplomates and graduates. Calculations suggest that rental rates of Rs. 30-35 per 8-hour day for the tool carrier alone, and Rs. 50-60 including bullocks and a driver, would generate an attractive return to an entrepreneur if they were utilized for 180 days per year (Binswanger et al. 1980, p.209). These latter rates are 3-4 times higher than the costs of hiring a pair of bullocks with local implements and a driver. As our results show, however, the potential extra returns could more than justify hiring the tool carrier by small farmers. Besides credit arrangements for entrepreneurs, though, small farmers will require credit to finance the hiring cost of the tool carrier, which in the initial year could amount to Rs. 350/ha or more, depending on whether or not he has bullocks which can draw it.

7. On-farm verification. The conclusion that there seems to be great potential for profitable cropping in the rainy season in deep Vertisol areas having relatively assured and high rainfall has been based largely on research conducted at ICRISAT Center. The conclusion is of course supported by the success of AICRPDA's Indo-British project at Indore, in Madhya Pradesh. The ICRISAT results have not yet been fully tested in on-farm situation in the high-potential areas. The Kanzara (Akola District) and Shirapur (Sholapur District), on-farm tests reported in the paper were in areas with low potential. The former area has rela-

tively high and assured rainfall, but the Vertisols are not deep. The latter area has deep Vertisols but meagre and uncertain rainfall.

The current on-farm testing in Tadthanpally village of Andhra Pradesh is in a high-potential area and will give us more confidence about the viability of the technology. However, there is an urgent need for on-farm verification in other high-potential areas, as identified by S.M. Virmani and his colleagues.

8. Training To implement the broadbed-and-furrow technology requires considerable surveying, design, and engineering expertise. Soil conservation officers have the basic skills required, but they have to be trained to use them in a different way for designing and implementing the improvements required to achieve the benefits reported in this paper. Training of Agricultural Officers in the use of the wheeled tool carrier will also be required so that they can train farmers.

Close working relationships are going to be required between the Soil Conservation and Agricultural wings of state Departments of Agriculture if these technology options are to be extended. Improved soil and crop management are both necessary to achieve the food-grain production increases and reduced erosion reported here. This suggests the need for training the soil conservation and agricultural officers as a team, with each being exposed to the others' particular role in extending the options

The word options is used purposely here. There is no one "package of practices" with this technology. Experience in village studies clearly shows that we must take the time to sit down and discuss at length the nature of the technology with farmers. We should of course begin with the basic concept. However, there must be options at hand which will allow us to modify the nature and timing of the technology to meet farmers' various constraints. Some will not have bullocks, others will have defaulted on previous loans and be ineligible for additional credit, and some may have irrigated land that they give preference to. Recommending one package under such circumstances may be like pushing on a string. Identification of watershed-based technology options requires on-the-job training in villages. If we take farmers into our confidence and spend the time to explain the nature of the technology to them we find they are willing to adopt. A rigid approach to farmers will not work.

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