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Early Adoption of Improved Vertisol Technology Options and Double Cropping in Begumgunj, Madhya Pradesh

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Abstract

Perceptions of 25 verification trial watershed and neighboring farmers were elicited to assess the early acceptance of the Vertisol technology options tested in Begumgunj from 1982-83 to 1984-85. The economic analysis showed the main economic advantage of the improved technology stemmed from the highly profitable soybean/pigeonpea intercrop which substituted for traditional rainy season fallow - postrainy season wheat. Despite its impressive performance in the trials, interest in the soybean/pigeonpea intercrop has waned with only four of 25 farmers growing it in 1986-87. Frost risk was the most common explanation for the lack of interest. Preference for postrainy season subsistence crops instead of pigeonpea was also cited by several farmers. Not mentioned by farmers, but perhaps an important explanation, is the difficulty of sowing intercrops in rows with modern seed drills.

Several general constraints to large-scale double cropping (more than 50% of dry crop land) were identified. Conflict with secure postrainy season food and fodder subsistence crops is a major constraint, especially on smaller farms. With current technology, timeliness problems in both the rainy and postrainy seasons limit double cropping. Crop rotation requirements and practices also reduce flexibility for fitting double crops into the crop plan. A variable constraint is kansgrass (Saccharum spontaneum). In fields with serious infestation, kharif cropping is considered impossible.

Three components, kharif dry sowing, small watershed management, and use of the wheeled tool carrier were new to farmers in 1982. One farmer continues to dry sow but others based on unfavorable experience reverted to their traditional practice of sowing after the onset of the monsoon. Several farmers with middle elevation watershed land continue to use furrows (not broadbeds, though) and maintain field drains, but those uphill from them are indifferent and downhill are negative on the watershed management plan. The wheeled tool carrier is no longer in use, but several farmers said they liked its sowing performance. Areas for further agronomic, engineering, and economics research were identified.

CONTENTS

Page

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Over several years, ICRISAT has demonstrated the technical and economic feasibility of double-cropping on dryland with deep Vertisol soils where rainfall exceeds 750 mm per year (ICRISAT 1987). Estimates on the size of the production environment where double cropping on Vertisols is technically feasible and economically attractive range from 5 to 12 million hectares (Ryan et al 1982).

This double use of cropland, in contrast to the current practice of mostly rainy season or _kharif_ fallowing and postrainy season or _rabi_ cropping in these areas, could mean increased total production for the nation. The land would be working for two growing seasons instead of one and utilizing up to eight months of sunshine for production instead of the usual four months. Double crops also make more complete use of other fixed cost production resources such as dryland moisture, human labor, some bullock time, and cultivation tools.

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For three years, starting in 1982-83, ICRISAT and the Madhya Pradesh Department of Agriculture jointly supervised field level testing of dryland double cropping in the Central Indian village of Begumgunj, 120 km east of Bhopal on the Bhopal-Sagar road. Begumgunj typlifies one of the highest production potential environments in India's Semi-Arid Tropics. The village's soils are deep Vertisols, and average annual rainfall is about 1300 mm. But those abundant soil and rainfall resources are not effectively utilized as almost all dry cropland was fallowed in the kharif season prior to 1982. These characteristics, along with the large average size of farm and high educational level of the farmers, provided an ideal site for field testing a package of technology designed to achieve double cropping on dryland.

The new technology package is based on water management in a small watershed (drainage, infiltration, and conservation) plus improved varieties, fertility improvement, pest control and other practices. In the first year, all ten farmers with land in the selected small watershed participated. Two dropped out the second year. In the third year, more farmers in a neighboring watershed participated with a total of 45 cooperators, including the original eight.

Based on the trial data, the economic performance of double cropping in general and the Vertisol technology options in particular is discussed in the next section. The remainder of the report focuses on the early acceptance of the improved technological package. Participants plus a few non-participants (referred to as traditional or benchmark farmers) were interviewed in March 1987 two years after the verification trials ended. The objectives of that survey were to determine the extent to which current practices relate to the demonstrated field trial technology package for double cropping of dryland, to obtain farmers' experiential opinions about the tested technology, and to identify continuing constraints to double cropping.

Because of the restricted nature of the survey sample and the discussion nature of the questionaire, common statistical analysis and generalizations based on those analyses are inappropriate. This is a report on how a small group of farmers who were exposed to a package of promising new technology have responded to the technology, their opinions about it, and the problems they face in using it. A comment by only one farmer may identify an insight that other farmers all recognize but did not mention. It will be assumed, however, that the constraints to dryland double cropping identified by these farmers are applicable to a broad region of assured rainfall and deep Vertisols in northern Madhya Pradesh.

The early acceptance study starts with descriptive information on the farmers and their cropping patterns in 1986-87; then farmers' opinions on each part of the technology package are reported. The opportunities and constraints for double cropping are examined. The soybean/pigeonpea combination, which appeared so profitable in the field trials, is considered first followed by a more general view of double cropping with emphasis on sequential _rabi_ crops following _kharif_ soybeans. The report concludes with a summary and specific suggestions for further research designed specifically to respond to farmers' comments [1].

Economic Performance of the Vertisol Technology Package

As a result of the impressive performance of the Vertisol technology at ICRISAT Center, on-farm verification trials were conducted during 1981-82 through 1984-85 at different sites in dependable rainfall, deep black soil areas in India. Begumgunj, in Raisen district of Madhya Pradesh, was one of the sites chosen in 1982 by ICRISAT in collaboration with the Department of Agriculture, Government of Madhya Pradesh, for on-farm trials of the improved technology. The specific objectives of the verification trials were: 1) to test the improved Vertisol management technology in the context of conditions prevailing in the Begumgunj area; 2) to help in transfering system management capability to the Department of Agriculture; and 3) to obtain feed-back from farmers and officers of the Department of

[1] This report complements several other studies about the Vertisol technology options, their verification trials, and their double cropping environment. Agronomic and engineering results specific to the Begumgunj verification trial are contained in Heinrich and Sangle (1983) and Sangle and Sharma (1985). Implications of the Vertisol technology from a whole-farm perspective in Begumgunj are analyzed in Ghodake and Lalitha (1986). Diagnostic research on the determinants of kharif fallowing and on the economic feasibility of water harvesting and supplementary irrigation to establish the rabi crop is presented in Michaels (1982) and Pandey (1986), respectively. Early acceptance of the tested technology in another verification site is examined in Sarin and Walker (1982).

Agriculture on their perceptions of the prospective technology package.

In this section, we focus on the first objective and analyze the economic performance of the prospective Vertisol technology in the on-farm verification trials. That analysis sets the stage for the early acceptance study which follows. Before discussing economic performance, we briefly describe the Vertisol technology and the crop production environment in Begumgunj.

The Vertisol technology

The improved technological options are targeted to address the problem of rainy season cropping on deep black soils with poor drainage. The locus of the verification trials was a small watershed designed to enable farmers to improve their management of soil, water, and crops (Ryan et al. 1982). Broadbeds and furrows are developed across the slope to improve *in situ* drainage and moisture conservation. Farmers can then grow two crops under sequential cropping or add three months to the growing season with intercropping. Components of the package include the following:

1. Timely post harvest cultivation following the postrainy season crop;
2. Improved drainage and water conservation by smoothing the land and installing field and community drainage channels and using graded broadbeds and furrows;
3. Improved farm implements for better placement of seeds and fertilizers for optimal crop stands;

4. Dry seeding before the onset of the monsoon;
5. Use of modern cultivars and moderate amounts of fertilizer;
6. Improved cropping systems and row arrangements; and
7. Improved plant protection

Most of these practices are implemented with a bullock-drawn wheeled tool carrier (WTC). Engineering, agronomic, biological, and mechanical components comprise the package which should be flexible enough to be adjusted to location specific conditions.

The crop production environment

The soils of Begumgunj are deep Vertisols (120-150cms), level to gentle sloping, and moderately well drained. During the dry summer period, they develop cracks up to 100 cm deep and are difficult to work. They are low in phosphorus and organic carbon and medium in potash and calicium and are mostly neutral to mildly alkaline in reaction (pH 7.4 to 8.0) throughout the profile (NBSSLUP and ICRISAT 1983).

The rainy season usually starts in the second week of June, and the rains recedes in October. More than 90% of the total annual rainfall is received during the rainy season. August is the month of heaviest rainfall (Fig. 1). The mean annual rainfall during 1982-84 was 1433 mm.

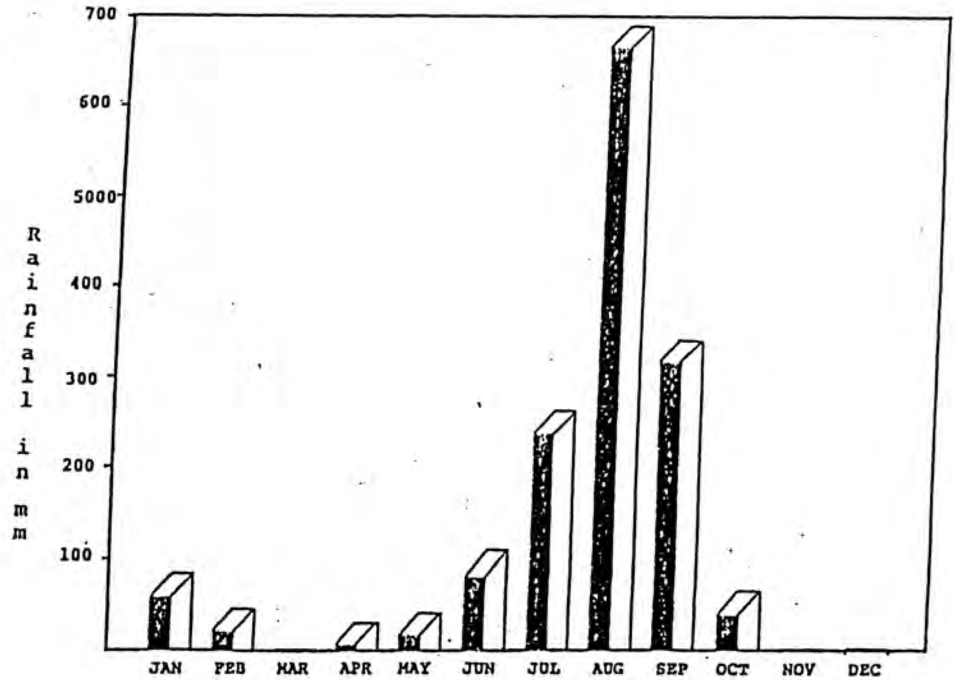

Figure 1. Average monthly rainfall at Begumgunj village for 1982-1984.

With the onset of the monsoon, farmers begin the rainy season or kharif planting in the third week of June with soybeans and pigeonpea. This work is mostly finished by the first week of July and planting stops completely in the second week. Farmers are busy with weeding and interculturing during the months of July, August, and September. The soybean harvest starts in the second week of October and lasts until the end of the month (Fig. 2).

When the sowing of the kharif crops is completed, the preparation of fallow fields reserved for postrainy season or rabi crops is initiated. During breaks in the rain, the fields are harrowed about four times to eradicate weeds and enhance moisture infiltration. By late September the rabi crops - wheat, chickpea, lentil, linseed, and sesamum - are planted. The harvesting and threshing of these crops begins in the second week of February and continues for a month. From April until the onset of the monsoon farmers prepare their fields for the next kharif season.

Development cost of the watershed

The development cost of the small watershed at Begumgunj in 1982 was Rs. 1035 per hectare which was Rs. 200 to 500 more than in the other verification trial villages (Walker et al. 1983). The greater cost resulted from the need for greater drainage because of the higher rainfall and the substitution of more expensive tractors for cheaper bullocks in developing the watershed.

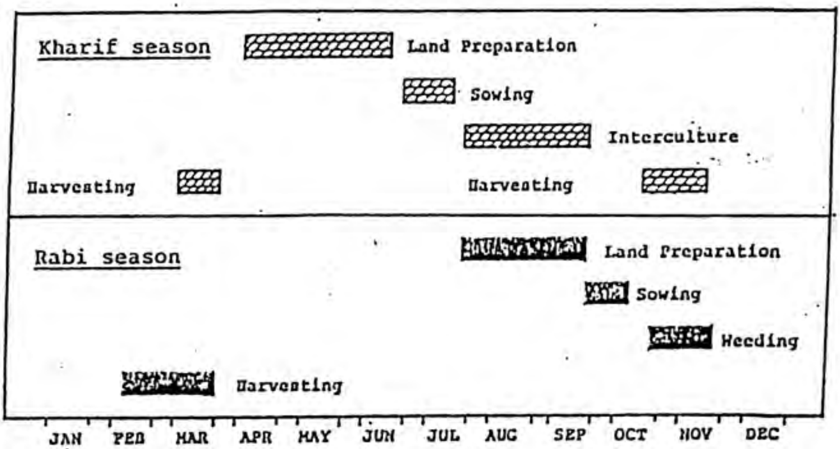

Figure 2. Traditional seasonal sequence of farm operations in Begumgunj village.

In 1984-85 the area under the project expanded considerably. No development work such as levelling and field drain construction was done in this new area except partial development work of community drains serving about 40 hectares. These drains were constructed by the Department of Agriculture without help from the participating farmers. The cost of these community drains was Rs. 300 per hectare.

Overall economic performance

During the first year, the watershed project encomposed 24 hectares and involved 10 farmers (Table 1). In 1983-84, the area was reduced to 15 hectares with 8 farmers. (One farmer sold his land, while a tenant gave up his leased-in land). In 1984-85, farmers from the neighboring village, Sumer, also participated in the trials and the project area expanded to 103 hectares involving 45 farmers.

ICRISAT and the Department of Agriculture recommended crops and cropping systems, but the farmers selected their own cropping systems. As a consequence, several combinations were grown (Appendix Tables 1, 2, and 3).

The results from the 1982-83 trials show that the average profitability of the improved technology was lower in the Begumgunj watershed than in other field-trial sites (Walker et al 1983). This relatively poor performance was partly explained by a drought between June 19 and July 9 - the first time in 30 years that it did not rain between those dates during the planting

Table 1. Costs and returns for the improved watershed technology tested in Begumgunj, Madhya Pradesh, 1982-83 to 1984-85.

Particulars	Cropping years		
	1982-83	1983-84	1984-85
No. of farmers involved	10	8	45
Area of watershed (ha)	24	15	103
No. of plots in watershed	17	11	79
No. of cropping systems selected by the farmers	9	4	12
Weighted average gross profits (Rs/ha)			
o improved technology	1172	2743	2523
o traditional technology [a]	786	1611	1638
Weighted average operating cost (Rs/ha)			
o improved technology	2348	2321	945
o traditional technology [a]	866	1250	636
Marginal rate of return (%) [b]	26	106	186

a. From fields neighboring the watershed. See Appendix Tables 1, 2, and 3.
b. Ratio of the difference in benefits between the improved and traditional technologies divided by the difference in cost.

season (Heinrich and Sangle 1983). Nonetheless, some of the improved cropping systems, particularly the soybean/pigeonpea intercrop, performed well with profits [2] exceeding Rs. 3300 per hectare, while the farmers' benchmark or traditional practices netted profits of only Rs. 800 per hectare. On the other hand, farmers trying to sequential crop with chickpea and/or wheat as second crops without irrigation found it difficult if not impossible to establish those crops (Heinrich and Sangle 1983).

Results for 1983-84 showed considerably improved profits over those for 1982-83 despite problems of frost and wilt in the pigeonpea crop. Furthermore, costs of production were unusually high because of gap filling and intensive weed management in dry sown fields. Similar problems with dry sowing occurred in the previous season. Unlike in 1982-83, rainfall was copious in 1983-84 and its distribution was exceedingly favorable for sequential cropping (Sangle and Sharma 1985). Sequential cropping systems generated profits of Rs. 2500 per hectare in the watershed and in neighboring farmers' fields.

The improved watershed-based technology continued to perform well in 1984-85. Watershed farmers, compared to a benchmark of "traditional" farmers with fields close to the watershed, received an additional profit of Rs.576 with an additional operating cost of about Rs.309 per ha or a marginal rate of

[2] "Profits" means gross value of crop minus operational expenses of seed, fertilizer, pesticides, all human labor, bullock labor, wheeled tool carrier, tractor, thresher, winnower, and sprayer.

return of 186%. Although the *kharif* crop suffered from erratic and low rainfall during germination, continuous rains during growth, and a dry spell during the maturity (Sangle and Sharma 1985), this represented a considerable improvement in performance. In 16 plots, sole soybean was planted during the *kharif* season and sequential crops were intended to be grown during *rabi* season. Only four farmers planted *rabi* crops; their crops failed, and they lost the cost of inputs. The other plots were not sown because of lack of moisture. Thus, only one of the three years was conducive to sequential cropping in dryland conditions. The 3-year verification trial period was fairly typical of the recent history as data from rainfall records indicate that moisture will be available to establish successfully the sequential *rabi* crop in 8 of 29 years (Pandey 1986).

In 1984-85, the average operating cost of improved technology was substantially lower than in the preceding years (Table 1). In that year in the larger watershed, farmers choose to plant about 38% of the area to the traditional *kharif* fallow *rabi*-cropping systems. In contrast, in 1982-83 and in 1983-84, all land in the improved watershed was either intercropped in the rainy season or sequentially cropped.

Profitability, labor use intensity, and risk of alternative types of cropping systems.

The cropping systems planted by the watershed and neighboring benchmark farmers during 1982-85 can be grouped into four types: (1) the soybean/pigeonpea intercrop, (2) sequential cropping systems usually soybean-wheat or soybean-chickpea, (3) rainy season or _kharif_ sole crop - _rabi_ fallow systems mostly soybean-fallow and (4) the traditional _kharif_ fallow - _rabi_ cropping systems usually fallow-wheat or fallow-chickpea. Separating the cropping systems into those four groups helps identify the major source of the disparity in economic performance between the improved watershed and neighboring farmers' fields. The economic attractiveness of the improved technology was largely derived from the high profitability of the soybean/pigeonpea intercrop in the three cropping years and to a lesser extent by the sequential cropping systems in 1983-84 (Table 2). Within types of cropping systems, notable differences between plots in the improved watershed and in neighboring farmers' fields generally did not emerge (Table 2). Sequential cropping systems were the exception because watershed farmers attempted sequential cropping in 1982-83 and 1984-85 which were unfavorable to sequential crops, while neighboring famrers only sequentially cropped in 1983-84 which was characterized by late rains conducive to the establishment of the _rabi_ crop. Summing up, the larger area of the soybean/pigeonpea intercrop in the watershed drove the comparative economic results.

The improved soybean/pigeonpea intercrop and sequential cropping systems also more intensively utilized both men's and women's labor compared to the farmers' traditional practice of fallowing in _kharif_ and planting wheat or chickpea on residual

Table 2. Comparing the average profitability of different types of cropping systems in the watershed verification trial and in neighboring farmers' fields in Begumgunj, Madhya Pradesh, from 1982-85.

Type of cropping system	Profitability[a] Improved watershed technology	Benchmark farmers' practices
	------------Rs. per hectare--------------	
Soybean/pigeonpea intercrop	2686 (55)[b]	2828 (10)
Sequential cropping	702 (13)	2565 (4)
Kharif sole crop-*rabi* fallow	833 (12)	993 (16)
Kharif fallow-*rabi* crop	630 (27)	685 (36)

a. Simple average of the total number of fields planted to each type of cropping system from 1982-85.

b. Number of fields.

moisture in the rabi (Table 3). In shifting from the labor extensive traditional kharif fallowing-rabi cropping systems to the improved intercropping or sequential systems, labor use requirements more than doubled. Successful sequential cropping during 1983-84 under benchmark farmers' practices appeared to be as or even more intensive than the soybean/pigeonpea intercrop.

The frequency distribution of profits is presented in Table 4 to assess the relative riskiness of the different types of cropping systems. The traditional kharif fallow-rabi cropping systems epitomize a low return, low risk activity as profits from 50 of the 63 fields fell in the range of 1 to 1000 Rs. per hectare. The improved soybean/pigeonpea intercrop also involved little risk as losses were not incurred on any of 65 sample fields. In other words, a high level of profitability was relatively assured with the soybean/pigeonpea intercrop. Returns were much more disperse with sequential cropping and kharif sole crop-rabi fallow alternatives. Sequential cropping was particularly risky as losses of more than Rs. 1000 were incurred on 4 of the 17 sample plots. The high incidence of losses substantially reduced the average profitability of sequential cropping. Farmers' unwillingness to take risk could certainly be a source of friction to the adoption of dryland sequential cropping systems, but risk aversion should not impede the diffusion of the low risk, highly profitable soybean/pigeonpea intercrop. Because the soybean/pigeonpea intercrop scored so well in the verification trial on profitability, labor use intensity, and risk criteria, its acceptance by farmers is

Table 3. Comparing the average labor use intensity of different types of cropping systems in the watershed verification trial and in neighboring farmers' fields in Begumgunj, Madhya Pradesh, from 1982-85.

Type of cropping system	Improved watershed			Benchmark farmers' practices		
	Male	Female	Total	Male	Female	Total
	Hours per hectare[a]					
Soybean/pigeonpea intercrop	212	216	418	123	235	358
Sequential cropping	121	185	306	174	213	387
Kharif sole crop-rabi fallow	74	105	179	108	125	233
Kharif fallow-rabi crop	59	72	131	79	85	164

a. Based on the same number of fields as in Table 2.

Table 4. Frequency distribution of the profitability of different types of cropping systems in both the watershed verification trial and in neighboring farmers' fields in Begumgunj, Madhya Pradesh from 1982-85.

Range of profitability in Rs. per hectare	Type of cropping system			
	Soybean/ pigeonpea intercrop	Sequential cropping	*Kharif* sole crop *rabi* fallow	*Kharif* fallow-*rabi* crop
Less than -1000	0	4	3	1
Between 0 and -1000	0	0	0	0
Between 1 and 1000	3	5	13	50
Between 1001 and 2000	15	1	8	11
Between 2001 and 3000	24	5	4	1
Between 3001 and 4000	18	2	0	0
More than 4000	5	0	0	0
Number of observations	65	17	28	63

treated at length in the early adoption research discussed later in this report.

Profitability of Component Recommendations: Broadbeds and Furrows and dry seeding

Two component recommendations, Broadbeds and Furrows (BBF) and dry sowing, were the subject of experimentation within the watershed. In 1984-85, 21 fields in broadbeds and furrows were compared to 11 fields managed under the farmer's practice of flat cultivation on a grade (Appendix Table 3). While "true" benefits from different in situ land management alternatives are often not manifested or confounded on a smaller field scale, farmers presumably base their adoption decisions on such field-to-field comparisons. In 1984-85 profits (Rs. 2983 per hectare) in fields with broadbeds and furrows were not significantly different from profits (Rs. 2818) in plots which were cultivated flat-on-grade.

In general, dry sowing was not as economically attractive as the farmer's traditional practice of wet sowing. Dry sowing often demands more intensive weed management as weeds germinate with the crops and compete for resources. For example, the cost of interculturing in the seven dry sown plots in 1983-84 was about Rs. 320 per hectare, while weeding expenses in the four fields planted after the onset of the monsoon was less than Rs. 50. From these results, we expect that farmers' reluctance to accept BBF and dry sowing can be explained in the relatively poor economic performance of those two component recommendations in the veritication trial.

Characteristics and Cropping Practices of Sample Farmers in 1986-87

Begumgunj is a large village with a population of more than 16,000 people and straddles a main road from Bhopal (120 km) to Sagar (60 km). It is an agricultural service center for surrounding villages. Its substantial bazaar has numerous non-traditional products and services available, such as a cinema, several medical, TV, and tractor repair shops, as well as more traditional shops and services. Major consequences of these characteristics for local farmers include an adequate supply of labor, services and supplies for their tractors and other machinery, and an organized market for any product they want to sell.

Farmer characteristics

The 25 farmers interviewed for the early adoption study are generally large farmers with high levels of education (Table 5) [3]. Their farm size averages 28 acres [4]. The largest has 73 acres, and eight have 40 or more. Even the smallest farm has 4.5 acres; only seven have less than 10.

[3] Two watershed farmers chosen in the sample could not be interviewed when the survey was carried out; they were replaced with two other cooperators in the 1984-85 larger watershed trial. All of the "original" watershed farmers who participated in 1983-84 were interviewed.

[4] Acres are used in the rest of the report to express land area because "acres" was used in conversation with farmers.

Table 5. Selected characteristics of 25 sample farmers in Begumgunj, Madhya Pradesh 1987.

	18 Watershed farmers	7 "Traditional" farmers	All farmers[a]
Land Resources			
Average crop acres per farm	26	34	28
No. of farmers with wetland	9	4	13
Average acres on farms with wetland	9	5	8
% wetland of all crop-land of 25 farmers	18	7	15
Power Resources			
Ownership of tractors	4	4	8
Hiring of tractor	8	2	10
Total using tractor	12	6	18
Using tractor only	3	2	5
Using bullocks only	6	1	7
Owning bullocks	14	5	19
Level of Education			
Less than primary completion	2	0	2
Primary completion	5	4	9
Middle school completion	5	3	8
College completion	6	0	6

a. The sample includes 18 watershed cooperators of 1984-85 and 7 farmers who did not have this experience.

Half the sample farmers (13) can irrigate some of their land from wells or the nearby river but none can irrigate all their land. The average farmer with irrigation has eight acres of wetland. Fifteen percent of all cropland of all sample farmers can be irrigated although water supply is limited to one postrainy season irrigation on much of the area. The universal intent is to double crop all wet land every year. Some kharif crop failures and an inadequate water supply prevented double cropping in 1986-87.

The power resources available to these farmers are substantial. Eight of the 25 farmers own tractors; another 10 hire tractors. Only seven limit their power to bullocks. Six own no bullocks and depend entirely on owned (3) or hired (3) tractors.

Ninteen farmers continue to own bullocks, and twelve use both tractors and bullocks. Use of both power sources is probably transitional with six farmers having completed the transition. Among the 19 who continue to use bullocks, production of fodder is an important criterion for cropping decisions.

The eight farmers who own tractors average 59 acres per farm while the 10 hiring tractors operate an average of 19 acres. The seven depending entirely on bullocks average 10 acres per farm and 8.6 acres per pair of bullocks. Except for one farmer who farms 19 acres with one pair, the maximum seems to be about 10 acres per pair.

Educational levels are another important resource for these farmers. Six have finished college and an additional eight have completed middle school. Nine others have completed primary school, leaving only two with less education, both 50 or older.

The level of education is a major asset for this study in two ways. One is the general attitude toward innovation that comes with education. We also needed farmers who could understand our probing questions and articulate their answers. The general conclusions of the survey can be given substantial weight because of the educational level of the sample.

Commercial vs. subsistence production

Most farmers in our sample combine subsistence and commercial production. Perhaps a clear definition of these two commonly misunderstood terms will be helpful. We can think of a continuum of the percent of total farm production sold. The continuum starts with zero production sold (a pure subsistence farmer) and ends with 100% sold (a pure commercial farmer). Farmers selling less than 10 percent (an arbitrary point cn the continuum) are usually called subsistence farmers.

Farmers who have increased sales to more than 10 percent, say 25 percent, are still consuming 75 percent of their production but net income and response to market signals are becoming important to them. Farmers selling a higher and higher percentage of production, moving along the continuum over time, are called commercializing or semi-subsistence farmers.

Eventually most farmers will arrive near the end of the continuum, selling more than 90 percent of their production but the transition can take a long time.

The farmers in our sample, except two, are commercializing farmers. They have started moving along the continuum but still produce most of the family's food grains and fodder. The two exceptions have completed the transition and are depending on the market for most foodgrains and selling most of their farm production. One of these two farmers grew only soybeans and sells 100 percent of his production. He was clear that maximum profit, a true commercial attitude, is the criterion for his cropping decisions.

For all but two of our sample, therefore, subsistence requirements tend to have first priority or form the starting point in putting together the annual crop plan. These 23 farmers would grow food grains even though an alternative cash crop was more profitable, and food grains were available in the market. Fifteen were emphatic about this, while eight showed various levels of flexibility but continue to grow their foodgrains and fodder. These large farmers are subsistence farmers first and profit maximizers only for those resources not needed for subsistence production.

Answers to several other questions were helpful in shedding light on the importance of subsistence production objectives in conditioning adoption. In response to a completely open-ended question about the problems of rainy season cropping, eight farmers independently said there are no problems except that they must have postrainy season food crops and can't count on successful postrainy season crops after rainy season soybeans.

Twenty of the 25 farmers try to grow a minimum wheat acreage (assumed to be a proxy for subsistence needs) each year. The average minimum was about 9.5 acres with a range from 2 to 17 acres. At 700 grams per day, average Begumgunj wheat yields will feed 1.0 to 1.5 people per acre. Average family size is 12 people with 7 of them older than 11 years. Given that people also eat other grains, the average minimum acreage seems somewhat high for subsistence needs but is, perhaps, within a reasonable range, including a safety factor for year to year variability.

Closely associated with family food grain needs is the imperative for home produced livestock feed with wheat producing both the preferred food grain and the preferred fodder. Farmers' comments suggest that those owning a tractor without bullock pairs are more likely to grow more profitable chickpea than wheat because they do not need bhussa (wheat straw) for bullock feed.

A further subsistence need supplied by the traditional system is cooking fuel (dung cakes). Any reduction in fodder production, such as on the tractor farm mentioned above, will involve an alternative cooking fuel source, probably a purchased hydro-carbon.

Decisions and constraints involving subsistence food grain and fodder production are clearly part of the total picture of double cropping possibilities among these large, well educated farmers in Begumgunj. The consequences of these perceived subsistence requirements on double cropping of dryland will be explored further later in this report.

Cropland use in 1986-87

The 1986-87 cropping pattern was strongly influenced by the distribution of rainfall in 1986. Total rainfall was about average but half of it fell in four consecutive days in July. The rains receded completely about August 20th. September rains needed for good postrainy season crops failed. In the following discussion, farmers' actual outcomes and cropping intentions are reported.

Uses of cropland by the 25 farmers in 1986-87 are shown in Tables 6 and 7. The 18 watershed farmers, who had supervised experience with the new technology in 1984-85, are separated from the "traditional" or the control group of farmers who did not. Both the percent of farmers following specified cropping systems and the percent of land involved in the systems are presented.

Use of dry (unirrigated) cropland

Seventeen of the 25 farmers intended to double crop dryland but on only a small part of their total cropland. Seventy two

Table 6. Intended utilization of cropland in Begumgunj, Madhya Pradesh, in 1986-87 in percent of farmers.

Type of use	Watershed farmers in 1984-85[a]	Watershed farmers in 1986-87[b]	Traditional farmers in 1986-87[b]
Dryland			
No. of farmers	45	18	7
Kharif cropping	100	72	57
Kharif cropping with pigeonpea	73	22	0
Sequential cropping	10	28	14
Total double cropping	83	50	14
Kharif single cropping	27	22	43
Rabi single cropping	38	89	86
Wetland			
No. of farmers	10	9	4
Percent of farmers			
Kharif only cropping	0	0	0
Rabi only cropping	44	0	0
Double cropped Pigeonpea	11	0	0
Other double cropping	89	100	100

a. Watershed land only
b. All operated land

Table 7. Utilization of cropland in Begumgunj, Madhya Pradesh, 1984-85 and 1986-87 in percent of area.

Types of use	45 watershed farmers in 1984-85[a]	18 watershed farmers in 1986-87[b]	7 traditional farmers in 1986-87[b]
Dryland			
Kharif cropped	63	26	11
Kharif with pigeonpea	39	7	0
Sequential rabi cropped	12	9	5
Total double cropped	51	16	5
Kharif single cropped	12	10	6
Rabi single cropped	37	74	89
Total (acres)	98	386	225
Wetland			
Kharif cropped only	0	0	10[c]
Rabi cropped only	40	8	0
Kharif with pigeonpea	3	0	0
Other double cropped	57	92	90
Total (acres)	14	86	18

a. Watershed land only.
b. All operated land.
c. *Rabi* fallowed only because of water shortage.

percent of watershed farmers and more than half the traditional farmers cropped dryland with soybeans in the rainy season. The crop combination soybean-pigeonpea recommended as most profitable during the field trials, was grown by only four (all watershed) farmers. Adding another five watershed farmers who sequential cropped after soybeans, half the watershed farmers tried double cropping compared to one of the "traditional" farmers. Four other watershed farmers planted only rainy season crops on their dryland although they may have intended sequential crops if the rains had not receded so early. Eight of the 25 farmers grew only rabi crops on their dryland.

The comparison with watershed farmers in 1984-85, shown in the two tables, must be made with great care because the earlier data include only watershed land while the 1986-87 data include all operated cropland. However, the comparison in Table 6 of the number of farmers with field trial double cropping experience and those still trying it seems useful. Based on intentions, the proportion of watershed farmers planning double cropping dropped only from 83 to 72 percent in the two years. One "traditional" farmer also double cropped dryland in 1986-87, a small encouragement for the spread of the practice.

The rainy season crop grown by the sample farmers is exclusively soybeans, mixed with pigeonpea by four farmers. In the first year of field trials, six farmers grew sorghum with pigeonpea, but sorghum has not been mentioned since. Twenty of the 25 farmers said no kharif crops were grown before soybeans while the other five mentioned small areas of sorghum, mung, black gram, paddy, and pigeonpea.

The four main *rabi* crops are wheat, chickpea, lentil (masoor) and linseed. A few farmers also mentioned mustard. No change was suggested for these traditional crops in the field trials. Pigeonpea is the one crop needing both seasons to mature.

Table 7 shows the use of dry cropland in 1986-87. Watershed farmers *kharif* cropped 26 percent of their dry cropland. Double cropping was attempted on 16 percent, a substantial change from the pre-1982 practice. The "traditional" farmers in our sample have moved in the same direction but with less change.

While 1986-87 was an unusually bad year for dryland double cropping, the results are instructively sobering for double cropping advocates. Among the four farmers trying pigeonpea, two reported a complete crop failure and the other two about a 50 percent crop. Of the six trying sequential crops, one reported an average soybean crop and a "good" chickpea crop, our one clear example of double cropping success. Four reported *rabi* crops varying from 25 to 50 percent of normal. One had a soybean failure but good *rabi* crops. In spite of poor experience in 1986-87, a significant number of farmers accept the double cropping possibility and will continue the slow process of working it into their on-going system of farming for a portion of their dryland.

Use of irrigated cropland (wetland)

About half the sample farmers own some wetland, a total of 15 percent of all cropland on the 25 farms. The average of those having wetland is 8 acres and the maximum is 21.7 acres.

Wetland is used to grow exactly the same crops as the same farmers grow on their dryland. They are using the water entirely for double cropping insurance. The intent is to double crop all irrigated land every year, but in 1986-87 several farmers were unable to irrigate rabi crops because of water scarcities.

The attitude toward digging new wells is instructive. Eight to 10 wells are being dug in the area each year, perhaps the result of consciousness raising about double cropping during the field trial years. A few sample farmers had recently dug or are planning to dig wells, and a tubewell driller was soliciting work in the week of the survey. Dug wells in the area typically cost up to Rs. 40,000, including pumping equipment and an electrical connection, and usually irrigate 3 to 4 acres. With good crops in both seasons together producing a gross income of Rs. 4000-5000 per acre, this seems like expensive insurance.

One farmer mentioned the risk of digging a dry well. While the risk is apparently quite low in most assured rainfall areas of the SAT, a dry well dug with a loan may economically destroy a small or medium farmer through the need to pay back the loan from other income sources. This risk must be a major deterrent to digging wells in spite of government encouragement.

Irrigated acreage is gradually increasing and double cropping opportunities on it will expand. However, this study focusses on dryland double cropping and irrigation will not be discussed further. In the next section, current use and farmers' attitudes toward the individual components of ICRISAT's technology package are reviewed against the background of cropping practices described above.

Use of The Technological Package and Its Components in 1986-87

Begumgunj farmers were asked which of the several components of the technological package they continued to use two years after the end of the field trials and why they continue or do not continue this use. The farmers do not view this group of innovations as an interrelated package. Instead, they view them as a cafeteria collection of innovations from which they can choose attractive individual components. Some parts of the recommended package have been widely adopted while others have not.

Only three parts of the package were completely unknown in the Begumgunj area prior to 1982: small watershed management with broadbeds and furrows, the interrelated use of the wheeled tool carrier, and dry seeding. The other recommended practices were all in use at least by one or a few sample farmers, although the initial use of several was recent. The field trial effort stimulated the rather rapid adoption of several components of the package and farmers have usually continued to use those components after the end of the field trials. This wider experience with the inovations can be expected to facilitate their general spread within the community as shown by answers of the seven non-watershed farmers.

Table 8 shows the use level of package components prior to the field trials and summarizes the adoption and survival rates since then. Short summaries of the 1986-87 acceptance of each component of the package are given below followed by an analysis of farmer responses and reasons for acceptance or rejection.

Dryland double cropping

Ten of 25 farmers double cropped dryland and seven others planted kharif soybeans but left the land fallow in the postrainy season because unfavorable rains discouraged rabi sowing. Twelve percent of the dry cropland was double cropped and an additional 8 percent was kharif cropped only. In terms of intentions, 20 percent of dryland was to be double cropped by 17 of 25 farmers. Few had grown kharif crops prior to 1982. The kharif crop is exclusively soybeans, intercropped with pigeonpea by four farmers. Farmers' current acceptance of double cropping and prospects for extending the area under this practice are discussed later in this report.

Table 8. Use of components of the double cropping technology package in Begumgunj, Madhya Pradesh by 18 Watershed and 7 non-watershed farmers in 1986-87.

	18 Watershed farmers			7 Non-watershed farmers
Practice	Number using before 1982[a]	Number adopting during field trials	Number using in 1986-87	Number using in 1986-87
Kharif soybeans dryland	4[b]	14[b]	13[c]	4[c]
Dryland double cropping	Probably none	17	9+4[d]	1+3[d]
Summer plowing	18	-	18	6
Improved drainage furrows	0	18	2	0
Broadbeds	0	18	0	0
Dry *kharif* sowing	0	8	1	0
Improved seed	3	13	16	4
Use of chemical fertilizer	4	11	15	5
Using recommended dose of fertilizer	-	-	4	1
Mixing seed and fertilizer		All who use fertilizer at seeding time		
Row seeding *kharif* crop	1	14	14	5
Chemical plant protection	1	6	7	6
Use of wheeled tool carrier	0	18	0	0

a. ICRISAT field trials began in 1982.
b. Includes wet and dryland
c. Including those growing soybeans on land that can be irrigated, 23 of 25 farmers grew soybeans in 1986-87.
d. The second number indicates the number who planned to double crop but had to fallow in the postrainy season because of a moisture shortage.

Summer harrowing

Although it generally isn't done until _rabi_ threshing is completed, post harvest cultivation is a traditional practice in this area with only one of 25 farmers not narrowing in the summer season; he harrows after the rains begin. Farmers gave a variety of reasons for summer harrowing:

1. To kill weeds, particularly _kansgrass_ and deep rooted weeds (mentioned by 15 farmers);
2. Kills insect pests in the soil by exposing them to the sun (6 farmers);
3. Removes stubble of previous crop (9 farmers);
4. Pulverizes the soil which improves moisture absorption (7 farmers);
5. Fills cracks and improves soil structure (3 farmers); and
6. Improves soil fertility (3 farmers).

Improved drainage

Broadbed and furrows were not "sold" during the three year field trial period although six farmers said soybeans do better on BBF. Two farmers continue to use the furrows and one has extended them to all his _kharif_ fields. From this tenuous hold, the use of drainage furrows may gradually catch on in those fields with recognized drainage problems.

Even for six farmers who see benefits from BBF, the costs must be larger than the benefits. Most farmers failed to offer reasons but hid behind the unavailability of the proper implements (WTC) to form them. Other reasons mentioned for not using BBF were wastage of area (presumably in the furrow area) (one farmer), lack of any advantage (5 farmers), difficulty of maintaining the beds during other operations (4 farmers), and the opinion that they are uneconomic and impractical, given the uncertainity of the rains (one farmer).

Of the 14 watershed farmers who answered the question on field drains and community channels, 12 said they were not using them. Of these, eight said they had no drainage problem while four others said they saw no advantage. Farmers seldom seem to recognize a drainage problem and thus see little benefit from drainage furrows. This benefit will vary in any case, depending on the location of the field within the watershed and the natural slope of the land. The seven traditional farmers had no experience with this technology so their opinions were not elicited.

The community channel question was often answered on the basis of, "what do you think of the community channel?", instead of the actual wording, "do farmers cooperate to maintain the channel?" Both formulations are relevant and both sets of answers from the 18 watershed farmers are reviewed.

Nine farmers gave their opinions about the usefulness of the community channels. The opinions were related to the location of fields on the watershed. Two farmers with fields in the upper part were indifferent. Four with fields at middle level saw positive benefits from drainage, and the three at the bottom, particularly those near the drain's discharge area, were strongly negative. The latter felt that additional water is now gathered into the drain, which causes them greater drainage and erosion problems. This difference of opinion suggests the problems of achieving a necessary level of cooperation among watershed farmers for a widespread program of small watershed management.

Among the other nine watershed farmers, seven answered the question as it was worded. Five said farmers are uncooperative and indifferent, one said lack of action was due to money problems (government handouts?), and one said he likes the channel and regularly does his part to keep it in good condition, (presumably refering to his own field channels that feed into the community channel).

Dry seeding

Dry seeding (the kharif crop before the rains start) was given a good trial during the three years of field trials by eight of our 18 watershed farmers. One farmer continues to use it. He started at ICRISAT's suggestion and likes the results. The others are unambigious on its disadvantages. The pattern of rainfall at the beginnning of the rains can often cause germination problems and consequent loss of inputs and the weed problem is perceived to be significantly greater than with wet sowing. One farmer suggested that soil heat was a problem if rains were delayed and that low levels of moisture, combined with the fertilizer mixed with the seed, caused death of the seedlings. Dry seeding can help to avoid the timing bottlenecks of wet sowing and facilitate an early start of the kharif crop. The farmers, however, (all but one) see the disadvantages as outweighing the advantages.

Improved seeds

All but two watershed farmers and three traditional farmers now use high yielding varieties (HYVs) for at least some of their crops. Of the 20 user farmers, however, only five were using HYVs before 1982. While improved seeds were not a completely new idea at the beginning of the field trials the trials for many farmers clearly provided the incentive to try them. All who tried them, except one, have continued their use.

The attractiveness of HYVs is dominated by increased yield (mentioned by 15 farmers). Other advantages include greater response to fertilizer, earlier maturity, and less shattering. Most farmers probably had soybeans in mind in answering this question.

The five who do not now use HYVs couldn't afford to buy them, said the family was against taking loans, or gave no answer. In other words, no persuasive arguments against HYVs were offered.

Use of fertilizer

Five of the 25 farmers use no chemical fertilizer. The cost is the main problem since they realize that yields are increased. One farmer is against taking loans on principle while another recognizes the risk of losing the fertilizer cost if the crop fails. Another avoids this risk on wheat by not applying the basal dose fertilizer during sowing and top dressing later if it rains.

Farmyard manure is valued by all farmers and 20 said it is superior to chemical fertilizer. Its long term effects (2-3 years) and its impact on soil texture, water holding capacity, and general soil condition were most often mentioned. Some mentioned its "free" nature. Farmers clearly understand the benefits of soil organic matter.

The five who saw chemical fertilizer as superior mentioned quick results and avoidance of the supply problem involved with farmyard manure. Twenty farmers use chemical fertilizer because "it increases the yield". Only five were using fertilizer before 1982.

The farmers of the area seem to have been generally slow to start using fertilizer. It was in general use in some parts of India in the 1950's and early 1960's (even in some parts of SAT deep vertisols). In defense of those farmers who grew only rabi crops (most of them in Begumgunj), the successful use of fertilizer on unirrigated rabi crops requires a substantial level of sophistication, and the payoff is likely to be small. The amount used must be closely adjusted to the moisture level in the soil. If too much is applied, relatively lush growth is stimulated during the first part of the growing season. Stored soil moisture can be completely used well before the crop matures. A little too much fertilizer can cause crop failure.

All but four farmers know the fertilizer type and recommended dose. Extension work seems to be effective.

Most farmers who use fertilizer use the recommended type but only five of 20 use the recommended amount. Lower amounts are preferred with some farmers reporting the use of about 50% of the recommended levels. One actually used the language of marginal analysis ("not much benefit from more fertilizer") while four gave answers related to soil moisture and the amount which can be safely used. Another suggested that, at the recommended levels, fertilizer hurts germination which may be true when fertilizer and seed are mixed for sowing. Three feel that fertilizer, used at recommended levels, will "spoil the soil" over time. This is, taken together, an impressive set of answers and a review of recommended levels of fertilizer application for dryland agriculture in the Begumgunj area is strongly indicated.

Row seeding of _kharif_ crops

The use of row seeding for _kharif_ crops (soybeans, sometimes intercropped with pigeonpea) has a strong level of acceptance. Twenty of the 25 farmers sow _kharif_ crops in rows, and only one started to do so before 1982. Only one of the farmers, who tried it in the field trials, has now reverted to broadcasting.

Several advantages for row sowing over broadcasting were mentioned. More uniform spacing and better crop stand because of better depth control, easier intercultivation, weeding, pest control, and harvesting (the latter especially when intercropped), and better fertilizer placement were most commonly cited. Others stated advantages were use of less seed, better germination if rains are delayed, drainage improvement and soil and water conservation, better control of plant density and easier filling in pigeonpea gaps with a rabi crop.

This again is an impressive list of advantages. Among the five non-acceptors, one grows no kharif crops, three gave no explanation, and one mentioned that broadcasting is faster. Lack of timeliness is a major constraint to row sowing, since the total sowing season is short and will usually be further shortened by lack of or too much rain. The widespread adoption of row sowing must indicate substantial benefits over broadcasting.

Placement of seed and fertilizer

All farmers who use fertilizer at sowing are mixing it with the seed and sowing the mixture. Almost all farmers know the recommendation that they should not mix seed and fertilizer. No farmer is following this recommendation. Most said it was not followed because they have no implement to place the fertilizer separately from the seed. Some apparently pictured themselves going over the field twice to sow seed and place fertilizer separately; consequently, they said it was too time consuming and costly for the extra labor. Some feel they get good results with the mixing (as long as they use low doses of fertilizer). Straightening out the issue of the magnitude of benefits from separate and ideal placement in comparison to the costs of developing (if needed) and purchase by farmers of an effective sowing implement would be a reasonable, and fairly complex, research undertaking.

Chemical pest control

Half the farmers (12) used chemical pest control in 1986-87, primarily for pod borer on pigeonpea and chickpea. All farmers purchasing improved seed are using treated seed. The universal reason given for chemical protection is increased yield.

Farmers expect insect damage in pigeonpea to average 2/3 loss in three out of four years without chemical treatment. No effective treatment prior to the use of chemicals was mentioned but one farmer said pod borer on pigeonpea was not a problem before the introduction of fertilizer.

One farmer used chemical pest control in 1981 and all the remaining users started in 1982 or later. Three farmers explicitly credited the field trials for getting them started. Five of seven traditional farmers undertook plant protection and all started in 1982 or later.

The most common explanation for not spraying is the lack of need (note that pigeonpea is the most commonly attacked crop and only four grew it in 1986-87). A few cited the expense but the lack of infestation was first mentioned. In general, farmers do spray when they have a bad infestation but rather not otherwise.

Wheeled tool carrier (WTC)

Among the seven farmers expressing a positive opinion about the WTC, all said it is good for sowing because it has good depth control and is helpful for seed and fertilizer placement. Three of the seven commented on its moisture conservation and drainage improvement abilities. One observed that it worked faster than traditional implements.

Most who have no interest in the WTC either have (or hire) tractors or have bullocks which cannot pull it over a sustained time period. One commented that he couldn't see any difference in yield between the WTC and traditional implements. In our opinion, that is a key answer. Another observed that the traditional implements are easier to operate and repair.

Seven farmers would be willing to rent the WTC. For most, this meant for only a few days a year for sowing and, of course, all would want it at about the same time.

When asked about their preference between a WTC and an owned or hired tractor, five chose the WTC, all of whom had said yes to wanting to use it for sowing. Reasons for the preference centered on sowing advantages and lower cost. Two of the five observed that they could use their own bullocks and family labor (fixed costs). One said it was more flexible than tractor equipment for gap sowing.

Most of the remaining 20 farmers either now use tractors or preferred tractors because of their speed in getting the work done. Tractors may actually be cheaper per hectare, than a WTC at a necessary rental rate, because of their speed. In addition, the speed can be advantageous, in itself, for getting kharif crops planted.

Summing up

This section has reviewed farmer use of the components of the technological package recommended by ICRISAT during the field trials. The residual impact of most components is substantial while the current impact of dry seeding, watershed management, and interest in the wheeled tool carrier is small but not zero.

The major focus or objective of the package was to grow two crops per year on dryland where kharif fallow is the traditional practice. Seventeen out of 25 farmers are trying to make this work on 20 percent of the sample dryland. In the next section, the constraints for double cropping are reviewed, and research to remove or reduce them is suggested.

Double Cropping on Dryland: Advantages and Constraints

Double cropping of dryland in the Begumgunj area is slowly expanding. The expansion will continue as farmers gain experience and confidence. None of the constraints identified below limit it absolutely to its current level but all will become constraining as double cropping increases. The objectives of this section are to: (1) identify the forces stimulating farmers to try double cropping, (2) identify double cropping constraints, and (3) suggest approaches to reducing those constraints. The soybean/pigeonpea intercrop is given special attention because of its high profitability estimated in the field trials from 1982-85.

Farmers' attitudes toward double cropping

Farmers generally see substantial advantages to double cropping. The prevailing mood is captured by the comment, "Give us moisture and we will double-crop the world!". The comment also suggests the main constraint seen by farmers, reinforced by the interest and investment in irrigation as insurance for successful double crops. Numerous farmers, however, are quietly trying to work out methods of securing double-crop advantages without irrigation. While their success is variable and sometimes disappointing, they continue their efforts, usually on a small part of their land. If the current interest is associated with the field trials, it may be their major long-run contribution.

Advantages of double cropping

The major advantages of double cropping are increased net income for the farmer and increased total production for the nation. Although crop failures associated with double cropping efforts are sobering, the marginal or additional cost of growing a second crop is likely to be modest. A partial crop or a reasonable crop once every two or three years may provide enough added income to more than cover the added costs (not necessarily the total costs). Studying these additional costs and returns would add substantially to understanding the reality of double-cropping benefits perceived by farmers.

Another important advantage of double cropping for farmers growing only rabi crops is the change in their cash flow. Farmers planting only postrainy season crops receive income at the end of the rabi harvest or must store and gradually sell products throughout the year. Planning to have enough money to purchase rabi inputs for the following year must be particularly difficult. Several farmers mentioned that soybeans provides income in September for family living and for the purchase of rabi inputs. These comments may indicate less need than is suggested in some ICRISAT publications, such as Ryan et al. 1982, for a two-season credit system.

Kharif cropping and its problems

Every double cropping plan will involve Kharif cropping which was uncommon in the area before 1982. Farmers must learn how to manage *kharif* crops as well as their integration in the existing system in order to successfully grow two crops per year.

The main problem of *kharif* production is erratic rainfall. The ICRISAT term, "assured rainfall", may create an incorrect image of *kharif* crop management in the Begumgunj region. The total amount of rain which falls each year is adequate compared to other SAT areas. The unpredictable way it is received, however, creates high risk, major management challenges, and conservative decision making. The pattern of onset, cessation, and distribution within the season can cause crop failure, flooded crops, weeds out of control, and wet harvested crops on the threshing floor in September.

Kharif weed problems, however, were mentioned by only five farmers. Only seven of the 23 farmers growing soybeans in 1986-87 hired weeding labor, an indication that most farmers manage to grow their soybeans without hand weeding. Only one of the four growing pigeonpea with their soybeans hired weeding labor. Kansgrass is a special problem to be discussed later.

Insects were mentioned as a *kharif* problem by only one farmer. Soybeans are not generally bothered by insects or diseases at present. One mentioned the time constraints involved with planting the *kharif* crop, also discussed later.

A few farmers said *kharif* inputs are difficult to obtain. This probably results from the supply system lagging behind increases in *kharif* cropping.

Soybeans are considered an ideal *kharif* crop with an attractive price, limited pest problems, and a low risk of crop failure. One farmer called soybeans a "great boon to the farmers of this area". One might reasonably ask, then, why they are grown on only 20 percent of the dry cropland of our sample farmers. The answer to this question is explored in the next two sections.

The soybean/pigeonpea intercrop

In the three year field trials, this intercrop combination was shown to be superior to all other crop combinations in yield and profitability, and in the third year, 30 of 45 watershed farmers grew it. Among "traditional" farmers used for comparison, 8 of 29 grew the combinations. Yields of the two crops were satisfactory during the three years although pigeonpea suffered some frost damage in the second year. These crops were all grown on small plots, with only a few as large as two hectares.

In the second crop year following the field trials, only four of 25 farmers tried this crop combination. The discussion below attempts to explain this decline in interest.

First, however, additional advantages of the combination are examined. Only one seedbed preparation and sowing per year is needed for intercrops. Compared to sequential cropping, it is not only cheaper but relieves the time and labor bottleneck in September/October and reduces the time pressure for kharif sowing because the early harvest of soybeans is somewhat less critical.

Soybean yield is not reduced when pigeonpea is added. In the field trials, yields of sole soybeans on 35 fields averaged 619 kg per hectare while 48 fields of soybean/pigeonpea averaged 642 kg of soybeans. The marginal (additional) cost of adding pigeonpea to the soybeans prior to observing moisture conditions in October, then, seems to be limited to pigeonpea seed. The risk of crop failure because of low rabi moisture is also lower than with sequential crops. When expected pigeonpea yields are equivalent to alternative rabi crops and fetch a higher price per quintal than most of them, the high calculated profitability of this crop combination is not surprising.

Yet most farmers now grow sole soybeans when they grow soybeans. Several factors influence this loss of interest and are instructive for understanding the process of change in a farming system.

Thirteen of 25 farmers said they plan to continue growing the soybean/pigeonpea intercrop, and some expressed considerable enthusiasm for it. Yet, only four actually planted it in 1986-87. Because the crops are planted in June, poor pigeonpea conditions at the end of the rains did not influence these planting decisions.

What can be made of the difference between what farmers said and what they did? Nine farmers may plan to grow pigeonpea with soybeans in most years but happened to skip 1986-87. But that is unlikely, given apparent benefits. Of greater concern is the possibility that these farmers were telling us what they thought we wanted to hear. Fortunately, 12 farmers did tell us their objections to the combination.

Traditional preferences for _rabi_ food grains and oilseeds is a major deterrent to pigeonpea. The preference is tied closely to subsistence production needs for the family and livestock. Several farmers said they would rather try sequential crops than pigeonpea. One said he could tolerate the pigeonpea only because he could still plant sequential crops between the pigeonpea rows when moisture conditions permitted.

Two farmers revealed their systems thinking, preferences, and risk avoidance. They like to plant the intercrop but planned to pull out the pigeonpea and plant _rabi_ crops whenever moisture conditions permitted. They prefer to grow the _rabi_ crops and can avoid the pest and frost risks of pigeonpea (discussed below) but were reducing the risk of complete _rabi_ crop failure if October moisture conditions prevented _rabi_ sowing.

Crop preferences, partly associated with subsistence thinking and traditional cropping practices, seem to be involved in the lack of interest in the intercrop but, at the level of current soybean acreage, do not provide a satisfying total explanation.

The explanation most commonly offered by farmers was frost risk. Other risks of insects, rabi moisture shortage, and kharif waterlogging were also mentioned.

All farmers see some frost risk, ranging from 2 in 10 years to every year. Eight farmers expect frost damage in seven or more years in 10. When the crop is frosted in the flowering stage, the loss is often 100 percent. The variation in opinions about frequency is understandable because of the nature of frost. Locally low lying fields will be damaged more often and more severely than those with somewhat higher elevation.

Frost risk clearly acts as a friction to planting the combination. Other risks were less frequently experienced, and insect pests can be controlled by spraying. In view of the modest additional costs of adding pigeonpea and our earlier discussion pointing out the assured performance of the soybean/pigeonpea intercrop, farmers' risk aversion is also not an entirely satisfying explanation for loss of interest in the intercrop. With current levels of soybeans acreage and the size of farm in the area, most farmers could allocate higher lying low frost risk fields to the intercrop, saving their lower lying, moisture laden fields for sequential crops.

Another possible problem of the intercrop surfaced too late in the survey to ask farmers about it and no farmer happened to mention it. Once identified, however, it seems more satisfying than the above explanations. Before designing an approach to eliminate this problem, however, its validity should be explored with farmers.

Row sowing of intercrops with modern seed drills must be inconvenient. Farmers may be dismissing the intercrop because of this inconvenience in a severely time-constrained period of the year. With traditional row seeding equipment, the person dropping the seed can easily change from one seed to another as the sequence of rows requires. As soon as one changes to a seeder with a single seed tank and automatic feed, changing from seed to seed becomes more of a problem. Do you empty the seed tank each time you need to change crops?; do you have two seeders and keep changing which one is hitched to the draft power (with the possibility that the one you want is at the other side of the field); or do you plant the required rows with one crop and then come back to plant the carefully marked omitted rows with the other crop. A possibility would be to have a seeder with two seed tanks and appropriate feeding mechanisms but we have not heard of such seeders being available in Begumgunj.

As farmers move to seed drills (sowing is apparently one of the major uses of tractors in the area), sowing the intercrop becomes a problem at a time when they are in a hurry. They may be avoiding the problem by growing sole soybeans, especially when factors mentioned by farmers are considered. Only two of the four farmers growing the two crops together in 1986-87 intercropped in rows. Hand harvested pigeonpea stubble may also damage tractor tires, another problem which has surfaced since the survey and could not be verified by discussion with farmers.

We are still not satisfied that the decline in the intercrop is entirely explained above. With the apparent level of net income incentive, we would expect farmers to figure out ways to solve these problems. Someone should review the above discussion with a few farmers in Begmgunj and press them for other explanations. The lack of interest in what outwardly appears to be such an economically attractive cropping system merits more scrutiny in more focussed diagnostic research.

This review suggests, however, several steps to increase the attractiveness of the intercrop to farmers. The frost problem seems the easiest to solve and was the problem most often mentioned by farmers. No changes, apparently, were recommended in pigeonpea variety during the field trials, and farmers continue to grow their long duration, traditional varieties. The frost avoidance potential of somewhat shorter duration varieties could be reviewed and new cultivars made available to farmers if beneficial.

The insect problem (Heliothis) on pigeonpea could be reduced substantially. Most farmers are already willing to use chemical spray and supplies are available. They probably need training on the most effective time to spray.

Solving the problem of sowing row intercrops with tank seed drills might have the largest impact on the acceptance of the intercrop. The development of a seed drill which would solve this and other problems is discussed later in this section.

On smaller farms, the intercrop will often compete for <u>rabi</u> acreage with subsistence crops and extension effort in favor of the intercrop would probably be misplaced, for the time being, with such farmers. Most farmers in our sample, however, could use more land for the intercrop without competing with subsistence needs.

Constraints to large scale double cropping on dryland

The general objective of ICRISAT's technological package is to achieve double cropping on a large proportion of dry cropland in deep Vertisol, assūred rainfall regions of the SAT of India. The definition of large scale double cropping, as the term will be used here, is arbitarily set at greater than 50 percent of dry cropland under intercropping and sequential cropping each year. The ultimate objective would be a higher percentage, but most constraints mentioned below become operative below this level.

The constraints identified are not generally influencing the current level of double cropping in Begumgunj (20 percent). Most farmers, however, will bump against one or more of these constraints with fairly modest acreages of double crops.

Institutional resources

Before beginning a discussion of constraints, a possible problem area needs to be eliminated from consideration. Institutional inadequacies might play a major role in discouraging farmers from double cropping, but that is not the case in the Begumgunj area.

The information system available to farmers is used and is highly respected by them. Farmers were asked an open-ended question on how they would obtain information about growing a new, profitable crop. All but three would make an effort to do so. Eleven mentioned the Village Level Worker (VLW) as their primary source of information. Twenty farmers knew the VLW, and all 20 considered him to be helpful. Eight mentioned other farmers, relatives, or neighbors. Five mentioned the Government Seed Multiplication Farm Manager, a highly respected and entertaining character. One would go to the field where the new crop was growing - a reasonable response - and one would depend on the mass media.

In addition to these on-going information resources, the 18 watershed farmers were exposed to intensive training in the new technology by ICRISAT and staff from the Department of Agriculture. The conclusion must be that reluctance by farmers to double crop cannot result from lack of needed information or knowledge of how to get it.

With regard to credit, only one of the 15 farmers who used production credit in 1986-87 used a non-institutional source (a money lender). A cooperative was the most common source (11 farmers), and three borrowed from a commercial bank. Only four farmers reported difficulty in getting credit, and all received it. The credit institutions in the area are effectively performing their assigned function, and credit is generally available to farmers who want it.

The input supply system in Begumgunj appears generally favorable for farmers. No farmer had any problem getting seed and only two had difficulty in obtaining spray material of the desired type and at the desired time. Eight farmers reported difficulties in procuring fertilizer, either the desired kind or when they needed it for the kharif planting. Since 12 farmers use fertilizer with no supply problem, these issues appear to involve minor on-going market adjustments rather than the general failure of the fertilizer supply system. Only one of ten farmers reported difficulty in hiring a tractor, and he was successful.

No farmer reported any problem in selling any product. All use the village organized market operated by an effective committee. Several farmers specifically mentioned their respect and appreciation for the operating committee.

One institutional area associated with the recommended technology has failed to develop. Small watershed management requires a structure for cooperation among farmers and for obtaining planning help for drain layout and land leveling. No such organization exists in the field trial watershed or in any other watershed with land owned by the sample farmers. Except for watershed management, the agricultural institutions of the Begumgunj area are serving farmers adequately and create no constraints for the expansion of double cropping.

Subsistence production

Most farmers in our sample plan to produce food grains needed by their families and fodder required for their livestock. Their first priority in cropping decisions is to provide for these needs plus a safety factor to cover yield variability. They respond to income increasing opportunities only after land and other resources are allocated to these subsistence needs.

A poorly informed person might see an opportunity rather than a constraint to double cropping here. Food and traditional fodder crops are all rabi crops and will not directly conflict with a crop in the preceding kharif season. To maximize the certainty of subsistence food and fodder crop success, however, farmers do not grow a prior kharif crop on land allocated to the subsistence crops. Inadequate moisture conditions for a rabi crop following a kharif crop have a high probability (21 of 29 years, Pandey 1986). A rabi food and fodder crop following the traditional kharif fallow, on the other hand, is generally expected to be successful. Only five of 25 farmers expected any failure and among the five, only two estimated as high as 3 years of failure in 10.

If the seasonal order of crops was the opposite with subsistence crops grown in the kharif season and cash crops in the rabi, prospects for double cropping would be enhanced. Farmers would grow the traditional subsistence crops in the kharif and the rabi cash crop whenever possible. Since this is not the case, assured subsistence crops require kharif fallow.

Acres allocated to subsistence crops will vary with size of family, number of livestock, and other factors. Farmers in our sample allocated about one third of their 28 acres for subsistence production. On the more common smaller farms, the subsistence requirement will be much more constraining for double cropping.

A seldom mentioned aspect of subsistence production is the supply of fodder for livestock. This need was often stated by farmers in the same breath with family food needs. It may actually be more compelling in cropping decisions than family food which could be shipped in and obtained from the market if necessary. Fodder cannot be transported in except at enormous cost.

The favorite and traditional fodder is wheat straw (bhussa). Other rabi crops do not produce bhussa. Farmers have found that soybean bhussa can be fed but the feed value produced per acre is less than one fourth that of wheat.

While the kharif crop does produce some bhussa and partially relieves the necessity for wheat bhussa, an adequate supply of wheat bhussa is still considered essential. This constraint to double cropping will decline in importance with increasing dependence on tractors, a process that seems well under way in Begumgunj. In areas of small farms and less tractor work, and with less acres per bullock pair, the fodder constraint could dominate the resistence to large scale double cropping.

Time constraints for kharif sowing

For successful sequential crops, and even for intercrops, timely sowing of the kharif crops is critical. The crops must be started as early as possible in June so they can be harvested and the sequential crops sown while October soil moisture is adequate.

The kharif land preparation and sowing period is typically only three weeks. Yet in this period, heavy rains can cause waterlogging or delayed rains can cause dry soil. Both will delay sowing while farmers wait for favorable soil moisture conditions. The number of acres which can be successfully sown with kharif crops in time will fluctuate from year to year. Farmers sometimes run out of time with current levels of kharif cropping. Timeliness bottlenecks would loom larger with large scale kharif cropping.

The dry sowing recommendation of the ICRISAT package was designed to relieve this time constraint but only one farmer in our sample undertakes dry sowing. When erratic rains at the beginning of the period cause germination followed by seedling death from moisture stress or waterlogging, farmers lose their seed and must also use labor to reseed during the normal wet seeding period. Weeds with dry sowing are an additional liability.

The direct questions designed to obtain farmer opinion about this critical time period largely failed to provide useful responses. Several indirect indications of timeliness problems, however, were mentioned by farmers such as crop failures from late sowing and unplanned tractor hiring to get kharif sowing done on time. The largest kharif acreage reported by a tractor farmer was 25 but he fallowed the land in the rabi season. The largest kharif acreage planted with only bullock power was 6.6 acres, but the soybeans failed. One bullock farmer grew 5 acres of soybeans and expected a 50 percent rabi crop which must be considered a good performance for 1986-87. A tractor farmer reported 15 acres of soybeans followed by a fair to good rabi crop which is also a good performance. Timeliness of kharif sowing will be less of a constraint on small farms with one farmer demonstrating successful double cropping with bullocks on 5 acres.

Time constraints for rabi sowing

While successful sequential crops require timely planting of the previous kharif crop, the season of greatest double cropping labor pressure is at the end of the kharif season. Farmers must get the kharif crop harvested and threshed, the seedbed prepared, and the rabi seed planted after the kharif crop is mature and before soil moisture becomes unfavorable. Double cropped acreage beyond the current level of 12% (with 8% sequentially cropped) will result in greater timeliness problems. Two of the six farmers with sequential rabi crops failed to complete their rabi sowing on time in 1986-87. The availability of bullocks, tractors, and cultivation equipment also limit the amount of labor that can be used effectively.

Farmers were asked if labor supply would be a problem if they were to double crop all their land. Three things were wrong with this question. They had difficulty envisioning 100% double cropping. They tended to answer from the prospective of their own farm with the assumption that no one else would be wanting labor for doing the same thing. Several dismissed the basis of the question (all land double cropped) as impossible and the question irrelevant.

The few farmers who answered the question as intended saw serious labor problems. One specifically mentioned the kharif harvest/rabi sowing season, and two others mentioned planting seasons as the most difficult. Two saw no problem except that they would need to raise wages (presumably to draw labor away from other farmers). As concluded in previous ICRISAT publications, farmers also believe that large scale double cropping would be good for agricultural labor.

The double cropping level at which lack of labor would begin to cause yield reductions assuming current technology is unclear but probably would be well below 50% of dryland. This constraint might be less severe on small farms where family labor availability is greater per acre. Faster harvesting and sowing technology, relay sowing, and a system to delay kharif threshing to after rabi sowing would all relieve this constraint.

The soybean/pigeonpea intercrop requires little attention in this season, except for harvesting the soybeans, and will achieve the double cropping objective. A combination of inter and sequential crops on the same farm would allow expansion of double cropping while coping with this labor bottleneck. No farmer in our sample used this combination in 1986-87. If farmers tried it, the time constraint at kharif planting would probably be more powerful than the labor constraints at rabi planting.

Rotational requirements

Farmers are generally aware of the benefits of crop rotation. In general, the problems identified as associated with lack of rotation were more insect and disease damage, more weeds, and hardening of the soil. One farmer asked us to suggest a kharif crop to be rotated with soybeans. He wanted it to be as remunerative as soybeans.

Farmers follow traditional practice in rotating their rabi crops. Soybeans are rotated with kharif fallow and one said double cropped fields must be fallowed every third year to maintain fertility. Because chickpea and lentil are the preferred sequential crops after soybeans (they are more tolerant of moisture stress than wheat), one can assume that the kharif crop will tend to be grown on fields to be rotated into these two crops that year.

Rotational constraints to large scale double cropping, then, include the perceived need for periodic kharif fallow and the preference for teaming soybeans with chickpea and lentil. Wheat, the major rabi crop, will tend to follow kharif fallow at least with current perceptions of risk.

In the study year, the 25 farmers used 48 per cent of their rabi cropland for wheat and wheat/chickpea mixtures. Sole chickpea and lentil occupied 42 per cent of rabi cropland. With current land allocations to the several rabi crops, double cropping of sequential crops is unlikely beyond 50 per cent of all cropland because of rotational constraints.

If soybean/pigeonpea intercrop is also grown, the pigeonpea will compete with and fit into the rotation of non-wheat rabi crops. While this does not prevent the production of pigeonpea, its total acreage is constrained since chickpea, lentil and linseed are desired crops and needed for consumption and rotational purposes.

Small farms, where subsistence crops dominate will have low flexibility for meeting rotational requirements. On larger farms and on farms where commercial production dominates, farmers have more flexibility for working out rotational systems which respond to profit opportunities. Double cropping rotational recommendations in both situations would be welcomed by farmers.

Kansgrass

Kansgrass (Saccharum Spontaneum) is a serious perennial weed in the Begumgunj area. Its severity is reflected in the market for crop land. In the study area, typical crop land in Begumgunj sells for Rs. 8,000 per acre. The same land, infested with kansgrass, sells for only Rs. 5,000 per acre. In the village of Sumer, next to Begumgunj, one-third of the crop land is infested.

Infested land cannot be kharif cropped. The grass must be frequently knocked down during the kharif season to weaken its vitality. With this treatment, its growth is subdued during the rabi season, and reasonable crops can be obtained. This grass eliminates substantial acreage from double cropping but it also limits the flexibility of rotations for double cropping on the remaining land of the farm.

The problem of this grass has long been recognized. Both indigenous and scientific approaches to its control have been developed. None have worked well enough to become widely used. Some people accept the hypothesis that the grass thrives in low fertility soils and will die out if fertility and organic content are improved. This hypothesis could easily be tested. If valid, the research challenge would be to develop a system, feasible in the reality of the village, for improving fertility and organic matter.

If the hypothesis is invalid, successful research on a truly effective and feasible control of this weed would have large benefits. The value of benefits could be calculated by assuming that Rs. 3,000 per acre is the capitalized value of losses incurred, estimating the number of infested acres in the SAT or in all of India, and then subtracting the capitalized cost of successful control. For illustration only, if one assumes 5 million infested acres (the actual number is unknown), the capitalized losses from this grass come to Rs. 15,000 million. With a 10% capitalization rate, the annual loss would be Rs. 1,500 million with current agricultural technology. Average control costs would need to be subtracted to obtain an estimate of the benefits from control.

Long-term fertility management under double cropping

Some farmers are concerned about fertility and soil management under large scale double cropping. Their current answer to this issue is periodic fallow. With increased levels of double cropping, this concern may discourage farmers from further expansion. Research on this issue, followed by careful recommendations to farmers, would contribute to the growth of double cropping.

Summing up and general research suggestions

Several constraints to large scale double cropping in the Begumgunj area were recognized. Comments on their greater or lesser relevance to areas with smaller farms have been included. The probability that substantial constraints remain hidden from view is at least moderate. The approach to finding them requires careful thinking through why farmers do what they do, how they do it, and how double cropping would affect both the what and why questions.

From this analysis, come several general suggestions for research which, if successful, would improve prospects for large scale double cropping in deep Vertisol, assured rainfall areas.

1. Solve the problems of dry sowing of _kharif_ crops or find alternative ways of getting more land sown in the _kharif_ season. The recommendation of dry sowing in the original technological package was based on sound understanding of double cropping requirements. It can relieve the serious time pressure associated with wet sowing and insure an early-as-possible start for the crops. Problems to be solved include premature germination response during erratic initial rains, high soil temperatures, and increased weed growth.

2. Develop suitable rotations for _kharif_ and _rabi_ seasons, incorporating double cropping, subsistence needs, control of insect, disease, and weeds and long-term fertility considerations. Farmers are comfortable with their traditional _rabi_ rotation but are uncertain and a bit worried about how to add double cropping to the system. Some perceive the need for an alternative, profitable _kharif_ crop to be rotated with soybeans.

3. Discover ways to relieve the time and labor bottleneck during the _kharif_ harvest/_rabi_ sowing period for sequential crops.

The sequential cropping problem was well illustrated earlier in Fig. 2 showing _rabi_ sowing coming before _kharif_ harvesting. With current double cropping practice, the _kharif_ crop must be harvested and threshed, the seedbed prepared, and the _rabi_ crop sown between the time the _kharif_ crop is mature and the surface moisture becomes deficient for _rabi_ sowing.

4. Develop a true and feasible solution to the kansgrass problem. Many have tried and failed, but the payoff for success would be enormous and the supply of land for double cropping would be increased substantially.

5. Decrease the risk of _rabi_ crop failure following soybeans, and/or increase yields of _rabi_ crops following _kharif_ fallow. Since assured subsistence _rabi_ crops are needed, double cropping is strongly constrained on small farms. If some way could be found to significantly increase the probability of _rabi_ crop success (especially wheat) after soybeans, farmers would be more willing to risk planting the soybeans prior to subsistence _rabi_ crops. Alternatively, if yields of _rabi_ crops following _kharif_ fallow could be increased, farmers would probably be willing to allocate less land to assured subsistence crops, thereby releasing more land for profitable double cropping.

Summary and Specific Research Suggestions

A package of technology was developed at ICRISAT to facilitate double cropping of rainy season or kharif-fallowed dryland in SAT regions with deep black soil and assured rainfall. Field trials of the package were conducted in the high production potential environment of Begumgunj, Madhya Pradesh, for three crop years, 1982-83 to 1984-85.

The field trial experience was successful with increased production per acre (national objective) and increased net income (farmer objective) compared to nearby, traditionally farmed fields. The soybean/pigeonpea intercrop emerged as substantially more profitable than other crop combinations on both field trial and traditional fields.

Near the end of the 1986-87 crop year, two years after the end of field trials, researchers returned to Begumgunj to study the survival rate of the technology package and the emerging constraints to double cropping of dry land.

Farmers are aware of potential benefits from double cropping. They say, in effect, "Give us moisture and we will double crop the world". The consciousness raising experience of the field trials will probably be their major long-run contribution. Once farmers see such an opportunity, they will work out ways to take advantage of it, and this effort is underway in Begumgunj.

In 1986-87, 17 of 25 sample farmers planted rainy season or *kharif* crops on dryland and 10 double cropped 12 percent of all dryland in the sample. Others may have intended to double crop but decided on a postrainy season or *rabi* fallow on their *kharif* cropped land because of poor moisture conditions. Like two of the cropping years when the verification trials were conducted, rainfall in 1986-87 was poorly distributed for dryland double cropping but most farmers seemed to accept these partial and total failures as a part of their life experience and hoped for better results next year when they will try again.

Much of the technology package was in use by a small number of farmers prior to the start of the field trials but adoption by field trial farmers expanded dramatically during the trials. The new adoption levels have been sustained for these components of the package and their use has spread to other farmers.

Three components, *kharif* dry sowing, small watershed management, and use of the wheeled tool carrier were new to farmers in 1982. One farmer continues to dry sow but others, confronted with unfavorable experience, reverted to their traditional practice of sowing after the onset of the monsoon. Several farmers with middle elevation watershed land continue to use furrows (not broadbeds, though) and maintain field drains, but those uphill from them are indifferent and downhill are negative about the watershed management plan. The wheeled tool carrier is no longer in use, but several farmers said they liked its sowing performance.

Interest in the soybean/pigeonpea intercrop has dramatically declined with only four of 25 farmers growing it in 1986-87. Thirty of 45 planted it in the last year of the field trials. Frost risk and pod borer damage were the most common explanations for the lack of interest in this cropping systems which exhibited the most economic promise in the verification trials. Preference for _rabi_ subsistence crops instead of pigeonpea was also mentioned by several farmers. Not mentioned by farmers, but perhaps an important explanation, is the difficulty of sowing intercrops in rows with modern seed drills. Nineteen farmers grew sole soybeans in 1986-87 (including those using irrigated land) and only two of the four growing soybean/pigeonpea row intercropped them.

Several general constraints to large scale double cropping (more than 50 percent of dry cropland) were identified. Conflict with secure _rabi_ food and fodder subsistence crops (security requires _kharif_ fallow) is a major constraint, especially on smaller farms.

With current technology, timeliness problems in two seasons limit double cropping. Sequential _rabi_ crops require a prompt start for the _kharif_ (soybean) crop in June so it can be harvested and the _rabi_ crops planted while surface moisture is adequate. Erratic rains at the beginning of the monsoon often delay sowing because soil conditions are too dry or too wet. This limits the _kharif_ area that can be sown within the acceptable time period. The sheer amount of work which must be accomplished in the kharif harvest/rabi sowing period after the kharif crop is mature and before surface soil moisture drys will also severely curtail double cropped rabi area.

Crop rotational requirements and practices reduce flexibility for fitting double crops into the crop plan. Rabi crops are traditionally rotated. Chickpea and lentil are the most acceptable sequential crops after soybeans, while wheat will seldom be successful as a sequential crop. Thus, land to be kharif cropped must be related to a planned rabi rotation with wheat following kharif fallow. Since wheat is the main rabi crop, this limits kharif and double cropped acreage.

A variable constraint is kansgrass (Saccharum spontaneum). In fields with serious infestation, kharif cropping is considered impossible. The grass must be periodically knocked down during the rains to reduce its vitality and permit a reasonable rabi crop. Not only does this eliminate infested land from double cropping but it reduces flexibility of managing the remaining land on a farm for double cropping given rotational requirements.

Farmers see moisture limitations as the major constraint and irrigation as the ultimate facilitator for double cropping. About half of our sample, however continue to gain experience and knowledge about its potential on dryland. They are likely to continue these efforts because the payoff for success appears substantially greater than the marginal costs of trying.

As illustrated in this report, fitting this new element (double cropping) into the ongoing cropping system, is likely to have consequences on many and sometimes unexpected elements of the existing system. However feasible and beneficial double cropping may actually be, farmers must be awarded time - a span of years - to achieve a sense of comfort with double cropping as a routine part of their system.

The following research topics are suggested as an outcome of this study. Six areas for further economic study are identified:

1. Determine the marginal (additional) costs and returns of producing the second crop (either kharif or rabi crop); remembering that the opportunity cost of several production resources may be low.

2. Study the economic aspects of double cropping rotational recommendations.

3. Study the economics of the improved seed drill suggested later in this report.

4. Measure the costs and benefits from farmer and national perspectives of owning bullocks vs hiring a tractor on a small farm. Address timeliness issues, alternative uses of fodder or options to produce no fodder, and possibility of collusion

among tractor owners to raise rental rates. At what rental rate would the tractor be more attractive than bullocks?

5. To relieve subsistence pressure on dryland, increase understanding of farmer investment in irrigation wells by a partial budget study from both the farmer and national prospectives.

6. Study the feasibility, effectiveness, and cost of insurance against the risk that a new well will be dry.

The following suggestions for agronomic and engineering research have economic implications which require study prior to recommendation to farmers:

1. Carry out some base data analysis and further diagnostic research on the impediments to adoption of the soybean/pigeonpea intercrop. In particular, assess the risk of frost damages to pigeonpea and importance of the absence of an improved seed drill designed for row intercropping.

2. Investigate the feasibility of shorter season pigeonpea cultivars to escape frost incidence.

3. Solve the problems of dry sowing of the kharif crop.

4. Study the feasibility of relay planting of sequential crops to relieve time pressure.

5. Consider the adoption or development of an improved bullock drawn seed drill. Such a drill should: (a) have reliable depth control, (b) be able to achieve optimal placement of seed and fertilizer, (c) solve the problem of sowing row intercrops, (d) have low draft requirements and perhaps with an adjustable number of rows to accommodate bullocks of different strength, and (e) be low cost since it will be used for only a few days per year on an average-sized farm and probably can not be rented since everyone would want it at the same time.

6. Study the agronomic aspects of double cropping rotational recommendations.

7. Develop recommendations for long term fertility maintenance and soil management under double cropping.

8. Review recommended levels of fertilizer use and the current constraints, other than financial issues, which limit the amount used.

9. Develop feasible ways of increasing the organic matter content of the soil.

10. Study the timing of spraying for pod borer to see if improved control is possible through extension education to farmers.

11. Increase labor efficiency or extend the time period of task completion (relay planting and/or post-sowing threshing) in the _kharif_ harvest/_rabi_ sowing season.

12. Develop effective control of kansgrass, including testing the hypothesis that improved fertility and organic matter is an effective control. If so, methods to achieve this in the reality of the village are needed.

13. Reduce risk of _rabi_ crop failure after a _kharif_ crop.

14. Increase the _rabi_ yield after _kharif_ fallow to reduce the amount of land required for secure subsistence production.

15. Go back to the drawing board on _kharif_ water management. Traditional bunding is used to increase water infiltration with _kharif_ fallow. Broadbeds and furrows were designed to achieve infiltration without waterlogging while taking a _kharif_ crop, but they are not being used by farmers. Farmers now using only improved drainage are reducing infiltration when their double crops need more moisture than their previous single crops. Recommendations should be implementable by individual farmers without the need to cooperate with their neighbors. Perhaps tractor farming and

maintenance of broadbeds and/or weeders attached to bullock cart axles could be investigated.

This list of suggested topics is admittedly a tall order, but the newness of double cropping in this high production potential environment markedly enhances the value of such adaptive research.

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Appendix Table 1. Economics of the improved watershed-based technology options on deep vertisols in the Begumganj watershed, Madhya Pradesh, 1982-83.

Cropping systems	Proportions grown	Gross returns[a]	Operational costs	Gross profits	Crops	Yields: Grain	Yields: Fodder	No. of plots[b]
	%	Rs/ha				kgs/ha	Qts/ha	
IMPROVED WATERSHED								
Sorghum-pigeonpea intercrop	32	3144	1405	1739	Sorghum	253	29	4
					Pigeonpea	673	20	
Sorghum-pigeonpea-chickpea	7	4712	2210	2502	Sorghum	100	16	2
					pigeonpea	1173	28	
Soybean-pigeonpea-chickpea	10	6785	3250	3535	Soybean	811	14	3
					pigeonpea	1135	34	
					Chickpea[c]	42	-	
Soybean-pigeonpea-lentil	2	5579	3347	2232	Soybean	543	9	1
					Pigeonpea	1045	30	
					Lentil	-	-	
Soybean-wheat-sequence	24	2257	2450	-193	Soybean	405	6	3
					Wheat	568	6	
Soybean-wheat-chickpea	7	2644	3457	-813	Soybean	359	9	1
					Wheat	779	8	
					Chickpea[c]	-	-	
Soybean-chickpea mustard	8	3598	3303	295	Soybean	595	7	1
					Chickpea	633	5	
					Mustard	150	-	
Soybean-linseed	8	3172	2476	696	Soybean	540	7	1
					Linseed	354	-	
Soybean-lentil	2	6625	3410	3215	Soybean	1320	10	1
					Lentil	1090	20	
Weighted averages	100	3520	2348	1172				
TRADITIONAL FARMERS' FIELDS								
Pigeonpea sole	2	2182	474	1708	Pigeonpea	572	9	1
Soybean sole	4	1497	963	534	Soybean	514	11	5
Wheat sole	7	1332	962	370	Wheat	667	7	3
Wheat-chickpea intercrop	34	1452	954	498	Wheat	582	7	3
					Chickpea	125	-	
Chickpea sole	22	1264	920	344	Chickpea	572	4	3
Lentil sole	24	2421	741	1680	Lentil	787	23	3
Linseed sole	7	1460	664	796	Linseed	307	-	3
Weighted average	100	1652	866	786				

a. Prices in Rs. per quintal are:

Grain	Rs/qtl.	Fodder	Rs/qtl.
Sorghum	100	Sorghum	10
Soybean	250	Soybean	20
Pigeonpea	350	Pigeonpea stalks	12.5
Wheat	180	Wheat	20
Lentil	250	Lentil	20
Chickpea	210	Chickpea	15
Mustard	375		
Linseed	475		

b. Data refer to 24 ha of watershed and 19.88 ha of traditional farmers' fields.

c. In these two plots, chickpea gave no production.

Appendix Table 2. Economic evaluation of the improved watershed-based technology options on deep vertisols in the Begumgunj watershed, Madhya Pradesh, 1983-84.

Cropping systems	Land and water management	Proportions grown	Gross returns[a]	Operational costs	Gross profits	Yields			No. of plots[b]
						Crops	Grain	Fodder	
			Rs/ha				kg/ha	Qts/ha	
IMPROVED WATERSHED									
Soybean-pigeonpea intercrop	BBF	60	5036	2310	2726	Soybean Pigeonpea	1013 478	10 10	8
Soybean-pigeonpea intercrop	Flat on grade	5	4507	2172	2335	Soybean Pigeonpea	830 476	8 15	1
Soybean-wheat	BBF, Flat on grade	22	5378	2261	3117	Soybean Wheat	1078 969	11 9	1
Soybean-chickpea	Flat on grade	13	4877	2532	2345	Soybean Chickpea	850 709	10 -	1
Weighted averages		100	5064	2321	2743				11
TRADITIONAL FARMERS' FIELDS									
Soybean-pigeonpea intercrop	Traditional	10	4584	1497	3087	Soybean Pigeonpea	654 679	6 10	3
Soybean-wheat sequence	Traditional	25	3888	1488	2400	Soybean Wheat	739 773	7 7	3
Soybean-chickpea sequence	Traditional	15	4690	1781	2909	Soybean Chickpea	550 980	5 -	1
Fallow-wheat	Traditional	30	1315	914	401	Wheat	664	6	3
Fellow-chickpea	Traditional	20	1665	937	728	Chickpea	555	-	3
Weighted averages		100	2861	1250	1611				13

a. Prices in rupees per quintal are:

Grain	Rs/qtl	Fodder	Rs/qtl.
Soybean	300	Soybean	20
Pigeonpea	350	Pigeonpea	12.5
Wheat	180	Wheat	20
Chickpea	300		

b. Data refer to 14.7 ha. of watershed, and 9.2 ha. of traditional farmers' fields.

Appendix Table 3. Economic evaluation of the improved watershed-based technology options on deep Vertisols in the Begungunj watershed, Madhya Pradesh, 1984-85.

Cropping systems	Land and water management	Proportions grown	Gross returns[a]	Operational costs	Gross profits	Yields			No. of plots
						Crops	Grain	Fodder	
			Rs/ha	Rs/ha	Rs/ha		kg/ha	Qts/ha	
IMPROVED WATERSHED									
Soybean-pigeonpea intercrop	Broadbeds & Furrows	22	4277	1294	2983	Soybean	566	12	21
						Pigeonpea	629	29	
Soybean-pigeonpea intercrop	Furrows on flat	5	4243	1267	2976	Soybean	628	13	4
						Pigeonpea	557	32	
Soybean-pigeonpea intercrop	Flat on grade	11	3908	1090	2818	Soybean	531	11	11
						Pigeonpea	559	28	
Soybean-wheat	Flat on grade	4	2768	1733	1035	Soybean	901	19	2
						Wheat	25	-	
Soybean-lentil	Flat on grade	7	2206	1519	687	Soybean	733	15	2
						Lentil	c	c	
Soybean-fallow	Broadbeds & Furrows	2	1861	1056	808	Soybean	617	13	2
Soybean-fallow	Furrows on flat	2	2325	980	1345	Soybean	771	16	2
Soybean-fallow	Flat on grade	9	1593	791	802	Soybean	528	11	8
Fallow-wheat	Flat on grade	17	953	490	463	Wheat	474	5	11
Fallow-wheat + chickpea	Flat on grade	2	966	622	344	Wheat	481	5	2
						Chickpea	c	c	
Fallow-linseed	Flat on grade	7	1795	501	1294	Linseed	374	-	4
Fallow-lentil	Flat on grade	12	1170	488	682	Lentil	300	6	10
Weighted average			2523	945	1578				
TRADITIONAL FARMERS' FIELDS									
Soybean-pigeonpea intercrop	Traditional	19	4285	1285	3000	Soybean	806	16	7
						Pigeonpea	463	20	
Soybean-fallow	Traditional	11	1549	894	655	Soybean	511	11	10
Fallow-wheat	Traditional	42	771	465	306	Wheat	384	4	5
Fallow-linseed	Traditional	18	1181	313	868	Linseed	246	-	5
Fallow-lentil	Traditional	10	1174	419	755	Lentil	301	6	5
Weighted average			1638	636	1002				

a. Prices used were based on actual realized or market prices. They are as follows:

Grain	Rs/qtl.	Fodder	Rs/qtl.
Soybean	260	Soybean	20
Pigeonpea	350	Pigeonpea	12.50
Wheat	180	Wheat	20
Lentil	350	Lentil	20
Linseed	480		

b. Data refer to 102.69 ha of watershed, and 48.84 ha of traditional farmers' fields.