Sustainability Dimension in the Adoption of Short Duration Pigeonpeas in Non-legumes-based Cropping Systems

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Abstract

This paper establishes the linkage of short duration pigeonpea adoption to farmers' perceptions on the issue of sustainability. Results from a formal on-farm survey and rapid rural appraisals conducted in a drought prone area in Central India, confirm that: a) farmers have a high degree of awareness regarding the effects of intensive cultivation of cash crops such as sugarcane or cotton in irrigated tracts - in terms of reduced yields and increasing use of inputs; b) appropriate crop/varietal adoption and management practices are consciously taken to maintain productivity levels in the context of existing and desired cropping systems; and c) farmers increase or maintain soil fertility by rotation with nitrogen fixing legumes and alternate pigeonpea in different plots each year. Farmers are aware of the nodulation capacity of legumes such as pigeonpea. For these reasons, short duration pigeonpea is chosen as most appropriate for profitable double cropping in deep black soils. The crop is also grown as a boundary crop to prevent soil erosion.

Key words: adoption, sustainability, short duration pigeonpeas

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I. Introduction and Objectives

Almost a decade after its release in 1986, a study on ICRISAT's short duration pigeonpea (SDP) variety ICPL 87 (also known as Pragati) was undertaken to determine the extent of adoption and impact in Central India. The aims of the study were (1) to determine the rate and extent of adoption of the SDP ICPL 87, (2) to document farmer preferences and constraints to adoption, and (3) to survey the impact of adoption on dimensions such as efficiency, sustainability and poverty. The hypotheses of the study included the following: farmers' main motivations in growing ICPL 87 are its benefits as a cash crop, a source of protein, and as a way of sustaining the productivity of the soil; strong public and private seed sector support was a major factor in the spread of ICPL 87; absence of irrigation hinders adoption and spread of ICPL 87; effective pest control measure is an important requirement for the spread of ICPL 87, and effective government extension significantly influenced farmers decision to take up ICPL 87. This paper focuses on one of these - the sustainability dimension.

Awareness among farmers regarding agricultural sustainability and their use of appropriate management practices to achieve it are areas of growing interest. This paper links varietal adoption (in this case the ICRISAT SDP cultivar ICPL 87) to the management practices of farmers in Western Maharashtra, in maintaining productivity levels and preventing soil degradation. The focus is on how farmers are able to maintain productivity levels in the context of a desired cropping system and improve efficiency through practices such as adoption of nitrogen fixing legumes, alternating legumes in different plots and recycling of the legume by-products. An adoption and impact assessment survey was undertaken to examine the level of adoption and benefits gained by farmers from growing short duration pigeonpea cultivar ICPL 87. Farmers' responses were analyzed to examine whether consideration of sustainability was a key factor in adoption. In particular, it is of interest to see whether the large number of farmers in irrigated tracts growing sugarcane or cotton are growing ICPL 87 as an alternate crop in order to improve soil fertility. Why are farmers growing pigeonpea and in particular ICPL 87 and not some other variety of

pigeonpea? What qualities does ICPL 87 have that led to its increased adoption in these tracts? This paper attempts to answer these questions based on quantitative and qualitative responses from the formal survey questionnaires and informal rapid rural appraisals.

II. Background

A large volume of literature exists on the residual benefits of growing pigeonpea in rotation with other crops. Researchers have identified a number of benefits of pigeonpea crop in general and SDPs in particular (Hoshikawa, 1991; Whiteman and Norton, 1980).

The nitrogen fixation ability of pigeonpea is well known. Experimental results have shown that the root nodulation of pigeonpea fixes nitrogen at a rate which reduces inorganic fertilizer requirement and nitrogen requirement for subsequent crops (Kumar Rao et al, 1980; Materchera and Chanachi, 1990; A.Ramakrisna et al, 1994; and S.P.Wani, et al, 1994). In on-station trials, it has been shown that pigeonpeas are worth between 30 to 70 $kgha^{-1}$ (A. Ramakrishna et al, 1994). More specifically SDP trials have revealed that they are worth in excess of 40 $kgha^{-1}$ (Kumar Rao et al, 1980; and ICRISAT Annual Report 1988). Apart from transferring fixed N2 to the succeeding crop, pigeonpea cultivation also substantially increases the total soil N in pigeonpea based cropping systems (Wani et al, 1994). Pigeonpea can also be used as green manure crop wherein the biomass in the form of pigeonpea residues is returned to the soil as manure/compost (Hoshikawa, 1991). It has been observed that pigeonpea material decomposes faster leading to rapid breakdown and release of N (ICRISAT Annual Report 1988).

Researchers have shown that factors other than N also contribute to the beneficial effects of pigeonpea on soil fertility (Arihara et al, 1991). These include utilization of iron based phosphorus -- pigeonpea converts soil P into an available form of phosphorus due to its unique root extrudes and increases the P pool available (N. Ae et al, 1991). It is noted that next to N, P is the nutrient usually most deficient in the soils of the semi-arid tropics (Hoshikawa, 1991).

The root extrudes of pigeonpea give it a deep rooting ability which creates a potential for greater soil water acquisition. It also increases the water infiltration rate for subsequent crops, helps in recycling nutrients and improves soil structure. Pigeonpea also contributes to increased soil microbial activity and breaks the pest and disease cycle (Wani et al, 1993 and Hoshikawa, 1991). That this is true for ICPL 87 is shown by Arihara, et. al. (1991).

It has also been observed in on-farm and on-station trials that medium and long duration varieties perform better than SDPs with respect to improving soil fertility, especially with reference to the nodulation and deep rooting ability of pigeonpea (Kumar Rao et al, 1980). However, the beneficial effect of pigeonpea to subsequent crops increases with higher density (Whiteman and Norton, 1980). Since SDPs are usually planted as a sole crop, they are planted at higher densities than medium and longer duration varieties.

It is of interest in this study to find out whether farmers are aware of the beneficial effects cited above and how farmers consciously take crop management decisions with the aim of maximizing the benefits of pigeonpea cultivation as a sequential crop within their existing cropping systems. It is also of interest to explore whether adoption of SDP is based more on expectations from previous knowledge about medium and longer duration varieties rather than on actual performance of SDPs with respect to enhancing soil fertility.

III. Methodology

Study Area. The farm-level surveys covered the pigeonpea growing districts of Central India cutting across the boundaries of production systems 7 and 8 as defined by ICRISAT. These production systems represent a) tropical, intermediate rainfall, rainy season sorghum/cotton/pigeonpea cropping system located in India's Eastern Deccan Plateau (production system 7) and b) tropical, low rainfall, primarily rainfed post-rainy season sorghum/oilseed cropping system located in the Western Deccan Plateau (production system 8). The estimated area grown to pigeonpeas in this research domain is

estimated at 472,300 ha. This area covers the districts of Dhule, Jalgaon, Ahmednagar, Nasik, Pune, Aurangabad, Beed, Jalna, Sholapur, Satara, Sangli which are mainly a low rainfall, drought prone area. The adjacent districts of Bidar and Gulbarga of Northern Karnataka State are also covered. The major crops in these districts include pigeonpea, cotton and hybrid sorghum, apart from pearl millet, sugarcane, horticulture crops, groundnut and vegetables in the rainy season (Kharif) and sorghum, wheat and chickpea in the post-rainy season (Rabi). The region also covers much of the Rabi sorghum tract of the semi-arid tropics.

The region is part of the vertisol zone of Central India. The soil type ranges from medium black soils in the plains, brown soils in hill slopes and coarse shallow soils in highlands. With respect to rainfall pattern, the area is known as a scarcity zone; it mainly experiences medium to low rainfall. From February to May, the area gets low rainfall of less than 50 mm monthly. From June to September the area gets medium rainfall of 50 to 200 mm per month. Zones which lie on the eastern and western borders of the area and which comprise a few blocks of ICPL 87 areas get more than 200 mm per month. During October to January, the region gets low rainfall of zero to 100 mm per month, with a majority of the region getting only less than 50 mm per month.

Survey Approach. The selection of the study site was primarily based on background data obtained from a reconnaisance survey of the pigeonpea growing tracts in Production Systems 7 and 8. Field observations and interviews with regional research and extension staff gave indications that the adoption of ICPL 87 occurred in the regions around Western Maharashtra. Data on sales of pigeonpea seeds by the public and private sectors confirmed that adoption was widespread in this region.

The survey covered a total of 277 farmers from a representative selection of villages and blocks in eight pigeonpea growing districts of Western Maharashtra and Northern Karnataka. The survey was spread over 35 villages.

The sampling strategy adapted for this study followed a stratified multi-stage sampling scheme where eight pigeonpea growing districts in the Western Maharashtra and Northern Karnataka regions were included. For each district, blocks were stratified according to area grown to pigeonpea, i.e. strata 1: high pigeonpea blocks and strata 2: low pigeonpea blocks. One block is selected to represent each strata, taking into account the blocks' geographical location. Two villages were then randomly selected from each block and finally, a random sample of farmers were taken from each selected village.

Follow-up rapid rural appraisals (RRA) augmented the results of the formal survey, particularly for inquiries related to qualitative indicators of impact. RRAs were conducted in 9 villages. Informal discussions with groups of farmers were also held in some of the villages during the formal survey. A copy of the modules used for the formal and rapid rural surveys is given in appendices 1 and 2, respectively.

IV. Results and Discussion

Initial Extension Target. ICPL 87 was first introduced in the Vidharbha and Marathwada regions in Eastern Maharashtra, i.e., regions which constitute one of the main pigeonpea growing areas in India. These areas were targeted by the LEGOFTEN technology transfer program -- a part of Government of India's Technology Mission on Pulses implemented in collaboration with the International Crops Research Institute for the Semi-arid Tropics (ICRISAT). Early adoption studies and subsequent reconnaissance surveys revealed that farmers in Eastern Maharashtra did not find ICPL 87 suitable in their cropping system. The spread of information about short duration pigeonpeas to the western part of the state is attributed to further efforts of local research and extension network.

Scientists from Mahatma Phule Agriculture University whose jurisdiction included Western Maharashtra recognized the importance of the short duration pigeonpea crop in irrigated cropping systems, primarily for the purpose of accomodating double cropping

and enhancing soil fertility. In collaboration with the LEGOFTEN technology transfer initiative, they introduced SDP materials in their on-farm trials and demonstrations and catalysed production and multiplication of breeder and foundation seeds on a large scale. At about the same time, a government extension program called National Pulses Development Program (NPDP), was active in providing funds for subsidies, on-farm (mini-kit) trials and demonstrations, and extension support with specific focus on selected varieties which included short duration pigeonpeas ICPL 87.

Adoption and Diffusion. The survey confirmed large scale adoption of ICPL 87 especially in the northern districts of Dhule (98%), Ahmednagar (89%), Jalgaon (49%). These three districts are classified in the early adopter class, where farmers took up this short duration pigeonpea soon after its introduction in the region in 1988. Secondary district level statistics indicate that the area of pigeonpea in Ahmednagar has doubled from 11, 387 ha in 1985 to 23, 309 ha. in 1992 and from 22011 ha. to 44839 ha. during the same period in Sholapur. The high rates of adoption in Dhule, Ahmednagar and Jalgaon are especially due to easy access to markets of the southern districts of Gujarat and availability of irrigation. Almost 70% of the area sown to ICPL 87 variety is under irrigation. Since the cropping intensity and input requirements for cash crops are greater under irrigated conditions, farmers find a greater need for a sustainable cropping system.

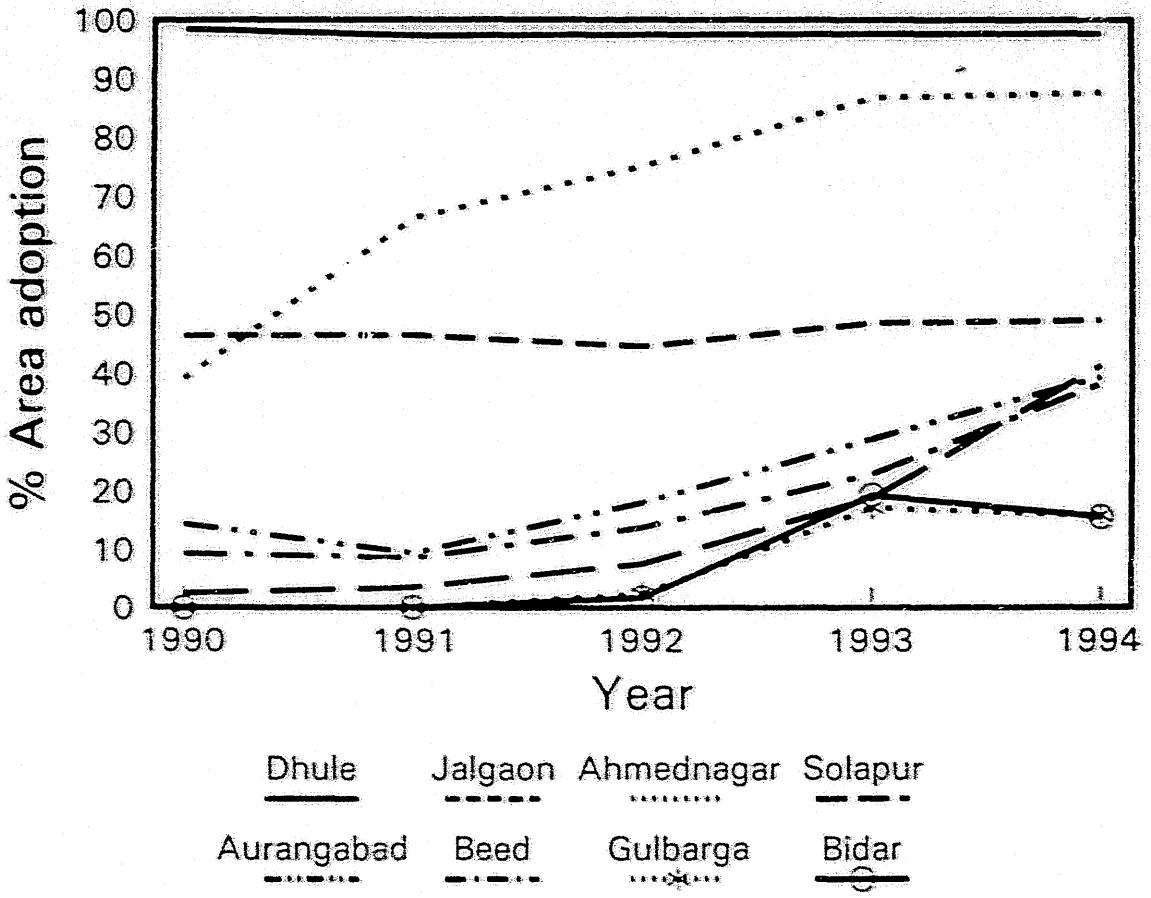
Adoption trends and the variation in adoption across districts in the states of Maharashtra and Karnataka are given in Table 1. The farm level data collected provide an indication that the area under pigeonpea has grown significantly by 51% in many parts of Maharashtra, especially in the northern blocks. Pigeonpea area has been stable in the pigeonpea growing districts of Karnataka. Substantial rise in the level of adoption during the period 1990 to 1994 was measured in both locations: adoption rate (in terms of percentage of total pigeonpea area) grew in Western Maharashtra from 3% in 1988, 35% in 1990 and to 57% in 1994. In Northern Karnataka, it rose from 0 to 16% over the seven-year period (refer to Figure 1). In terms of number of farmers, the rate of adoption grew from 45% to 71% in Western Maharashtra; and 0 to 24% in Northern Karnataka.

Figures 2 and 3 depict the extent of diffusion in the eight districts during the period 1990 to 1994. Out of a total of 17 blocks covered in the survey, 6 blocks have at least 90% of its pigeonpea area covered with ICPL 87 while 3 blocks registered an adoption rate between 42 to 65%. ICPL 87 has so dominated the pigeonpea area in this region that farmers in ten of the thirty five villages studied reported that "there is practically no other

Table 1. Adoption levels (% area) of ICPL 87 in Western Maharashtra and Northern Karnataka: 1990-1994.

State	District	Year				
		1990	1991	1992	1993	1994
W. Maharashtra		35.2	37.0	40.0	50.0	57.0
	Dhule	98.5	97.2	97.4	97.6	97.6
	Ahmednagar	39.1	66.3	75.0	86.8	87.6
	Jalgaon	46.4	46.4	44.6	48.4	48.9
	Sholapur	2.5	3.5	7.6	18.8	41.3
	Aurangabad	14.5	9.4	18.0	28.9	39.4
	Beed	9.4	8.7	13.8	22.9	38.2
N. Karnataka		0	0	2.1	18.0	15.7
	Gulbarga	0	0	2.3	17.2	15.8
	Bidar	0	0	1.7	19.3	15.6

Figure 1. Adoption of ICPL 87 in districts of W.Maharashtra & N.Karnataka, 1990-94



Note: Gulbarga and Bidar are in N.Karnataka

Figure 2. Adoption of ICPL 87, Maharashtra and Karnataka : 1990

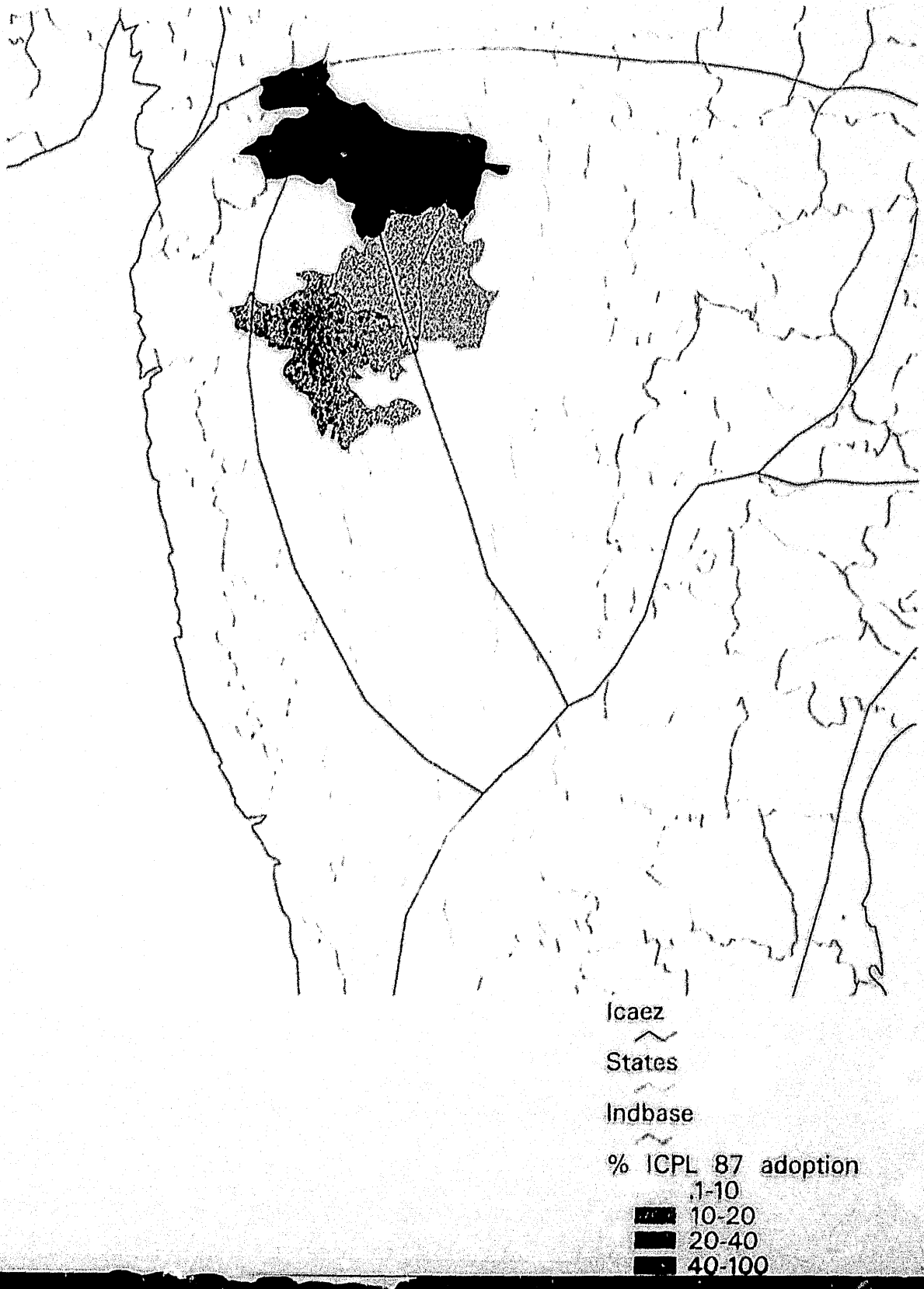
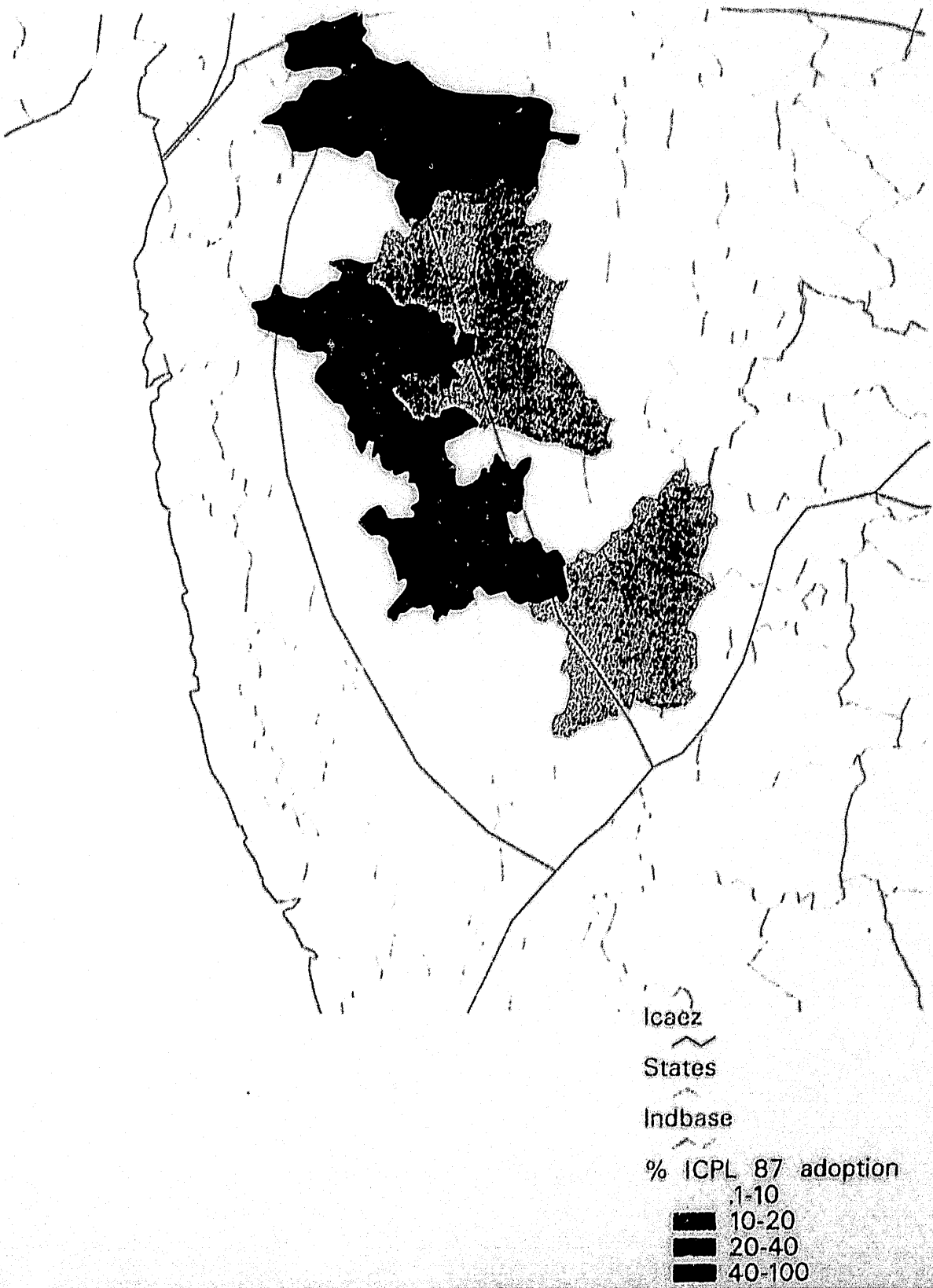


Figure 3. Adoption of ICPL 87, Maharashtra and Karnataka : 1994



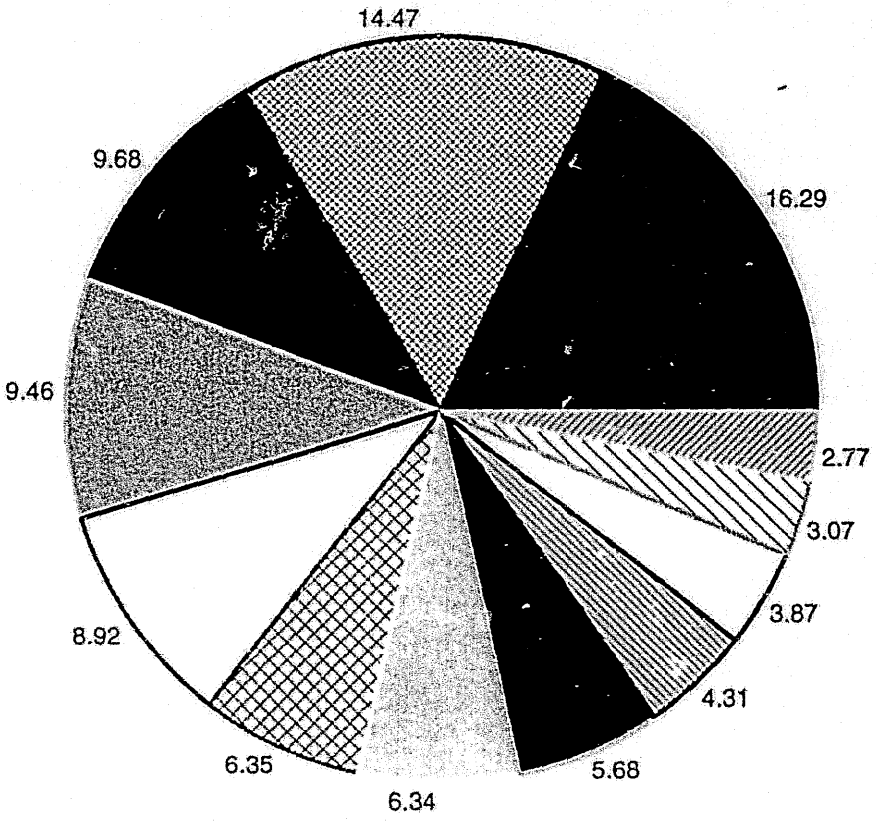
pigeonpea variety grown in their village except ICPL 87". In these ten villages, the estimated adoption level ranged from 91 to 100%.

Analysis of the trends in the cropping system obtained from the survey (refer Figure 4) shows that pigeonpea has become a major crop and is grown along or in rotation with cash crops under intensive cultivation and requiring large amounts of inputs. These include cotton, sugarcane, groundnut, and horticulture crops (banana, grapes and pomegranate) and vegetables. Analysis of district-level data confirms this same pattern and shows that sugarcane, cotton and pearl millet, along with pigeonpea are the major crops in all districts except Ahmednagar where horticulture crops and green gram are primarily grown in rotation with pigeonpea. It is noted that farmers had few other options to use as short duration rotation crop. Pearl millet and green gram are also important in two districts of Aurangabad and Beed. In all the districts, irrigation is mainly given for sugarcane, cotton, pigeonpea, horticulture and vegetables.

Why pearl millet and sorghum, generally the staple food of small farmers in this region, occupy less area is explained by the price advantage of pigeonpeas. The importance of the price factor both for the adoption of ICPL 87 and the increase in pigeonpea area is reflected in the price range of pigeonpeas (i.e. Rs.9 to Rs.13 per kg during the last season) compared with millet and sorghum price of about Rs.5 per kg. Analysis of cost of cultivation data confirms that pigeonpea apparently has become a more profitable alternative for the cropping system of small farmers.

Varying adoption levels are observed across the districts and blocks. The key factors explaining these variations include access to seed sector, and access to market and road infrastructure. The influence of extension via the National Pulses Development Program (NPDP) also significantly account for the differences in adoption levels across blocks and villages. Those villages that have picked up only in 1994 have been influenced by government policies such as NPDP. Non-suitability of the crop with respect to soil type, rainfall pattern and irrigation also account for variation in adoption. It was observed, for

Figure 4. Cropping Pattern 1994
Western Maharashtra



The chart is based on the on farm survey

example, that all villages and blocks located in the Production System 7 sections of Jalgaon, Aurangabad, Beed and Solapur districts have low adoption levels.

The sustainability dimension. An important observation that emerged during the survey is that farmers are aware of the sustainability impacts of ICPL 87. The formal survey and rapid rural appraisals strongly confirm that sustained productivity of the land is an important factor influencing technology adoption and cropping system decisions of farmers. Majority of the farmers from 12 villages declared keen awareness of the following aspects: (1) causes of declining fertility, (2) consequences of intensive cultivation, and (3) capacity of legume crops in improving soil quality. In six of the villages, farmers showed awareness of soil degradation problems such as soil erosion, water logging and soil salinity.

The observed increase in pigeonpea cropping intensity and gross cropped area in Western Maharashtra region is seen as a consequence of the adoption of SDP ICPL 87 (Refer to Figure 5). It emerged from farmers' responses that four considerations were involved in the choice of pigeonpea and particularly ICPL 87. These considerations were: a) nitrogen fixing ability of pigeonpeas, b) short duration variety providing scope for a second crop in the post rainy season, c) profitability of ICPL 87 crop compared to alternative crops; and d) compatibility of SDP with their desired cropping systems. The crop is also frequently mentioned as a boundary crop to prevent soil erosion. Farmers' responses to the query regarding their reasons for adopting ICPL 87 highlight the importance of sustainability dimension to farmers. The summary of responses to a multiple response question on desirable traits (refer to Table 2) indicates that four characteristics are most frequently cited, namely: (a) short duration; (b) more grain yield; (c) improves soil fertility; and d) favorable price. These four factors were also accorded highest ranks by the majority of the farmers (relative ranks are given in column 4 of Table 2). More than 90% of the respondents cited "short duration" and "grain yield" as desirable traits influencing adoption. Following these two factors, around 49% of the respondents specifically mentioned "improves soil fertility" as a reason for adoption. Importance is also given to "market price" (45%). Less frequently cited are other reasons like better taste (13%), disease resistance (12%) and less cooking time (10%).

Figure 5. Total Pigeonpea area in W.Maharashtra and adoption of ICPL 87

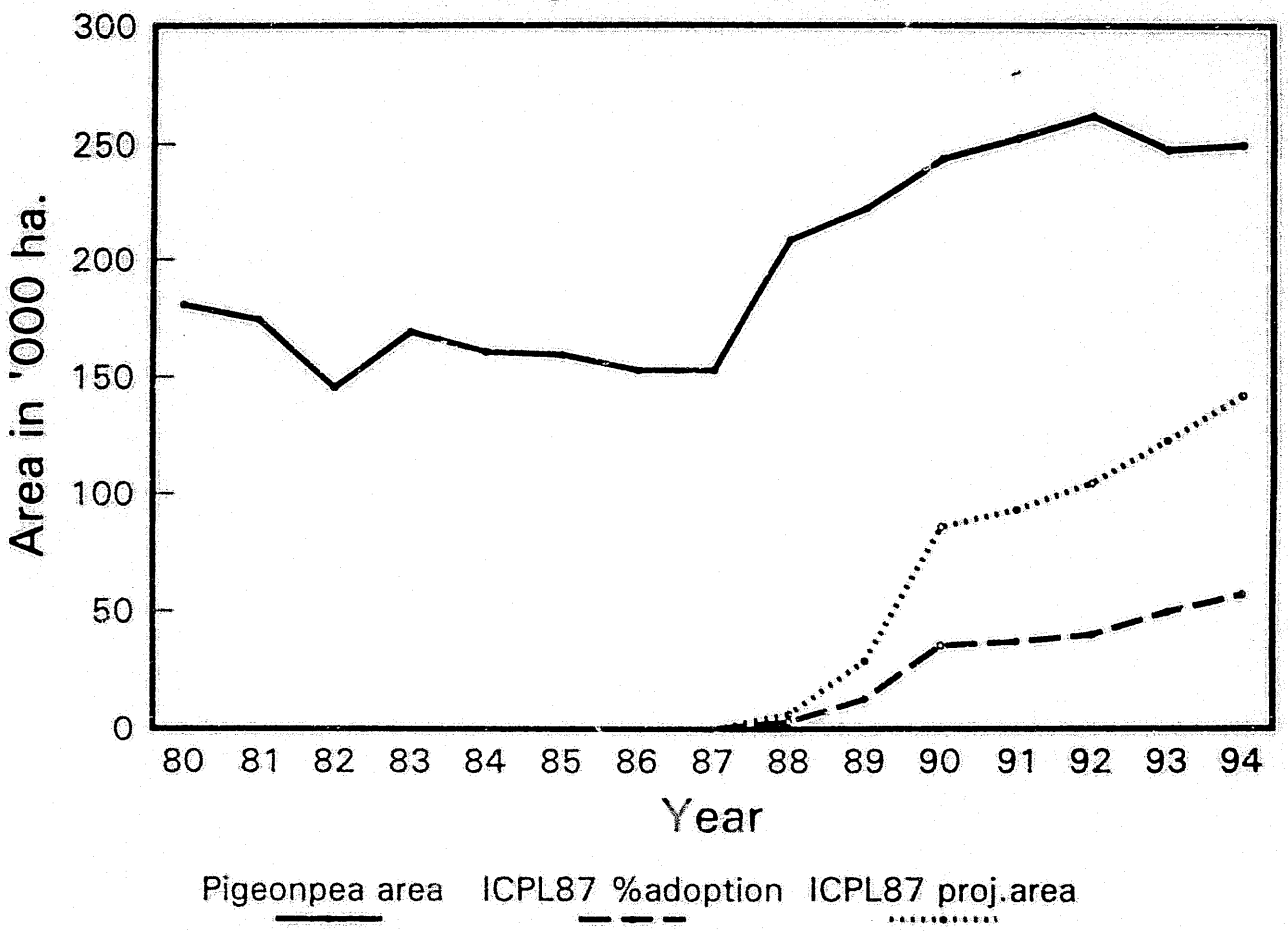


Table 2. Farmers' feedback regarding desirable traits of ICPL 87.

Traits	Frequencies[a]	Percent	Rank[b]
Short duration	133	93.0	1.00
More grain yield	128	89.5	.96
Improves soil fertility	70	48.9	.36
High market price	65	45.4	.36
Better taste	19	13.3	.09
Disease resistant	18	12.6	.10
Less cooking time	15	10.5	.06
Insect resistant	5	3.5	.03
Color	4	2.8	.01
Drought resistant	4	2.8	.03
Good fodder quality	2	1.4	.01
Bigger grain size	1	0.7	.01
Others	26	18.2	
Total	490		

[a] Multiple responses were provided by a random sample of 143 farmers.

[b] Relative importance of traits is weighted by ranks, r, provided by respondents.

The importance of ensuring soil fertility in intensive cropping systems was evident from farmers' perspectives obtained via interviews. Farmers involved in intensive cultivation of sugarcane, cotton, sunflower and hybrid sorghum perceived that "soil nutrients are being depleted". They observed declining yields inspite of using more inputs. Management practices were reported to be consciously taken in order to maintain productivity levels in the context of existing and desired cropping systems. In the villages studied, farmers practiced rotation of pigeonpea with crops such as sugarcane. In some villages, farmers rotated pigeonpea in all their plots by turns each year. Around 26% of those who were asked the reason for fluctuation in the area under pigeonpea responded that this is explained by their practice of crop rotation.

In five villages, farmers were found using pigeonpea biomass as manure/compost and were also using pigeonpea by-products for this purpose. Data on utilization of pigeonpea residues and by-products such as fodder and stalk also reveal farmers' intentions to enhance soil fertility. Among the sample farmers, 21% reported using pigeonpea residues as manure or compost (Table 3). Farmers either allowed the residues to decompose or burn the stalks after harvest in the field.

The pattern of land ownership among the farmers studied may explain the greater degree of concern among them for future productivity of their land. Almost all farmers (i.e. 97%) owned the land they cultivated. Half of those who did not own their land were recorded as non-adopters.

The introduction of short duration pigeonpea along with the increased availability of irrigation also enabled farmers to plant pigeonpea in marginal soils. Pigeonpea was a minor crop in this region until the release of ICPL 87. Responses from the survey showed that 70% of the area grown under ICPL 87 are marginal or inferior lands. For these farmers, land is an important resource and they have a strong incentive to seek options to ensure longer term productivity of the land. Thus, irrespective of the land holding size sustainability seems to be an important issue for farmers in the study region.

Table 3. Utilization of pigeonpea by-products: Western Maharashtra, 1994.

Utilization	Frequency	Percent
Firewood	119	31.7
Fodder	106	28.3
Compost	78	20.8
Construction material	46	12.3
Stalk, straw and husk	21	5.6
Given to friends	5	1.3
Total	375	100.0

Small farmers who constituted 22% of the sample and who owned less than 2 ha adopted SDP ICPL 87 on a large scale (70%). The cropping system of these farmers were different from the large farm-holdings. They grew pigeonpea, groundnut, cotton and pearl millet during the rainy season (Kharif) and wheat, sorghum and chickpea during the post-rainy season (Rabi). Area under cash crops such as sugar cane and horticulture was low due primarily to less access to irrigation facilities; only 43% of the area under pigeonpea was irrigated. Lack of irrigation could not be confirmed to deter adoption of short duration pigeonpeas. Among adopters of ICPL 87, 66% had irrigation for their pigeonpea plots in contrast to 74% access to irrigation among non-adopters. ICPL 87 has become a major crop in all blocks in the sample irrespective of the availability of irrigation.

Farmers in the region, especially those who were organized into cooperatives, were more aware of the sustainability dimension; they also played a large role in ICPL 87 seed production in collaboration with the Maharashtra State Seeds Corporation. Seed availability was a critical problem during the initial stages of diffusion.

V. Conclusion

Feedback from farmers obtained from two sets of on-farm surveys reveals a strong relationship between technology adoption and farmers' perceptions on the issue of sustainability. It confirmed that farmers perceive and plan for the longer term productivity of their land and they consciously adopt management practices to achieve it. The significant change in the cropping system in the study area was a result of the introduction of short duration pigeonpeas ICPL 87. It was essentially an introduction of a new crop in a traditionally low pigeonpea region. Farmers found ICPL 87 to be a viable option in improving soil fertility by rotating it with a major cash crop in different plots each year. The pigeonpea crop found its way in the fallow lands and in crop rotation with cash crops like sugarcane. SDP ICPL 87 found its niche in the scarcity zone around Western Maharashtra, where it was found suitable to the regions' agro-ecological features, resource availability and existing cropping system.

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