

Tamil Nadu Precision Farming Project: An Evaluation

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Contents

1. INTRODUCTION.....	1
2. PRECISION FARMING PROJECT (PFP): A BRIEF DESCRIPTION	3
MAIN TECHNOLOGIES AND MANAGEMENT	4
3. METHODOLOGY AND DATA.....	6
4. TRAVEL AND EFFECTIVENESS OF PFP.....	7
CORE AND ASSOCIATED TECHNOLOGIES.....	7
LABOUR AND WATER SAVING EFFECTS	10
POST-HARVEST PRACTICES.....	12
ROLE OF FARMER ASSOCIATIONS	13
5. IMPACT OF PFP.....	17
ESTIMATES OF PRODUCE AND GROSS REVENUE	17
ECONOMICS OF A PRECISION FARM	20
BEYOND BENEFICIARY FARMERS	21
6. CONCLUDING REMARKS.....	23

1. Introduction

This report is based on research that was originally conducted for a larger project at the London School of Economics (LSE). The LSE project is investigating the nature of evidence and how 'facts' are used in the construction, and communication of evidence. In this context, the LSE project team is investigating 'How "well" do facts travel?' This travel of facts can occur across various domains and disciplinary boundaries, as well as through time. To the project group, technologies constitute facts or embody facts (technical, procedural, scientific, etc.) and therefore the travel of technologies was one of the several instances of travelling facts that came to be studied. Technologies emerging from biological or agricultural sciences offer a rich source of study material as they often transcend disciplinary, social and temporal boundaries. In this context, extension education in developing markets promises to offer some particularly interesting instances of travel, addressing not only the 'how' of travel, but also the 'wellness' of travel: the assumption here being that the 'how' and 'well' of travel determines the effectiveness of extension efforts.

This was the main motivation when the LSE project team approached the Tamil Nadu Agricultural University's (TNAU) Directorate of Extension Education (DEE) in December 2006. Through numerous discussions, it became evident that the Precision Farming Project (PFP), which was in its second year of operation, was ideal for our purposes of studying travelling technologies. I was part of the initial discussions with DEE officers and have stayed involved with the project ever since. The result of these initial talks was that the LSE team proposed to conduct a study of the PFP

At the request of the DEE I have prepared this evaluation report based on the primary fieldwork that was conducted for the LSE project in August 2007. This evaluation report asks the following questions:

- a. How effective has been the transfer of Precision Farming technology from the University to the farmers?
- b. What has been the discernable impact of PFP?

This report evaluates the effectiveness of transfer on the basis of specific criteria such as the extent to which the farmers followed the fertigation schedule recommended by TNAU, the extent of labour and water savings experienced, evidence of the

changes in the post-harvest practices and the role of the farmer associations. This is discussed in section 4 of this report. The impact of the PFP is considered on the basis of evidence of improvements in yields and market value of produce, the economics of a precision farm, transfer of precision farming (PF) technology to non-participating farmers, etc. This is discussed in section 5 of this report. Prior to that, details of the fieldwork conducted in August 2007 are detailed in section 3.

The report does not evaluate the PFP technologies *per se*, but only their travel. The primary information source is the interviews conducted during my August 2007 visit. Wherever necessary this is supplemented by data kindly provided by TNAU/DEE. The report does not presume to make any contributions to the effectiveness of the extension model used in the PFP, nor does it profess to comment upon the merits or demerits of this model as compared to other methods of extension education. Further, a comment upon the issues and opportunities facing of horticulture sector, the changes in the cultivation and post-harvest management of commodities, growth imperatives for this sector, etc. is also beyond the scope of this report. Although the effectiveness of PFP is considered in a fairly focussed manner in this report, without claiming any broad generalizations, the possibility of extending the lessons from the PFP are evident. These are presented for consideration in the concluding section.

2. Precision Farming Project (PFP): A brief description

The stated objectives of the PFP can be classed into two broad types:

1. Promoting hi-tech horticulture through the use of precision technology that involved successfully transferring the latest cultivation and post-harvest technologies to the farmers
2. Promoting market-led horticulture by encouraging farmer's forums and associations and increasing the overall value accruing to the farmers.¹

The Tamil Nadu Precision Farming Project was implemented over three years (2004-2007) in the districts of Dharmapuri and Krishnagiri in the northern part of Tamil Nadu. The rationale for selection of these two districts was primarily the socio-economic status of both districts, which were considered to be backward, impoverished and water-scarce areas dominated by traditional agricultural practices. Further, Dharmapuri district is considered to be " Horticultural district of Tamil Nadu": the largest producer of tropical, sub-tropical and arid zone fruit crops like mangoes, banana, papaya, sapota, guava and grapes, and vegetables such as, tomato, brinjal, chillies, cabbage, etc. About 10% of the floriculture industry in the state is concentrated in Hosur area of Krishnagiri district.

The project was concentrated around clusters and about 400 farmers were selected in the two districts, progressively between 2004 and 2007 as follows:

Applications for PFP in Dharmapuri District	Received	Selected	Rejected
Aug-Sep 2004	130	30	100
Dec 2004	40	20	20
July 2005	140	44	96
Aug 2005	236	46	190
Sep 2005	35	10	25
Nov 2006	54	35	19
Dec 2006	116	15	101

¹ E. Vadivel (ed.), *Tamil Nadu Precision Farming Project: Expertise Shared and Experience Gained*, Tamil Nadu Agricultural University, Coimbatore (India), 2006, p. 1

Applications for PFP in Krishnagiri District	Received	Selected	Rejected
June, 2004	90	50	40
July to September ,2006	120	50	70
October,2006	87	23	64
July to November ,2006	89	27	62
December,2006	49	21	28
January ,2007	54	9	45
February ,2007	47	10	37
March,2007	17	10	7
<i>Source: DEE, TNAU, October 2007</i>			

The criteria used for the selection of farmers were several and included the minimum area, ability to provide for a minimum quantity of water, nature of the soil, location of the farm in relation to the cluster, etc., as well as other 'soft' criteria such as willingness to participate in associations, willingness to conform to practices recommended by TNAU, etc.²

The project has grown in profile over the years, primarily as a result of its effectiveness in transferring a package of technologies as well as in the demonstrable benefits that the participating farmers have experienced from a transition to hi-tech farm management. This is reflected, for instance, in the generally increasing proportion of applications received in the second and third years as compared to the first year of the project. This is also mirrored in the number and profile of visitors to the PFP farms over the years (see appendix to this report).

Main technologies and management

The PF technologies were structured in a package that had to be internally consistent and were transferable *as a package* to beneficiary farmers. These were essentially of two types: cultivation related and post-harvest management. Details of individual PF technologies are included in E Vadivel (ed), *Tamil Nadu Precision Farming Project*, (TNAU, 2006). Notable precision technologies included drip irrigation using Class 3 fertigation units along with water soluble fertilizers (WSF), the use of community nurseries, use of remote sensing technologies to develop a fertigation schedule

² See Vadivel, *TNPFP*, pp. 3-4 for details

according to crop and soil type, grading and sorting techniques and detailed documentation of farm activities.

The PF technologies were made available to the beneficiary farmers through a progressively reducing financial assistance that included the cost of the fertigation equipment and the cost of installation (including the installation of laterals) and the cost of cultivation (including the cost of WSF). This entire cost package was estimated to be about Rs. 115,000. The level of assistance was reduced progressively over the years as follows:

- Year 1: 100%
- Year 2: 90%
- Year 3: 80%

Beneficiary farmers recruited in year 2 and 3 were expected to bridge the cost difference themselves.

In terms of the organization, a Nodal Officer (appointed from TNAU) was overall in charge of the project, who in turn was further assisted by two project officers based at the district level. About 17 field scientists were based in the districts, reporting to the two project officers. The field scientists had regular contact with the farmers and provided direct assistance to the farmers and association in technical and farm management issues. Thus, the level of resources dedicated to the project in terms of manpower was considerable.

On the whole, the level of assistance provided to the farmers - in terms of financial incentives as well as technical expertise - was extraordinary. The issue is extent to which this level of assistance contributed to the effective of transfer of PF technologies.

3. Methodology and Data

The primary data for the LSE project was collected on the basis of 52 in-depth interviews conducted between 16th and 21st August, 2007 in the Dharmapuri (21 farmers) and Krishnagiri (31 farmers) districts. 34 beneficiary farmers (BF) as well as 18 non-beneficiary farmers (non-BF) were interviewed. The sample BF interviewed was spread over all the three years of joining, although the bulk of them were 2nd year farmers: 1st yr. - 9; 2nd yr. - 17; 3rd yr. - 8. Altogether 17 clusters were covered as shown in the table below. The interviews were based on a set of common questions, however, the discussion was essentially free-flowing and conversational. All interviews were conducted by me, accompanied by Mr S Annadurai, who kindly acted as a translator between the farmers and myself. All interviews were one-on-one and essentially reflect the opinions of individual farmers, rather than a collective group. Efforts were also made to interview the office holders of the various farmer associations formed around the PFP clusters.

Profile of Farmers Interviewed

Cluster	BF	Non-BF Applied for PFP but not selected	Non-BF Not Applied for PFP Scheme	Total
Baglur	2			2
Berigai	3		2	5
C R Palayam	2			2
Jakkeri	3	1	1	5
Jarugu	3	1		4
Kupatti	1			1
Mallasundaram			1	1
Moolaiyanur	2	1		3
Morappur	1	1	1	3
Pallacode	2	1		3
Paperetipatti	2	1	1	4
Royakottai	2		2	4
S Kurubatti	1	1	2	4
Sarakapalli	2			2
Somanahalli	3	1		4
Thirichipalli	3			3
Thorapalli	2			2
Total	34	8	10	52

4. Travel and Effectiveness of PFP

The effectiveness of the PFP technologies and the manner in which they ‘travelled’ from TNAU to the farmer community is assessed here by studying four elements. First, the extent to which the ‘package’ of PF techniques were adopted by the project farmers and the degree to which this package was modified or changed by them is assessed. Second, the extent to which PF techniques aided the farmer to economize on water and labour costs is also gauged. Third, the manner in which PF practices helped the farmer to manage post-harvest and marketing issues is studied. Finally, the role of the farmer associations, formed as part of the PFP, is explored.

PF technologies are found to have travelled well between TNAU and the beneficial farmers, and also to an extent among the non-beneficiary farmers with the sample surveyed. Most of the technologies were adopted with very few changes. The main reasons why the farmers considered the technologies to be effective is because they led to significant savings in water and labour costs. Further, post-harvest management of produce also ensured that the farmers received good value for their products. An analysis of this issue is the subject of the following section. Finally, apart from the close supervision by the TNAU scientists, the farmer associations played a pivotal role in ensuring that the knowledge and information ‘deficit’ about PF techniques was reduced, and facilitated in strengthening the small farmer’s position vis-à-vis the market.

Core and Associated Technologies

For the sake of this report, the drip irrigation system, and fertigation schedule recommended for each soil and crop type, is considered as the *core* technology within the PFP package of technologies. *Associated* technologies include crop-spacing, pest-management techniques, grading of produce and several others that guide cultivation and post-harvest activities. They are detailed in the TNAU project book and are not described in this report.³ I study whether there are any changes that are introduced by the farmers either to the core technology or to the associated technology, with or without consultation with TNAU scientists.

³ See Vadivel, TNPFPP.

As far as the core technology is concerned, inspection of farm records maintained by the PFP project office suggests that in the first year of participation the BF closely followed the fertigation schedule recommended by the TNAU scientists. The farm records contain detail information for the first year of the operation on any given PF. Thus, for first year farmers, the records are maintained during their first year of operation, but not in years 2 and 3. For the second year farmers the records are maintained for the first year, but not for the second year. The farm records although confirming that in the first year the fertigation schedule was followed closely, are not capable of commenting upon the practices in the subsequent years. However, during the personal interviews with farmers, all the BF claimed that they continued to follow the schedule as recommended by the scientists, without any deviation. Changes were made by the TNAU scientists themselves based on their increased experience of the region. Thus, the technology was not static, however, there does not appear to be any significant deviation by the farmers to the TNAU recommendations of the core technology.

The only exception to this case was Laxmipathy of Somanhalli, the secretary of the local farmers association. He claimed to have made 'mini changes' to the fertigation schedule according to the nutrient content of the soil. Upon being probed on this issue, he said that he had had his land tested for soil quality and based upon his experience and judgement, he would adjust the amount of fertilizer that he applied to various parts of his land. The changes to the fertigation schedule recommended by TNAU were quite minor according to him. Apart from him, I did not come across any other case in the sample where the BF admitted to changes made to the recommended fertigation schedule.

One of the major reasons why there was little or no deviation in the fertigation practices in the first year of the PF operations appears to be the fact that TNAU scientists would be present at during the mixing of water soluble fertilizers (WSF). This ensured that the correct dose was applied during fertigation, which also had a demonstration effect on the BF who could observe and learn the proper methods of mixing and applying the WSF.

In the subsequent years, the BF had a strong incentive not to stray from the fertigation schedule. The improvements in yield and market value in the first year of PF were directly attributable to the PF practices and fertigation. The apparent success

in productivity and value improvements acted as strong motivators to maintain the schedules recommended by the scientists. The farmers believed both in the science behind these recommendations and also the reputations of the scientists and TNAU, which had enhanced based on the success of the first years operations. This was evident through the interviews with the farmers.

For instance, Rajendran from Moolayinur explained how fertigation had an impact on soil aeration, that older methods, such as channel and flood irrigation left the soil hard while fertigation left the soil loose. This, he explained promoted growth through better root condition and better yield. Varadaraja from Morappur said that 'under flood irrigation, [we] could not get so much yield: only with fertigation can we expect [such high] yield'. He further explained how the 'workload' had decreased; 'I simply have to turn on the switch to start the irrigation', he said. Anbumani from Paperetipatti said fertigation 'improved [my] lands in terms of yield and income.' Dorairaj from Jarugu said that the 'regular application of fertilizer once every 3-5 days through drip irrigation had a better effect on growth.' Even at the end of the PFP, he wanted the university 'people to continue to stay with us' as new diseases and pests would be encountered. 'We will find it difficult if the university people leave us', he said, as 'department people do not give such good advice compared to university people.' Krishnan from Pallacode said that 'from sowing to market, the university guided me.'

There was no case of any of the farmers abandoning the core technologies. Quite the reverse was observed. Several BF had in fact extended the drip system from the 1 hectare (2.5 acres) sponsored by the project to encompass a greater extent of their land. Most of this extension was done at their own cost. Anbumani was interested in extending drip irrigation to an additional 3.5 acres to grow banana. He had applied for bank loan, which once received he planned to use to convert and maintain PF technologies on his entire 6 acres land. Varadaraja had extended drip on another half acre and was seriously considering extending it to another 3 acres, if necessary 'using his own money.' Similarly, Dorairaj had extended drip on an additional 2 acres, Laxmipathy had drip irrigation on 8 acres, Krishnan had extended it by 4 acres on sugarcane and was thinking of getting more area under drip, and Pallani had extended it by an additional 2.5 acres.

The farmers were keen to experiment and innovate with the *associated* technologies. For instance, several farmers mentioned that they experimented with the spacing between the crops to ascertain the 'optimal' distance and crop density. This was a deviation from the 'standard' distance recommended by the scientists for each crop. This was often done without consultation with the TNAU scientists. For instance, Pallani from the Somanhalli cluster experimented with 6ft and 3ft spacing for sugarcane instead following the 5ft recommended by TNAU. He told us that he discovered that 3ft was a more optimal distance than 5ft. for sugarcane.

Thangamani from Paperetipatti thought that the spacing for his banana should be 4 ft instead of recommended 5 ft. In this manner, he could use a single row system rather than the double row system and consequently was thinking of changing the existing system. He told us that he heard about this when some farmers in Krishnagiri district made this modification.

Similarly, Rajendran was not averse to extending the 'trailing' system he was using for tomatoes to bitter gourd after consultation with two other farmers both following PF techniques. On the other hand, Subramanian, also from Moolaiyanur, preferred to use the 'correct distance' as recommended by TNAU, and in fact was not using any of the 'older methods' he had been used to.

As far as the core technology of drip irrigation and fertigation is concerned, it appeared that the BF adopted these without making any modification, or if any (as in the case of Laxmipathy), then making only minor adjustments. There was no case of any of the farmers abandoning the fertigation technology from the sample of farmers, nor did I hear of any such case during my conversations with both BF and non-BFs. As far as the associated technologies were concerned, the farmers did use their initiative and introduced changes that they felt were either necessary to their particular situation or improved it.

Labour and Water Saving Effects

Almost all the farmers interviewed reported a considerable extent of labour and water savings as a result of adopting PF techniques. Often, this was cited as one of the most important aspects or benefit of PF technology. The extent of labour and water saved on individual farms was not assessed quantitatively, however, most farmers agreed that they were using at least half of both water and labour than

previously. These savings are manifested not only in the reduced quantum of labour or water used, but also the reduced effort applied for irrigation, weeding and other soil preparation activities.

According to Govindraj from Thirichipalli, 'a single labourer, who could previously only work on *three acre*, can now work on *eight acres*.' For, Venkateshappa (also from Thirichipalli) there was a saving in terms of number of labourers that he had to employ: from *fifty* to *twenty five*. Rajendran claims that he could irrigate his crops himself and did not require any additional labour. Reasons given for labour saving effects were fairly unanimous. Thangamani said he reduced labour by about 50% as his need for weeding and irrigation was reduced due to drip irrigation. According to Laxmipathy, as drip irrigation leaves the soil porous, he requires less labour, and therefore less ploughing, particularly for his cotton crop. He also experiences less weed problem, which reduces the need to use labour for weeding.

Similar savings were experienced in the case of water requirements. For Govindraj, the same quantum of water that he required to irrigate about *two* acres can now irrigate *eight* acres. Venkateshappa could irrigate three times as much area with the same quantum of water after he installed the fertigation system. Rajendran was able to get over his water problems as he was able to utilize the limited water more efficiently over his entire cultivated area.

The labour/water saving aspect of PFP was also cited by non-BF as one of the primary reasons for their interest in the PF techniques. Although most have no direct experience of this (apart from a few non-BF who had installed fertigation equipment at own cost), most were convinced of its significance through discussions with BF in the neighbouring areas, as well as through contact with TNAU scientists. Another aspect that both BF and non-BF mentioned was the precise application of WSF through fertigation, implying saving in the cost of fertiliser application.

Gnanavel, a non-BF from Moolayinur who had applied but was unsuccessful, stated that he was interested in applying to the PF project because he had 'seen the beneficiary farmers using less water, and saving on labour costs.' At the time of the interviews, he was employing about seven labourers per day and was convinced that he would have been able to save on those costs if he had implemented the PF technologies. He had also become aware of the tremendous wastage of fertilizers

when they were broadcast, rather than applied precisely through the fertigation methods: 'there is a 50% wastage in the broadcast method of fertilizing.'

Similarly, Saravanan from Somanahalli and Thottappa from S Kurubatti both got interested in the PF project once they saw other farmers in their village save on water and labour costs. Thottappa mentions how he saw that 'the land does not dry up' as with the current method of flood irrigation, and was convinced that 'somehow he has to implement the drip irrigation' on his land.

Post-Harvest Practices

This aspect includes improvements made in the techniques used to prepare and transport produce to commodity markets or directly to buyers. PF techniques improved, or in many cases introduced, a system of sorting harvest into quality grades using fairly simple methods. One of the most effective was the sorting of produce into crates indicating different quality grades (see picture).



Sorting helped in easy identification of grades and helped to obtain better prices for produce. A majority of the farmers mentioned that they realized better market value for their produce on adoption of PF techniques. The increased price was a result of several factors:

1. Increased yield - both in terms of quantity per harvest as well as increased number of harvests per plant
2. Better condition of the produce - weight, appearance, etc.

3. Better market price realization due to sorting and grading of produce

Additionally, the farmers associations helped to pool together resources to transport produce to the market, saving time and effort, and guaranteeing delivery. This aided better price negotiation particularly to organized buyers and markets, such as the SAFAL market in Bangalore, who prefer to deal with marketing associations rather than individual markets. Thus, improved realization of market value accrued due to four reasons; improved condition of produce, improved yields, better grading techniques and transport efficiencies.

The opinion of terminal market operators such as SAFAL market about the marketing practices and quality of PF products was also quite positive. Mr Palaniappan of SNX was of the opinion that when PF products were displayed for auction at Safal, 'buyers were keen to grab these products first.' He further stressed the importance of marketing through farmers associations, similar to the marketing practices of some of the PFP associations (discussed below). According to him, buyers prefer to contract with such farmers associations because 'getting large volumes is not a problem, the supply could be consistent and continuous, products are traceable as they are very sure of the source (which is very important today), and associations which can give provide high and consistent quality are very few in number.'

He further stressed that there was a noticeable difference in the way precision farms were managing their supply chain compared to other farms. He found that they were beginning to establish a network (through the associations) and a recognition in the market and that they could access various markets, beyond their local markets. Consequently, they could decide the best market to sell with the help of the network they have. He could also detect that precision farms has been improving in the post-harvest practices such as transportation and packaging; e.g. transport of produce (such as onions or tomatoes) in crates, or improved packing practices in the case of banana.

Role of Farmer Associations

The farmers associations appear to perform two vital roles in the dissemination and success of PF technology. The associations serve as nodes for exchanging knowledge and information. They also help farmers obtain better value for produce as well as

inputs (as mentioned above). Although, the extension model used in the TNPFP relies upon direct scientist-farmer interaction to transfer key PF technologies, the associations perform a vital support function as information nodes. According to the president of the Moliyanur Precision Farmers Association (19 members), the association holds regular monthly meetings to discuss marketing and other issues on the 2nd day of every month. Regular meetings such as these help BFs to raise, clarify and solve cultivation, marketing and farm management issues. Often TNAU scientists attend these meetings and are able to offer expert advice, but even in their absence local issues are raised and resolved multi-laterally. Many association meetings are also attended by non-BFs, which not only raises the profile of the PFP, but substitutes for the lack of direct scientist-farmer interactions in this case. The associations act as demonstration vehicles to disseminate both knowledge and information about the techniques and the impact that they have on cultivation and post-harvest results. They appear to help reduce the knowledge and information deficit.

According to Anbumani, the associations are really helpful as they 'meet government officials to keep track of subsidies or schemes', information which they then pass on to the members. They also 'pass on this information to non beneficiary farmers, including information about new technology.' Varadaraja felt that associations very helpful in disseminating information about the use of technology. For example, he was better informed about plant protection measures through the associations: 'don't use too much pesticides but spray limited quantity', he was told. Thus brought down overall cost as 'previously [we] used to use a lot of pesticides, now [we] know how much to use'. Dorairaj felt that the benefit of associations were the regular meetings 'on how to improve individual farms, use technology, and discuss marketing'

Rajan, a non-beneficiary farmer from Jarugu, said that he learnt a lot about precision farming methods by regularly attending the local association meetings. He said that he 'got to know how the drip irrigation system can save water' through regular interactions with precision farmers at such meetings. He further said that the farmer meetings and discussions 'have taught [me] about plant protection measures, what chemicals to use and how much to spray'. This was important because when 'representatives of pesticide companies visited me, I was able to make up my own

mind about what is [good] for my crops.’ Saravanan, a non-beneficiary farmer from Somanhalli, claimed that he continues to receive ‘new knowledge’ through association meetings and field visits to precision farms.

The associations also seem to help the farmers obtain better value by improving their negotiating position vis-à-vis buyers or input providers. As discussed above, organized markets increasingly prefer to deal with farmer associations as it helps to eliminate risks of delivery failure while providing a greater assurance of quality. This is also beneficial to the farmers as it helps them to secure better value by costing out delivery failures and in-transit damage to produce out of the revenue. By assuring minimum quality through proper grading and sorting, associations help farmers obtain better average prices than comparable produce sold without the association’s involvement. The associations also help the farmers to negotiate better price for inputs such as fertilizers, pesticides, seeds, etc. by guaranteeing minimum quantity, as well as negotiating for or arranging *timely* supply of inputs.

Thangamani said that he was ‘able to market mainly because of the association.’ Anbumani said that the role of the association was vital in facilitating in the marketing of the produce. Mahendran from Jarugu said the several precision farmers from his cluster would collectively send about 40-50 crates each to the market. Such practices, according to Rajendran meant that it led to ‘sharing cost of transportation between farmers and saving of time for all.’ Laxmipathy claims that the associations really do help the farmers collectively in both marketing, as well as ‘approaching the government as it is difficult to do this individually: we get better benefits if we go through the associations’. He also explained how large buyers approach the associations with large volume requirements, which then coordinates how the fulfilment is met.

Laxmipathy also explained how input costs are minimized through associations. The Dharmapuri farmers had formed a private limited company called Dharmapuri Precision Farmers Agro Services Limited (hereafter referred to as ‘Agro Services’) which acted as the distributor or dealer for several agri-product corporations and sold input materials such as seeds, fertilizers, plant protection materials, and other agriculture inputs. The products sold were of better quality and at cheaper rates. This association has become dealers for Jain Irrigation Systems Ltd, the supplier of the fertigation tanks and drip irrigation equipment used in the TNPFP, and had

begun selling fertigation equipment to all farmers. Varadaraja shared how such services, generally speaking, lead to 'less expenditure, since inputs cost are less.' Dorairaj told us how regular meetings between farmers associations and encouragement from TNAU gave rise to the 'agro services company.'

TNAU had made the formation of associations a pre-condition for the receipt of PF technology. In most of the clusters, where this study was conducted, the associations formed were working smoothly. In a few clusters, where the project had just been introduced in 2007, the associations had been formed fairly recently and it was still too early to assess their significance. In other clusters, particularly in the Krishnagiri district where they were proximal to a large market such as Bangalore, the significance of the associations appeared to be less. This aspect needs to be studied further to ascertain the extent to which the effectiveness of the association varies according to the financial independence of the farmer, their education levels, access to information, proximity to large markets (both produce as well as input) or degree of remoteness, and other technical and social variables. On the whole, there is sufficient evidence to suggest that the associations were vital in the successful transfer of PF techniques to the BF, as well as beyond to the non-BF.

5. Impact of PFP

The impact of the PFP can be established by examining the evidence of yields and gross revenue that the farmers realized using the precision methods, and by studying the economics of running a precision farm. Vially, the impact of the PFP as a demonstration project must be assessed by examining some evidence of its spread beyond the beneficiary farmers. This evidence is presented here. Since the collection of data used here was done primarily for other purposes, the study of the spread beyond beneficiary farmers is limited in scope.

Estimates of Produce and Gross Revenue

The impact of PF technologies on production is assessed by examining the detailed farm records maintained by TNAU and the BF. From these records a sample of 119 observations were made across nine crops to estimate (by each crop) the average number of times it was possible to harvest, the output per hectare for one season and the estimated gross income.

The nine crops from which the sample of observations were made were tomato, brinjal, banana, chilli, bhendi, watermelon, muskmelon, cassava and cabbage. Apart from cassava, all other crops yielded multiple harvests and the average number for each crop is given in the table below. What is immediately obvious is the enormously large number of times that tomato, brinjal, chilli and bhendi could be harvested. This implied a lengthened crop duration and increased harvest period using PF techniques, a assessment that is shared with TNAU's estimation of average durations for such crops.

In addition to the increased harvest period, the average tonnage obtained in one season was also considerable. Column 4 in the table below shows the average tonnage per hectare obtained for each crop. If we compare the average yield estimates for tomato, brinjal and banana against national average estimates (17.35, 10.46 and 28.58 tons per hectare respectively) we notice that the PF yields are at least 3 to 12 times higher. This analysis indicates the potential for increasing yields in 'real life situations' with the proper adoption of PF technologies. This is corroborated through conversations with individual farmers.

Thangamani claimed that his yield (for banana) increased threefold after adopting PF techniques, as did Varadaraja, who was growing tomato. Krishnan claimed that yield on his tomato crop increased by about 150 percent or about 2.5 times, whereas Pallani reported about 160% or 2.6 times increase in his yield. Mahendran reported that he got about 25 tons per acre (of tomato) whereas previously he would get about 5-6 tons per acre. He also told us about how he got interested in the PF techniques when he saw that one of the first year BF has got about 120 tons per hectare. Several BF also shared their experience of early harvesting periods. For instance, Dorairaj said that for sugarcane ‘earlier it used to take 12 months for harvest; with the fertigation system, within 8 months I am able to harvest.’

Table of Output and Estimated Gross Income of a Sample of PFP farmers

<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
Crop	Sample of Farmers	Avg. No of Harvests in Sample	Avg. output per crop for 1 season in sample (tons/ha.)	Avg. of Gross Income per crop (Rs./ha.)
Tomato	30	71	85	211,963
Brinjal	24	76	121	303,333
Banana	24	2	79	612,842
Chilli	8	42	25	152,273
Bhendi	5	33	13	90,720
Watermelon	5	3	33	97,860
Muskmelon	6	3	34	203,000
Cassava	9	1	40	168,725
Cabbage	8	4	56	168,109

Apart from yield, the quality of produced obtained was also reported to be high. Dorairaj said that ‘if normal crate [of tomato] is 26kg, [my] crate would give 28kgs for the same volume.’ He further claimed that his tomatoes had ‘good personality and were very attractive.’ Laximpathy said that due to fertigation the ‘quality and

size of the product was maintained, and there was uniformity in yield.' Krishnan claimed that the regular and spot application of water soluble fertilizers 'every 5-10 days has resulted in quality improvement.' Laxmipathy echoed this by comparing the PF techniques to older methods. For tomato, in PF, every 4-5 days there is equal application of fertilizers, leading to even growth through the life of the crop. He thinks this also results in an extended shelf life of the product: 'sometimes up to 15 days, where ordinary products would be 4-5 days.' According to Rajendran, the improvement in quality also translated into better price received. He obtained about Rs. 20/- extra per crate of tomato for same weight/volume. Similarly, Pallani thinks he gets about Rs. 5/- more per kg on tomato due to improved quality; his sugarcane crop similarly received about twice the income compared to earlier periods.

Thus improvements in yields as well as quality appear to have resulted in improved income for the farmers. Given the absence of and difficulty in obtaining reliable information on actual income earned, I have estimated the likely gross revenue per acre given estimates of average tonnage per hectare for the sample of crops in the table above. Further, given the fluctuations in the price of agricultural produce, I have relied upon the estimates of 'minimum prices' reported in several local markets that TNAU helped to compile. These estimates are reported in column 5 of the table above. The gross revenue per hectare ranges from about Rs. 100,000 to 600,000 per hectare, with the median range somewhere between Rs. 150,000 to 200,000 per hectare. Considering that these estimates are based upon minimum market prices, the actual farmer income could be higher, in some cases substantially higher. Without a detailed analysis of prices in local and regional markets, it is difficult to establish how much more actual gross revenue is likely to be. Nevertheless, these estimates provide a useful benchmark.

These estimates are also corroborated by individual reports by BFs during conversations. Balasubramanium reported that he earned about Rs. 300,000 in the first year from the PF area alone (1 heactre of tomato). Dorairaj said that he earned about Rs. 200,000 per *acre* himself, and he knows that some of his neighbouring precision farmers have earned upto Rs. 300,000 per *acre*. Anbumani said that 'previously the maximum revenue from 6 acres I would get would be about Rs. 150,000; now the 2.5 acres under PF alone generate about double this amount'. He

considers the 'increased income to be the most impressive result of precision farming.'

The true significance of such potential revenues per hectare from PF techniques can be appreciated once they are compared with the likely cost of operating a precision farm. This is discussed below.

Economics of a Precision Farm

The economics of a precision farm is driven influenced by the cost of converting from a non-precision farm to a precision farm. Conversion costs are affected by the type of irrigation equipment used and the use of high-technology input and other cultivation practices. Installation costs comprise of equipment cost and preparation costs. The cost of the fertigation equipment, including the cost of fertilizer tanks and pumps is about Rs. 18,750. In addition, the Class 3 PVC pipes used for drip irrigation cost about Rs. 14,000 for a 7000m lateral.⁴ The cost of preparation, which is mostly composed of providing the 'laterals' can be as high as Rs. 65,000. Thus, the total cost of converting a to a precision farm using Class 3 material is between Rs. 90,000 to Rs. 100,000. Naturally, this cost can be amortized over the life of the equipment, which is usually assumed to be about 10 years.

Precision farms entail different farming practices and use of hi-technology inputs compared to traditional farms. Thus, the difference in cultivation costs results both from the use of different inputs, and incurring greater costs of field preparation and management. Input costs consist of costs of hybrid seeds, water soluble fertilizers, and plant protection measures. Preparation costs include nursery costs, and labour costs for field preparation and irrigation, transplanting, harvesting, packing, etc. These could range from a minimum of Rs. 40,000 per hectare for perennial fruit crops to a minumim of Rs. 50,000 per hectare for annual vegetable crops.

Thus, allowing for the costs of traditional farming, the total cost of conversion of a 1 hectare (2.5 acre) farm from a traditional to a precision farm is anywhere between Rs. 135,000 to 150,000. This is the cash amount needed in the first year to begin operations. Considering that the equipment cost is amortized over 10 years, the actual cost of operation of the precision farm is considerably lower, and may range between Rs. 65,000 to 75,000 per hectare.

⁴ Class 2 PVC cost about Rs. 8,400 for a 7000m lateral and have an estimated life of 6 years. The life of a Class 3 material is about 10 years.

Comparing the conversion cost to the gross revenues per hectare reported in the table above we see that it is actually possible to recover virtually the entire cost of conversion of the precision farm in one season alone. There is therefore every possibility that the precision farmer may be able to absorb even a substantial reduction in the price per unit, assuming of course that there is no change in the production methods. This sensitivity analysis is beyond the scope of this report. However, these basic calculations are indicative of the profitability of this technology. In such a scenario, the main hurdle for the farmer wanting to convert to the precision method of farming of this type is likely to be financing the initial cash outlay in terms of the fertigation equipment, and not the recurring cost of cultivation and operation. We return to this issue once again in the next section.

Beyond Beneficiary Farmers

The impact of the PFP as a demonstration project was also noticeable in terms of the extent to which the PF technologies travelled beyond the beneficiary farmers. In the survey conducted, it became evident that several non-beneficiary farmers had adopted PF farming techniques. This was primarily due to their interaction with beneficiary farmers, which confirms the signalling effect that these demonstration farms have had on the larger farming community in the region.

Chandraraja from Papiretipatti said that he had installed a drip irrigation system on 3 acres of his 8 acres land, without the fertigation system, after seeing the precision farms. He also began following the 'bed system' and using hybrid seeds, but was unable to get the same improvements in yield and quality as the other precision farmers. Still he was able to increase yield by about 10% and believe that any further improvements can only accrue if he begins fertigating the crops. He also claims that some of his neighbours have installed drip irrigation after seeing his field.

Anbumani claims that he has been receiving many visitors and that his field have become an 'exhibition plot', and that several visitors have started growing the same hybrid bananas that he does. Rajan from Jarugu said that he had applied in the third round of the PFP after seeing the neighbouring precision farms. He became interested in the PF techniques when he saw his neighbours experiencing lengthened harvest periods due to fertigation. He had not been selected for the PFP and at the time of the interview was thinking of installing drip system and a fertigation tank to cover 1 acre at his own cost.

Sallaum from Pallacode had installed a fertigation system over 2 acres of his 5 acres land for banana. The fertigation equipment that he had installed was the same as the one used in the PFP, which he invested in using his own money. He first became aware of this technology when he visited some neighbouring precision fields. He wants to extend fertigation to the balance 3 acres. There are several such examples of non-beneficiary farmers visiting the precision farms in Dharmapuri and Krishnagiri, often from other districts or even from outside Tamil Nadu. Several anecdotes of such visits leading to investments in drip irrigation and fertigation equipment were narrated during the survey. Although such claims often cannot be verified, the increased sale of fertigation equipment to non-PFP farmers in Dharmapuri district can be considered a direct evidence of the impact of precision farming on the larger community. Officials of the Agro Services, one of the distributors of Jain Irrigation in Dharmapuri, claim that in the eight months beginning January 2007, about 82 farmers have been supplied with fertigation equipment without any subsidy involved. During the same period, about 50 beneficiary farmers of the PFP were supplied with fertigation equipment to extend the existing area under fertigation. These are all Class 3 equipment, which the farmers were investing in at their own cost.

Nevertheless, the adoption of the core technologies - fertigation and drip irrigation - by the non-beneficiary farmers has been limited, whereas the adoption of the associated technologies - hybrid seeds, plant protection measures, field preparation methods, etc. - has been comparatively greater. Most non-BF confessed that adopting only the associated technologies has not translated into the tremendous increase in yield and market value, to the extent experienced by the BF. The main barrier for non-adoption of the core technologies was the lack of financing available. Many declared that even a subsidy of 50% would be insufficient inducement for them to make the initial investment.

6. Concluding Remarks

This report has evaluated the TNPFP in two broad terms: the manner in which the precision farming technologies travelled from TNAU to the farming community and the impact they had on the farmers. In terms of the travel of technologies, the evidence presented here suggests that the core technology – fertigation – travelled unmodified from the producing domain (TNAU) to the receiving domain (beneficiary farmers). The extent of travel was complete in the sense that all beneficiary farmers adopted and continue to use this technology. The associated technologies – field preparation, plant protection, hybrid seeds, post-harvest practices, etc. – also travelled well between TNAU and the beneficiary farmers. The farmers did make marginal changes to these technologies, but to a large extent they remained unmodified.

Reasons that explain this effectiveness of travel are the close supervision of TNAU staff during the duration of the PFP and the reputation of the TNAU and its scientists among the farming community. The dense and close supervision by TNAU staff ensured that during the critical first year of introducing PF techniques the knowledge and skill deficit was bridged effectively. In subsequent periods, there was no incentive for the farmers to deviate from PF protocols as the impact of technologies on farm yields and income was considerably more than was expected. This helped to solidify TNAU's reputation, giving credence and weight to their suggestions; this further created incentives to follow PF protocols. This process seems to have made this extension model highly effective.

The impact on the beneficiary farmers in terms of improvements in yield and generating high revenue appears to be significant. Evidence presented here suggests that PF techniques are economical even though the initial cost of conversion is high (page 20). This raises an important limitation of the PFP: **the extent of spread of precision farming technology beyond the beneficiary farmers is likely to be limited by the quantum of initial financial assistance that is available to the farmer.** This is underscored by the evidence from non-beneficiary farmers, most of whom were convinced that the technology worked and adopted some of the associated technologies, but were largely unable to make the initial investment required to install the fertigation system. The scalability from a demonstration project to a generally accepted method of farming could be limited by this institutional aspect.

Another important reason for the effectiveness of the travel of the PF technologies is the role of the associations. Within the extension model adopted for the PFP, the associations functioned as the receiving and dissemination nodes for information, knowledge and skills. They supplemented and greatly aided TNAU extension efforts, strengthened connections to beneficiary farmers and made new connections to non-beneficiary farmers. Evidence presented here suggests that the spread of PF techniques was primarily through the interaction between farmers facilitated by the local associations. The demonstration effect of precision farms was greatly amplified through these associations. Other important roles of the associations seems to be to improve the competitiveness of the member farmers in terms of marketing and securing inputs. They also functioned as a clearing house of information from other non-TNAU sources (governments, other associations, markets and buyers, etc.). The cohesiveness with which they functioned was not uniform across the districts surveyed. This indicates another limitation of the PFP: **the extent of travel of precision farming technology beyond the beneficiary farmers is likely to be limited by the existence and effectiveness of local associations or similar institutions.** The scalability of precision farming depends upon this aspect.

There were three other limiting factors that need to be recognized. First, the economics of the precision farming have been estimated on the basis of a uniform size of 1 hectare across the beneficiary farmers. How these estimates vary with size, particularly with smaller farm sizes is not known. The project does not capture this sensitivity, and an analysis of this aspect has been beyond the scope of this report. Second, the project has been implemented on farms that have a minimum level of availability of water or infrastructure to access it. The economics of this technology where water sources are not regular or are difficult to access is again not captured. Third, the extension model followed by the PFP requires intense involvement of the extension agents – in this case it was the TNAU staff. The impact of greater or lesser extent of supervision by the extension agents could not be captured by the project or this evaluation report. In overall terms, the following quote from one of the beneficiary farmers neatly sums up the impact of this project:

'Since I am getting [so much] cash and high yield, how can I leave this technology'

