Impacts of participatory crop improvement in the low-altitude regions of Nepal

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EXECUTIVE SUMMARY

- As many poor people live in the Terai region of Nepal as in the rest of the country — the Terai has half of the country's population and is no more developed. Fifteen of the 20 terai districts are much poorer than average but grow half of Nepal's rice and have a third of Nepal's population.

- Most farmers in the Terai and low hills are resource-poor, food-deficit smallholders having less than 1 ha of land. Farmers in these areas rely on rice, and improvements in yield and quality have considerable benefits for their livelihoods. They grow rice in rainfed, low-fertility fields and these farmers have had limited, or no, access to new varieties.

- Participatory rice improvement in Nepal has been carried out by a network of partners (LI-BIRD; CAZS, UK; Department of Agriculture; NARC; and several NGOs). The project has created new varieties using client-oriented methods that involve both women and men.

- Most of the new varieties are adapted to rainfed, low-fertility fields, and because they are more disease and pest resistant need less, or no, environmentally damaging pesticides. Overall, rice varietal biodiversity is increased and other innovations introduced by the project, such as kidney bean, has increased crop diversity. The new rice varieties have improved grain quality so they can fetch a significantly higher market price (up to 25% more). They have combinations of improved drought tolerance, lower production costs, earlier maturity, and yield up to 50% more grain.

- These varieties are spreading rapidly from farmer-to-farmer in all 20 districts of the Terai and most of the low-hill districts bordering the Terai, aided by participatory extension by a network of Department of Agriculture Offices and NGOs.

- They are also performing extremely well in Bangladesh in the High Barind Tract, and in droughted conditions in the poorest, rice-growing states of eastern India.

- The impacts of the project are already considerable. Tens of thousands of farming households have adopted project varieties and benefited from them.

- Projections indicate very significant benefits with high net present values (£10 million by 2010 for Nepal) and high internal rates of return (83% by 2010).

- Institutional impacts in Nepal have also been considerable. The Department of Agricultural has now adopted project-introduced participatory methods as a means of extension and NARC is an active partner in the PPB programme. Institutional impacts are not restricted to rice, but have influenced programmes in maize and wheat.

- The project, in the long term, will have great impact outside of Nepal as international and national research systems adopt the methods developed by the project. PPB methods greatly enhance the returns to investment in plant breeding by saving as much as 10 years in bringing a new variety to farmers' fields.

INTRODUCTION

We have assessed the impacts of several research projects carried out in Nepal on participatory crop improvement (PCI) in improved agronomy, and new varieties, crops, and multipurpose trees[†]. Only the outputs pertaining to the adoption of new varieties of rice are considered here because rice is the crop where there has been the highest overall impact from project interventions. However, the impacts of other project outputs are also considerable (see Supplement 1).

In the research on rice in these projects, participatory methods for improving farmers' varietal portfolios were employed — participatory varietal selection (PVS) and participatory plant breeding (PPB) [Annex 1]. PVS tests pre-existing varieties with farmers, while PPB creates new varieties in breeding programmes carried out by plant breeders and farmers working in partnership.

A major limitation of PVS is that a suitable pre-existing variety may not exist. PPB overcomes this limitation by creating new varieties. However, PVS is more rapid than PPB. Nonetheless, PPB is still considerably faster than conventional breeding; varieties reach farmers years earlier than in a conventional system.

Both methods are designed to increase varietal diversity and to give farmers access to new varieties that better meet their needs. The PPB programmes use locally adapted varieties (landraces or introductions) as parents to build on local biodiversity. Farmers' knowledge and skills are incorporated into the breeding process to create a diverse range of varieties suited to local needs.

Institutional impacts of the projects are not reported in detail. These institutional impacts (e.g., the Nepal Department of Agriculture has adopted project-introduced participatory approaches to extension) will be the subject of another report (Stephen Biggs, in preparation). In addition, more efficient breeding methods developed by the project, if more widely applied, will have extremely large benefits but these have not been estimated in this report.

The impact of these projects is examined in detail for Nepal, but their wider impact outside of this country is first considered. For Nepal, the report concentrates on the impact of the germplasm on providing benefits to farmers. Other benefits, such as increased varietal biodiversity are also examined.

[†] Plant Sciences Research Programme (PSP) funded projects in Nepal, the earliest of which commenced in 1997. These projects were executed by LI-BIRD and CAZS in partnership with Department of Agriculture's District Agriculture Development Offices (DADOs), the Nepal Agricultural Research Council (NARC) and several NGOs such as CARE, FORWARD, REGARDS and PLAN.

THE WIDER IMPACTS OUTSIDE OF NEPAL

Wider impacts of these projects are of two types — the spread of the methods to other breeding programmes and the spread of the rice varieties bred in the PPB programme to countries outside of Nepal. The wider impacts of the PTD projects outside of Nepal may well be larger than their impact within Nepal although, overall, they will be more difficult to measure.

The Impact of Methods Outside of Nepal

The PPB methods employed:

- Greatly increase the speed of adoption of varieties (saving at least 7 years) and hence increase the benefits from the research.
- Enhance varietal biodiversity using locally adapted germplasm.
- Greatly enhance the cost-effectiveness of the breeding programme by simple changes in breeding methods, such as testing for grain quality before yield testing.
- Are very cost effective because of the low cross number, high population size breeding strategy employed in the PPB.
- Greatly enhance the efficiency of selection in difficult environments by farmers selecting in bulks in their own fields.

These results from Nepal will be more influential because they are strengthened by results in other DFID-PSP-funded projects in India that confirm the benefits of collaborative breeding.

The importance of early testing for grain quality before yield trials take place is a good example of the project outputs relating to participatory methods. The projects have developed simple methods for the participatory evaluation of organoleptic quality. It is cheaper to discard a variety because it has a poor taste, or poor milling quality than to test it in multilocational yield trials. This simple change can render plant breeding programmes much more efficient (Gyawali *et al*., 2002).

As more results emerge, more papers will be published and more presentations will be made in various fora on this work. Although their influence is difficult to measure, it is probable that many breeding programmes will be favourably influenced by this research, including those of IRRI, WARDA, CIMMYT and NARC.

The Impact of Germplasm Outside of Nepal

Eight PPB varieties[†] have been sent to the DFID bilateral project of the Gramin Vikas Trust (GVT) in India. These varieties were tested in medium upland and medium lowland conditions. Varieties Sugandha 1 and Judi 578 are under further trials.

[†]Sugandha 1, Judi 578, Barkhe 2001, Barkhe 2026, Barkhe 2027, Barkhe 3004, Barkhe 3009, and Barkhe 3010

PPB and PVS varieties have been sent to an NGO in Bangladesh (People's Resources Oriented Voluntary Association, B/220, Kazihata, Rajshahi, Bangladesh) where they have been grown in the main season in the Barind. Several of these varieties performed well in the main season of 2002, and because most are of early duration they will facilitate the growing of a subsequent *rabi* crop. Variety Pant 10, identified by PVS, and variety Judi 582, produced by PPB, are among the best performing varieties.

Rice varieties from the PVS and PPB programmes have been sent to China (Anhui Academy of Agricultural Sciences) where they are undergoing initial multiplication and it is planned to test a range of PPB and PVS varieties with CONCERN in Afghansistan.

Some publications from the Nepal PCI projects

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Joshi, KD, Gyawali, S & Witcombe, JR. 2002. **Participatory scaling up of participatory varietal selection**. *Proceedings of a DFID Plant Sciences Research Programme / IRRI Conference, Breeding Rainfed Rice for Drought-prone environments Integrating Conventional and Participatory Plant Breeding in South and Southeast Asia*, 12-15 March 2002, IRRI, Los Baños, Laguna, Philippines. CAZS, University of Wales, Bangor.

Joshi, KD, Sthapit, BR, Subedi, M and Witcombe, JR. 2002. **Participatory plant breeding in rice in Nepal**. In: *Farmers, Scientists and Plant Breeding: Integrating Knowledge and Practice*, David A Cleveland & Daniela Soleri (Eds), CABI, Wallingford, UK 10:239-267.

Sthapit, B, Bajracharya, J, Subedi, A, Joshi, K, Rana, R, Khatiwada, S, Gyawali, S, Chaudhary, P, Tiwari, PL, Rijal, D, Shrestha, K, Baniya, B, Mudwari, A, Upadhaya, M, Gauchan, D and Jarvis, D. 2002. **Enhancing on-farm conservation of traditional rice varieties in situ through participatory plant breeding in three contrasting sites from Nepal**. *Proceedings of a DFID Plant Sciences Research Programme / IRRI Conference, Breeding Rainfed Rice for Drought-prone environments Integrating Conventional and Participatory Plant Breeding in South and Southeast Asia*, 12-15 March 2002, IRRI, Los Baños, Laguna, Philippines. CAZS, University of Wales, Bangor.

Poudel, D, Chaudary, P, Chowin, KR & Ghimere, H. **Case studies of seed production and marketing through farmers' groups in Nepal**. CAZS Discussion Papers No 4. CAZS, University of Wales.

Joshi, KD & Witcombe, JR. 2001. **Participatory varietal selection, food security and varietal diversity in a high potential production system in Nepal**, 267-274. *An exchange of experiences from South and South East Asia: proceedings of the international symposium on participatory plant breeding and participatory plant genetic resource enhancement*, Pokhara, Nepal, 1-5 May 2000. SWPGRA, CIAT, Cali, Colombia.

Witcombe, J.R., Joshi, K.D., Rana, R.B. & Virk, D.S. 2001. **Increasing genetic diversity by participatory varietal selection in high potential production systems in Nepal and India**. *Euphytica* 122: 575-588.

Witcombe, J.R., Subedi, M. & Joshi, K.D. 2001. **Towards a practical participatory plant breeding strategy in predominantly self- pollinated crops**, 243-248. *An exchange of experiences from South and South East Asia: proceedings of the international symposium on participatory plant breeding and participatory plant genetic resource enhancement*, Pokhara, Nepal, 1-5 May 2000. SWPGRA, CIAT, Cali, Colombia.

Witcombe, J.R. & Virk, D.S. 2001. **Number of crosses and population size for participatory and classical plant breeding**. *Euphytica* 122:451-462.

Witcombe. J.R. 2000. **The Impact of decentralized participatory plant breeding on the genetic base of crops**. In: *Broadening the Genetic Base of Crop Production* Cooper et al., (Eds) CABI, Wallingford, UK 26:407-417.

NEPAL

Introduction

We now examine the impact of these projects in Nepal. The projects operate in the most important rice growing region of Nepal - the Terai. The area of rice in the Terai as a whole, of about 1.1 to 1.2 million ha, is about 75% of the total 1.5 million ha rice area of Nepal. Rice is the most important crop to the livelihoods of farmers in the Terai. They grow it in two seasons, the early or *Chaite* season and the main or *Barkhe* season. The area under *Chaite* rice (110,000 ha) is about one tenth of the main season area.

First we look at the socio-economic situation regarding rice improvement in the Terai, and then we examine the impact of the PPB programme. The outputs are described and then the impacts are described from surveys, interviews and a financial analysis.

Livelihoods and poverty in the Terai

Given the great importance of rice in the Terai, will increases in productivity benefit the poor? We examine how many poor people live in the Terai and the extent to which they depend on rice for their livelihoods.

Human development in the Terai

The UN has compiled a poverty and deprivation index for all of the districts of Nepal (Supplement 3). The average index for Nepal and for the Terai as a whole is 0.47 (on a scale of 0 for least developed to 1 for most developed). This overall average development in the Terai is only because a few districts are highly developed (Fig. 1). Of the 20 Terai districts, 14 are average, or below average, in development. Rautahat, the poorest district in the Terai has a population of over 500,000 and is the fourth poorest district in Nepal. Several population groups in the Terai, including the Tharus and Musahars, have been disadvantaged for generations and remain so. Moreover, the improvement in the human development index from 1996 to 2000 in the Terai as a whole (12.1%) was lower than in the hills (17.5%).

For the two project districts, one is below average (Nawalparasi) and the other (Chitwan) is better off.

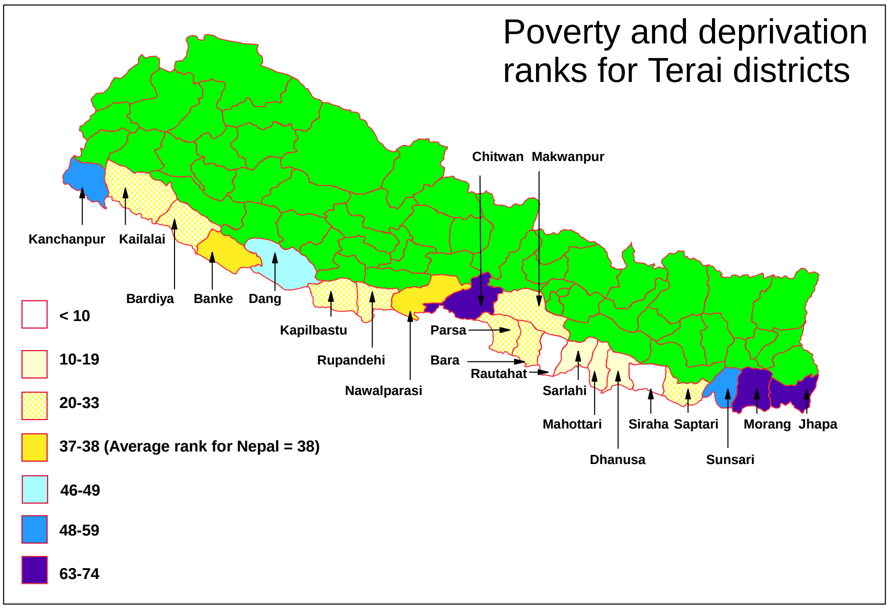

***Figure 1*. Poverty and deprivation index ranks (1 = least developed district, 75 = most developed district) for the Terai districts, 2001.**

Food self sufficiency

The UN does not provide data on food self sufficiency but project baseline data were obtained for households in eight villages in Chitwan and Nawalparasi. Despite the relatively high degree of development in these two districts, the majority of farmers in the 8 studied villages were food deficit (Fig. 2).

From interviews with key participants, the landholding of food-deficit farmers is very low, and is usually characterised as less than 0.5 ha (Supplement 4). Food balance farmers have about 1 ha of land, but this varies from village to village depending on the productivity (largely determined by the availability of irrigation water) of the village rice fields.

The key informants commonly mentioned the importance of off-farm income as a determinant of the wealth ranking of households. Nonetheless, rice production is important to people’s livelihoods and increased production provides more opportunities for earning income from labour since harvesting and threshing are predominantly manual operations in the Terai.

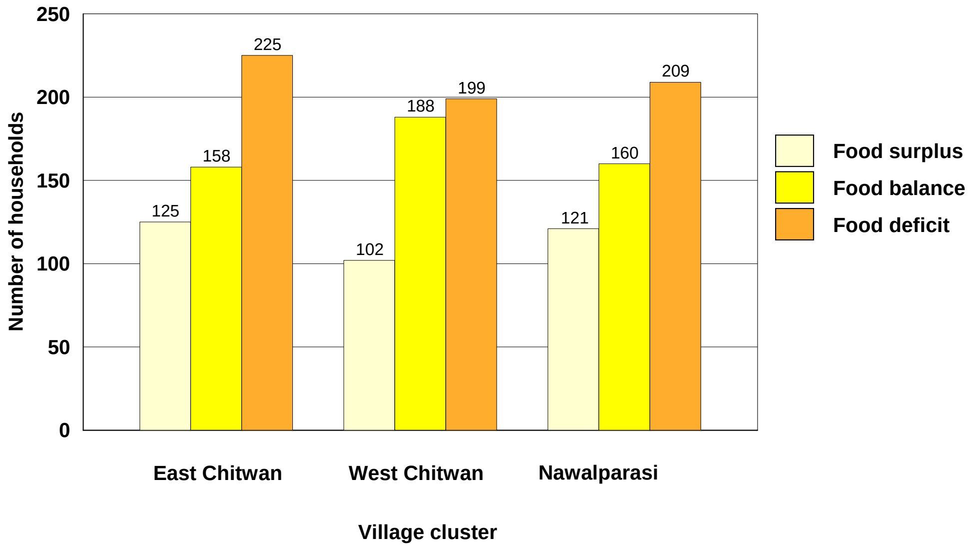

Figure 2. **Distribution of households according to whether they are food-deficit, food balance, or food surplus. Two villages from east Chitwan cluster, 3 villages from west Chitwan cluster, and 3 villages from Nawalparasi cluster.**

Less favourable environments for rice cultivation

Although the projects were initially designed to test PTD in high-potential production systems much of the project area is less favourable for agriculture. Rice is grown under rainfed conditions or with only limited quantities of irrigation water. It is estimated that about 70% of the main-season rice in the Terai is grown under rainfed and limited irrigation water conditions (Fig. 3 and Supplement 2).

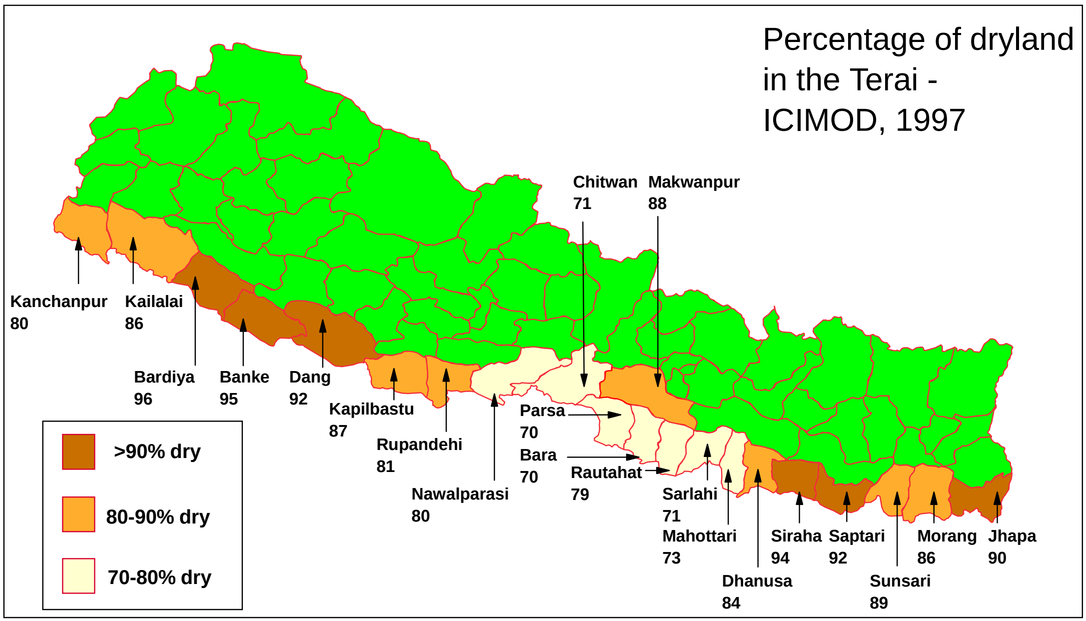

Figure 3. **Percentage of land that is without perennial irrigation according to ICIMOD, 1997.**

Constraints

Farmers grow few and old varieties

Participatory surveys, in the project villages of Chitwan and Nawalparasi, revealed that farmers were growing old varieties in both rice-growing seasons, sometimes as much as 40 years old (Witcombe *et al.*, 2001). The varietal diversity was often extremely low with the most popular variety occupying the majority - sometimes over 90% - of the area (Fig. 4).

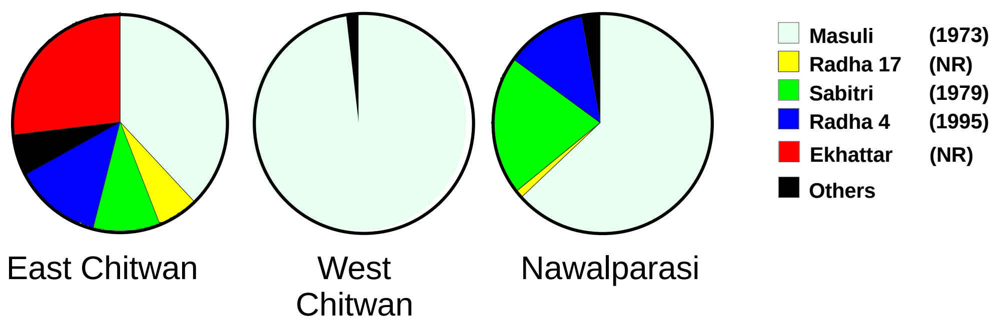

Figure 4. **Area under main-season rice varieties in three village clusters of East Chitwan, West Chitwan and Nawalparasi, 1997. (Year of release of variety in parentheses; NR = not released).**

The National Programme has released relatively few varieties for the Terai (Supplement 5) particularly in view of its importance in area, and the rate of release for the Terai has declined in recent years. Moreover, a minority of the varieties that have been released have been popular with farmers. Instead, many of the most popular varieties, such as Sarju 52 in the west of the country, are farmers' introductions, most of which are from India. Others are varieties from the Nepalese research system that have not been officially released, such as Kanchhi Masuli[†], in the east of the country, and Ekhattar and Radha 17. Sarju 52 and Kanchhi Masuli are two of the most popular varieties in the Terai and have spread entirely from farmer-to-farmer, without official support.

[†]Kanchi Masuli was originally from India and also known by Nepalese farmers as Jhapali Masuli, Aus Masuli, Banspate, and Bans dhan. Ekhattar and Radha 17 were tested for several years by NARC in yield trials and in farmers' fields while Kanchhi Masuli was tested in yield trials. None of them were released.

PROJECT OUTPUTS

Varietal choice has now increased

One of the main achievements of the PTD projects in Nepal has been the identification of an increasing number of rice varieties (Fig. 5), from both PVS and PPB, that farmers wish to adopt. More recently, these new varieties are mostly the products from the PPB programme (Annex 2).

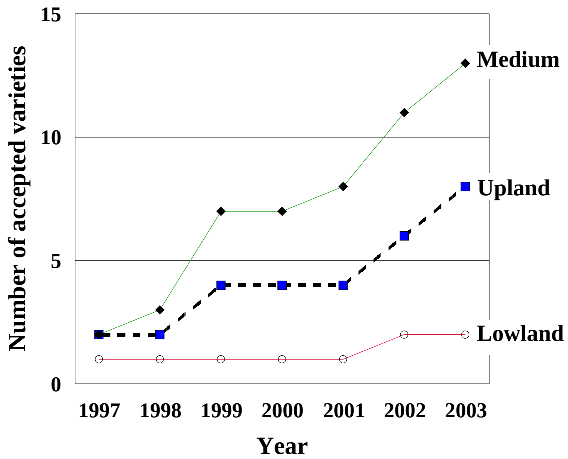

Figure 5. **Increase in available varietal choice for the main season from the project activities for farmers in the Nepal Terai. The increase in available diversity will be higher still in 2004.**

Over 15 varieties (Annex 2 and Supplement 8) suited to medium upland and upland conditions in the main season - the majority of the area in the Terai – have been identified. According to PRAs in the project area, having less productive fields is one of the indicators of a lower wealth rank. Hence, generally, it is the resource-poor farmers of the Terai that farm the uplands. Wealthier farmers have more productive land with permanent irrigation. Such land is more expensive (about twice the cost per area).

Scaling up the project outputs

After the PVS and PPB has identified or created new varieties, these are widely disseminated in activities termed by the project as ‘scaling up’. The time at which scaling up commenced has varied by district (Fig. 6, Supplement 6) and was earliest in the project districts of Chitwan and Nawalparasi.

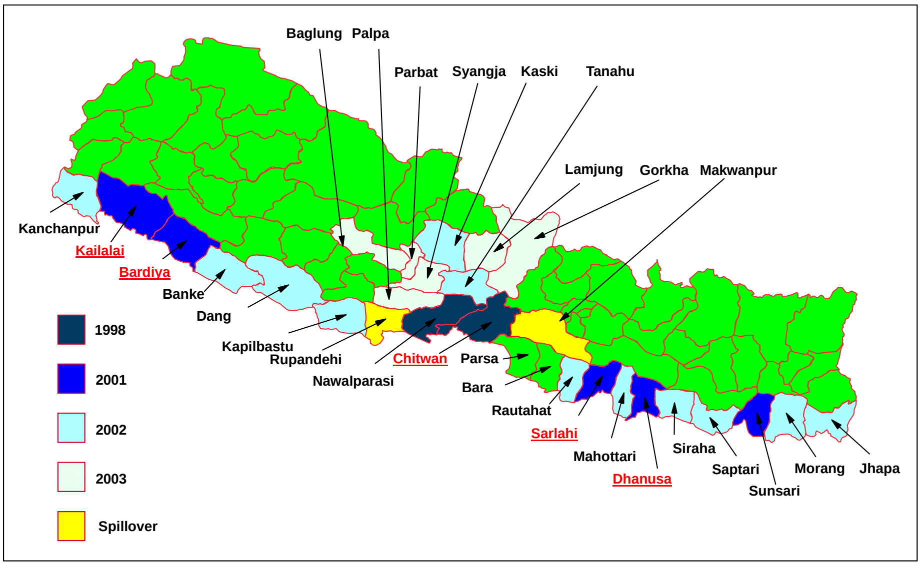

Figure 6. **Year of first scaling up activities by district, 1998-2003. Districts underlined denote that there was a letter of agreement between LI-BIRD and the Department of Agriculture in that district.**

The institutional impacts from this scaling up in Nepal have also been considerable. The Department of Agricultural has now adopted project-introduced participatory methods (i.e., Mother and Baby trials reported in Annex 1) as a means of extension and, under a Memorandum of Understanding with LI-BIRD, NARC is an active partner in the PPB programme. Institutional impacts are not restricted to rice, but have influenced programmes in maize and wheat. These institutional impacts are being considered in more detail in another report (Stephen Biggs, in preparation).

IMPACT - FARMERS' VOICES

A Case Study for Swarna Rice

Agauli village, Nawalparasi, 2002

I have been growing this variety for the last three years, and my estimation is that Swarna yields one and a half times as much as Masuli.

Masuli has to be harvested while the fields are still wet and this is very inconvenient. Swarna matures when the fields are dry and this makes harvesting much easier.

Swarna has spread in this village from 15 kg of seed [from LI-BIRD]. I got this seed from another farmer who got the seed from LI-BIRD

More or less every household in this village grows Swarna and it covers about 75% of the entire rice area of our village.

Although Masuli has a higher price than Swarna, because the yield of Swarna is higher the returns are more. It is difficult to distinguish the milled rice of Masuli and Swarna. If some miller mixes the rice [of Masuli and Swarna] and mills them together then nobody can detect the difference.

Masuli has more disease than Swarna.

Kamali and Arjun Kumar Shrestha of Agauli Village Development Committee (VDC), Sherganj village, Nawalparasi explained that they only own about one fifth of a hectare (7 *Kattha* in local units) of low-lying land where they used to grow variety Masuli. It never produced more than 0.75 t in that land - just enough to sustain the six members of their family for about six months. They heard about Swarna three years ago and first tried it in a small plot. Kamala says that, to her surprise, it did extremely well even when the field had standing water where Masuli generally does very poorly. They decided the next year to plant the entire plot to the new variety and it yielded nearly double that of Masuli (1.3 t). The household, along with the harvest from their early-season rice, had more than enough grain. They sold nearly 500 kg of Swarna and bought corrugated iron sheets for their cow shed.

In discussions with the Shrestha couple it was learnt that Swarna is now contributing to the food needs of about half of the farmers in Sherganj village.

Tek Kumari Thanet, Sherganj, also owns 7 *Kattha* of land. Like most other farmers she also grew Masuli in the past. She has been growing Swarna for the last two years. She never had enough rice to feed her family but now, because of the higher yield of Swarna, she no longer has to buy rice.

Pitmaber Chaudhary of Agauli is a food deficit farmer with only 4.5 *Kattha* of land. Masuli rice harvested in late November only lasted until about February. "*Once we started growing Swarna, we could meet all our family needs from our own harvest and do not have to buy rice*".

Sarswati and Sita Thanet of Bamnauli, Abhiyun**:** These two women live in a joint family of 15 members. They have a landholding of over 2 ha and produce surplus grain. They have been growing Swarna for the last five years. It started with a PVS trial in 1999, and now Swarna covers nearly 55% of their lowland. Although they have diverse sources of income (sale of vegetables, income from rice mill, tractor and salary from the Nepal Army) they consider that rice contributes nearly 75% of the family income. All the day-to-day family expenses, including hired labour and inputs for the farm, are met through the income from selling rice. They reckon that yield of Swarna is nearly one and a half times more than that of Masuli and that their rice sales have increased from 4 t to 6 t because of Swarna. The increased income has particularly contributed to paying for the education of children and for health care.

Dhan Kumari and Om Narayan Mahato of Agauli produces sufficient rice to feed their family. Apart from Swarna, this family has been growing a number of new rice varieties introduced in the PVS programme such as Pant Dhan 10, BG 1442 and Barkhe 1027. Before these new varieties they were growing Sabitri, which they abandoned because it was highly susceptible to zinc deficiency, difficult to thresh, and prone to pest damage. They have been growing Swarna for the last four years, one year while they were still in a joint family and three years after they became independent from it, and clearly see that Swarna yields more than Sabitri. Their net income from the new variety, this year, was at least Rs. 10,000. From the additional income from the increased sale of rice in the last three years they have paid off about Rs. 9000 of a loan. This year they spent nearly Rs. 11,000 to put corrugated iron roofing on their house and invested some money in establishing their small banana orchard. They say that their family needs have increased due to the schooling of the children and for investments in vegetable and banana farming but now they do not see any problem to meet them. "*With Sabitri, I was just meeting my family needs and it would have not been possible without Swarna to repay the loan, go for improved roofing or pay the fees of my kids!*"

Sun Maya Mahato of Agauli. She owns about 1.3 ha land and has grown Swarna for the last four years. This year the variety occupies nearly 80% of her rice area. She reckons that Swarna yields nearly 1.5 to two times more than Masuli, the variety she grew before.

"*We had to buy two new Bhakari*[1] *to store extra grain from Swarna while in the past we never bought extra Bhakari. We never sold rice while growing Masuli, as it was just enough to meet the family needs. But Swarna gave us much more cash. We repaid a Rs. 50,000 loan from the additional income from Swarna. This year, we had to spend nearly Rs. 30,000 for the maternity care for my daughter-in-law, which also came from the sale of Swarna. Had the cash not been with us, we had to sell out part of our land or borrow money at a very high interest rate. We do not have any other significant sources of income. Though, we have two fishponds, we hardly earn about Rs. 2000 from the sale of fish*".

[1] *Bhakari* is a local storage structure used for storing food grains, which may be an earthen pot or made of bamboo or wood.

IMPACT - ADOPTION AND BIODIVERSITY IN THE PROJECT DISTRICTS

Adoption in Chitwan and Nawalparasi

In Chitwan and Nawalparasi adoption of project-identified and project-bred varieties is high. Overall, across the two districts adoption of project varieties reached an estimated 13% of the total rice area in 2001 and as much as 17% in 2002[†].

As an example, the adopting households, area of adoption and benefits to farmers[‡] are given for Chitwan alone (Fig. 7).

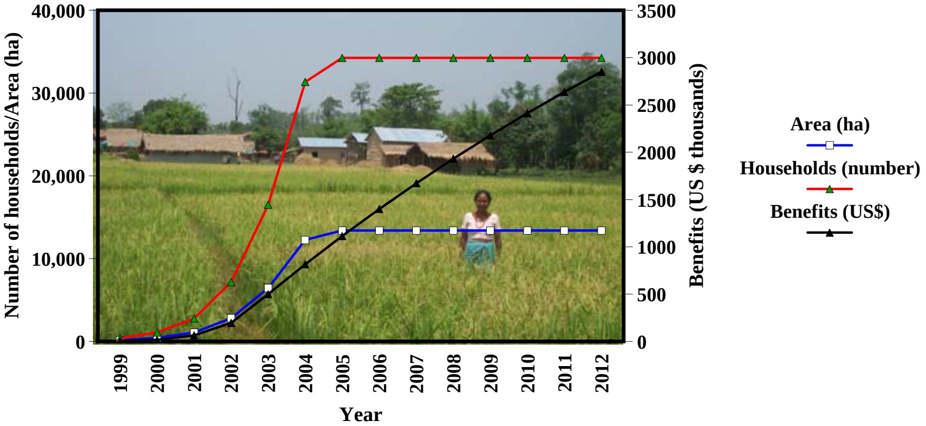

Figure 7. **The area (ha) under new rice varieties in Chitwan over time and the estimated number of households that will be growing them (assuming a maximum adoption of 40%) and the total benefits accrued to farmers (using a 5% discount rate). The woman farmer from Chitwan is standing in a field of a project variety, Barkhe 2001, that she has adopted.**

Varietal diversity

The introduction of new varieties contributed to a great increase in on-farm varietal diversity measured as varietal richness (number of varieties) in each village (Fig. 8). Varietal richness continued to increase over years. The greatest diversity was found in villages where there was higher diversity in rice growing conditions.

More varieties were found in project villages than in villages proximal to project villages or in the control villages. The increase in the number of varieties in the project villages was due to the introduction of promising PPB varieties.

Impacts on varietal diversity can easily be seen at a village level (Fig. 9).

† From a survey of over 3000 households in Chitwan and Nawalparasi.
‡ For details of this analysis see the full financial analysis below.

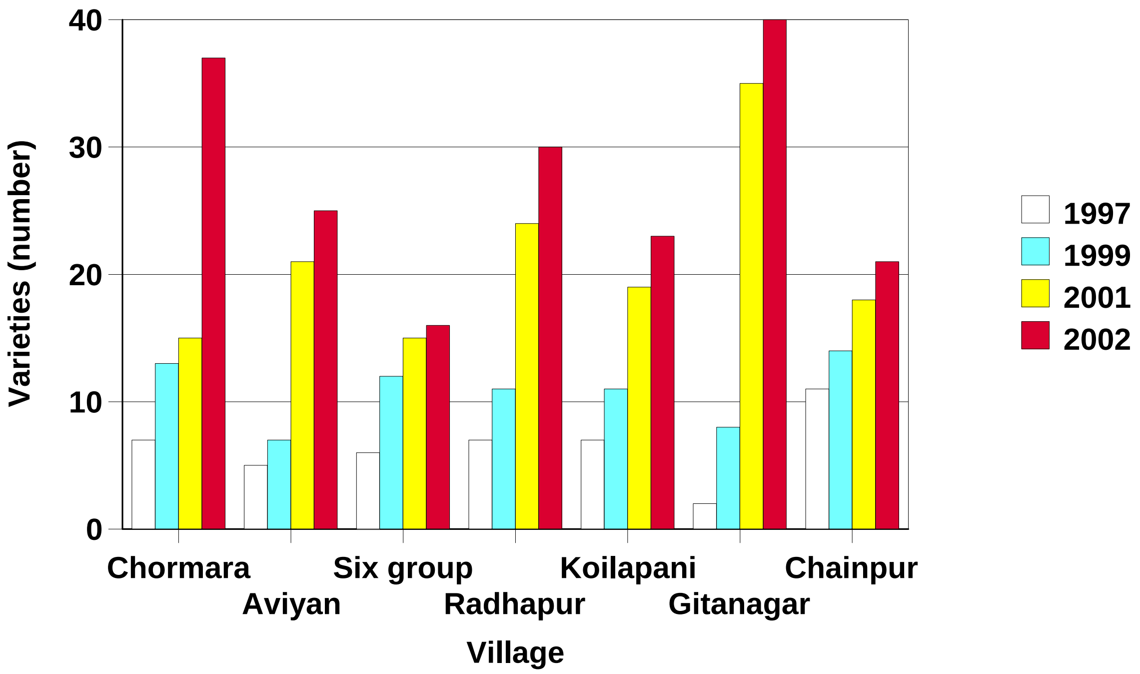

Figure 8. **Varietal diversity in rice before and after the project interventions across all project villages, 1997 to 2002.**

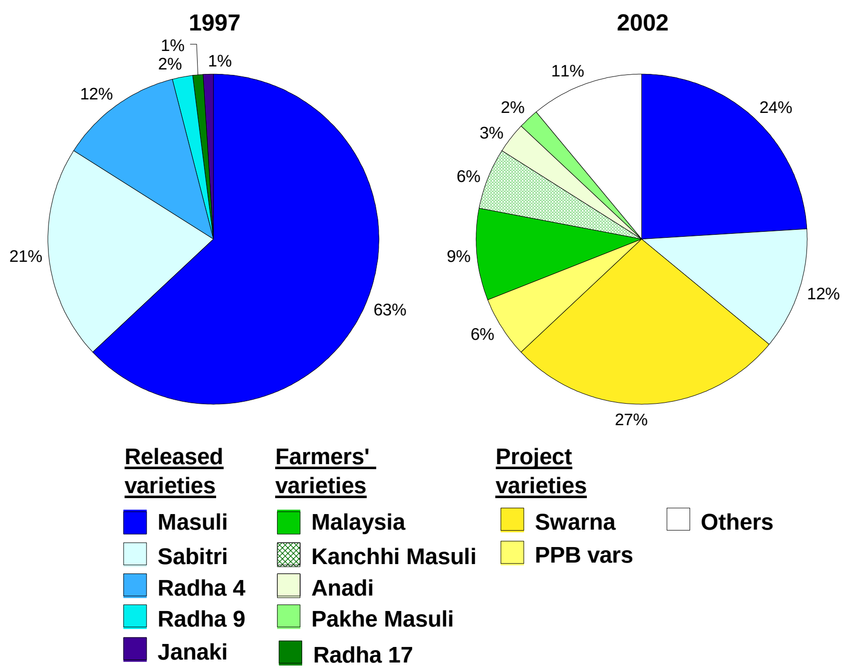

Figure 9. **An example of adoption of project varieties. Changes in varietal adoption in Nawalparasi village cluster (sample of 1637 households) from the baseline survey (1997) to the 2002 main season. By 2002, the adoption of project varieties is 33% of the total rice area in the village cluster.**

IMPACT - FINANCIAL BENEFITS

Three scenarios for estimating financial benefits of the new varieties in Nepal

Three scenarios have been examined to estimate the net present value of the new varieties identified or bred by the PTD projects in Nepal (Table 1).

All of the assumptions are supported by survey or trial data. The 2002 survey data of LI-BIRD and DADO, Chitwan, show that in many villages adoption of project varieties in Chitwan is above 40% and that adoption in the district as a whole is already in excess of 10%. Rates of spread have been measured from farmer-to-farmer for several varieties and vary, according to their popularity, from 1.5-fold to over 20-fold per annum. Recently, PPB varieties have increased on average in Chitwan (from main season 2001 to the main season of 2002) at a rate of over five-fold.

The areas of adoption were calculated for groups of districts according to the first year of project intervention. The NPVs were calculated on the total adoption across all districts.

Table 1. The three sets of assumptions employed in the financial analysis.

	Scenario		
Assumption	**Conservative**	**Realistic**	**Higher**
Spread from farmer-to-farmer per year (multiple)	2	2.5	3
Adoption ceiling (% of total rice area)	20	40	50
Benefit (£ ha^{-1})	24	33	42
Seed supplied per district†	5	7	9
Years seed supplied after first intervention	3	5	7

† As the number of ha of rice that can be transplanted from the project-supplied seed

Costs

The same cost assumptions have been assumed in all of the scenarios and are the marginal costs of undertaking the PVS and PPB programmes of LI-BIRD/CAZS.

It is assumed that the costs of NARC and DADO are part of their existing budgets and activities (rice breeding for NARC and extension for DADOs) and these funds would be spent in the absence of the project. The costs of the PVS/PPB programme are assumed to be £100,000 a year and incurred in every year for which a benefit has been calculated.

The DFID PSP-funded projects in Nepal, 1997-2005.

DFID number	Project title	Project duration	Total costs (£ '000)
R6748	PCI in high potential production systems in India and Nepal	1997-1999	£119
R7542	PCI in high potential production systems – piloting sustainable adoption of new technologies	2000-2003	£178
R7122	PPB in high potential production systems	1998-2000	£ 44
R8071	PPB in high potential production systems – an evaluation of products and methods	2001-2005	£170

As the surveys on adoption continue over the years, these estimates will be revised. The data available for adoption in 2002 are above the realistic scenario, and the amounts of project-supplied seed in 2003 were also above that of the realistic scenario.

The data for these analyses are shown in Supplement 7, and a detailed consideration of the realism of these assumptions is presented in Annex 3.

The total benefits at a 5% discount rate are substantial in all three scenarios (Fig. 8). The net present values (NPV) range from £2 to £29 million by 2010, and £4 million to £52 million by 2012. Even by 2005, the end of the current DFID RNR strategy plan, all scenarios show a positive return, with the higher scenario giving an NPV of more than £3 million. The internal rates of returns vary in 2012 from 43% to 126%. Hence the returns on this agricultural research are high, and at least as good as those for other development activities.

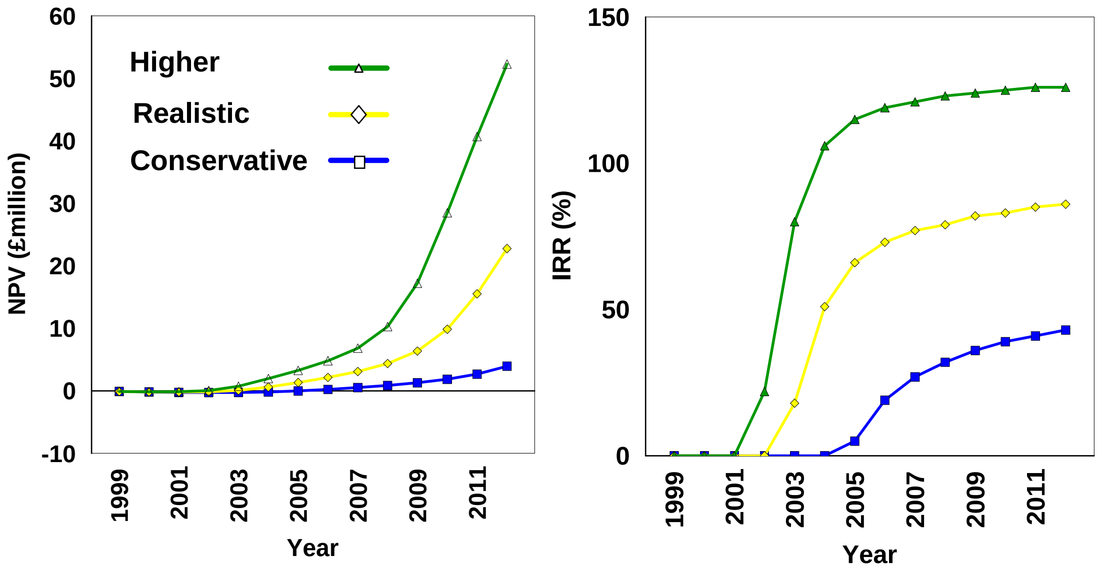

***Figure 10.* The NPV and IRR over time with the 'conservative', 'realistic' and 'higher' scenarios.**

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Annex 1. PPB and PVS

A brief introduction to participatory varietal selection and participatory plant breeding

Two methods of getting improved germplasm to farmers

Many farmers grow old varieties or landraces, and hence fail to benefit from the most modern products of plant breeding. One of the main reasons for low cultivar replacement rates is that farmers have inadequate exposure to new cultivars. One way of increasing the speed of adoption of new varieties is for farmers to be given a wide range of novel cultivars to test for themselves in their own fields. The method we use is termed participatory varietal selection (PVS). A successful participatory varietal selection programme has four phases:

1. Participatory evaluation to identify farmers' needs in a cultivar;
2. A search for suitable material to test with farmers;
3. Experimentation on its acceptability in farmers' fields;
4. Wider dissemination of farmer-preferred cultivars.

The cultivars are selected carefully. To save time and ensure availability of seed we have used already-released cultivars, not only from the target region, but also from other regions or countries. The varieties are then tested with farmers in a Mother and Baby trials system. A few Mother trials are conducted in farmers' fields that have all of the new varieties. There are many more Baby trials in which all the varieties are again tested. However, any individual farmer only tests one variety by comparing its performance to the local variety in his or her fields.

However, PVS is limited to employing the existing variation among cultivars, and sometimes well-accepted cultivars cannot be found. Participatory plant breeding (PPB), in which farmers select from segregating material, is a logical extension of PVS and is desirable when the possibilities of PVS have been exhausted. In our PPB programmes we exploit the results of PVS by using identified cultivars as parents of crosses. Weaknesses in cultivars are identified in the PVS programme and they can be crossed with varieties that have complementary traits to eliminate those weaknesses. For example, one can cross a high-yielding but low-grain-quality variety with one with superior grain characteristics.

What we have found is that PVS and PPB get to be used in combination. We start with PVS and that helps to identify parents, then we carry out PPB. As soon as there are products from this PPB, we test them in PVS trials. This can be a continuous process because new varieties, whether introduced or from PPB, are always becoming available that can be tested by PVS.

PVS does not just identify better varieties

One of the great strengths of PVS is that it is an extension method as well as a research method. For example, PVS trials resulted in a dramatic spread of new varieties (Fig. 1.1). The rates of increase from one *Chaite* season to the next are 18 to 30 fold increases in the size of the harvest with similar increases in the area sown.

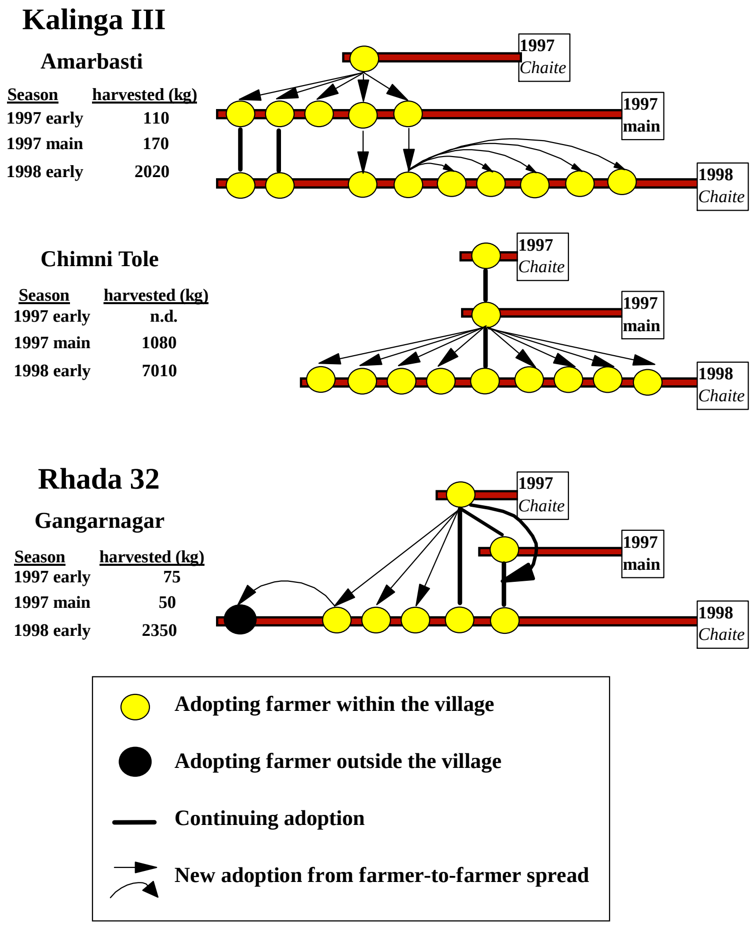

Figure 1.1. **Spread of seed of rice varieties Kalinga III and Radha 32 from farmer to farmer from one original farmer each in Amarbasti and Gangarnagar, west Chitwan; Chimni Tole, east Chitwan**

Notes: In the case of Amarbasti, two farmers, after the main season 1997, dropped the variety but passed it on to another farmer. Curved arrows in 1998 indicate spread in the same year, by distribution of seedlings. Curved arrow in Ganganagar indicates a continuing adopter grew the second crop by obtaining seed a second time.

An example of PPB methods

We have adapted PPB methods to take advantage of the strengths of breeders and farmers. The breeders produce material that is genetically homozygous but highly heterogeneous by advancing the bulk populations[†] from the F_2 to the F_5 generations with minimal selection (Fig. 1.2). This means that we give bulks to farmers at a quite advanced generation when it is expected that there will be a good response to selection between plants[‡], and when segregation in the next generation is no longer a major complicating factor[‡].

A key element of PPB is the *collaborative* participation of farmers who grow a bulk on their own fields and select amongst it. Using this collaborative breeding, it is possible to replicate selection cost-effectively by giving seed of a particular bulk to many farmers. The selection is thus replicated across physical environments (different farmers' fields) and across farmers (who may have different selection strategies and select for different traits that best meet their needs).

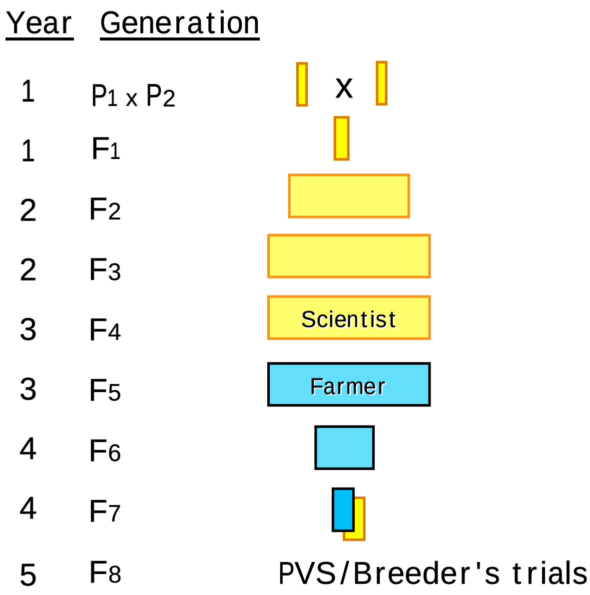

Figure 1.2 **A schematic diagram of a PPB programme. Breeders control the process until the F_4 generation, then farmers collaborate from the F_5 generation onward. Breeders include selected bulks in formal trials from the F_8 generation. It is assumed that two crops of rice are grown per year**

Giving farmers bulks to grow on their own fields is an effective strategy. Farmers are willing to select in the bulks over several generations and produce their own variety that can be phenotypically very uniform (Figs. 1.3 and 1.4).

[†] A bulk population is derived from many F_2 generation plants so that the bulk represents much of the variability generated by the cross. We often create a bulk by starting with seed from as many as 20,000 F_2 plants. Each subsequent generation is derived from many parental plants.

[‡] This is because, by the F_5, the genetic differences between plants are high (i.e. there is a high between-plant heritability). Also, because the individual plants are nearly homozygous (93.75%) all the progeny of an individual plant will tend to be alike and resemble the parent.

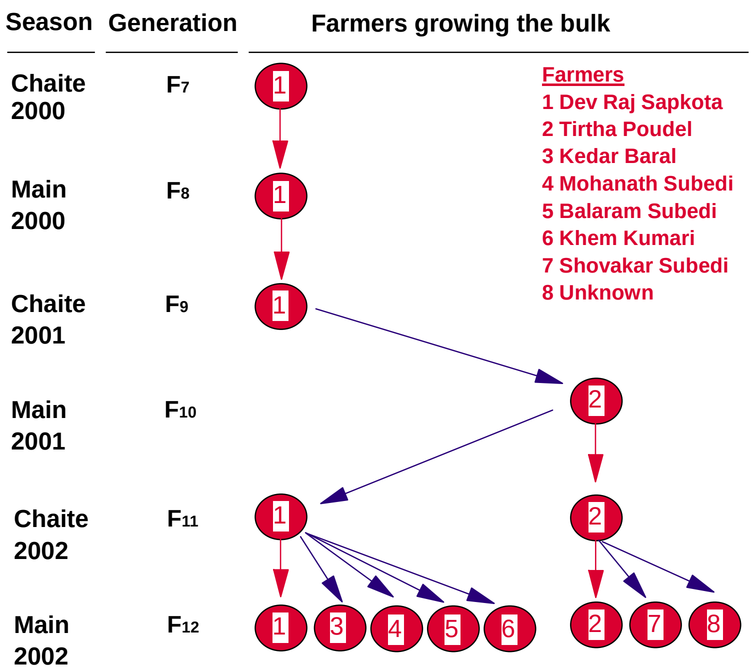

Figure 1.3. **An example of collaborative plant breeding where a farmer has grown a bulk for several years to produce variety Judi 141F. The bulk has been distributed to seven additional farmers. Red arrows continuing adoption, blue arrows farmer-to-farmer spread.**

***Figure 1.4*. Farmer Dev Raj Sapkota in the main season of 2000 with CH45 (left) and the PPB bulk from which Judi 141F was derived (right)**

One great advantage of PPB is that it is much faster than conventional breeding (Fig.1.5). The economic value of this reduction in time can be very large. Pandey and Rajatasereekul (1999) showed that the economic benefit of completing a breeding cycle only two years earlier was $18 million over the useful life of a rice variety in 5 million ha in northeast Thailand. They concluded that efforts to reduce the breeding cycle by two years can have a handsome payoff, and that the economic losses associated with a delay in official release were high. For example, a three-year delay in the official release of varieties, assuming it normally takes 13 years to complete, reduces economic benefit by about 25%.

	Ashoka 200F (PPB)	BD 101 (Conventional)
Years from cross to completing one year of testing	4 years 1996 to 1999	7 years 1975 to 1981
Years from cross to farmers	4 years From 1999 (the same year it was entered in trials)	14 years From 1988 (three years after its release in 1985)
Yield gain (%) over check	20% over Kalinga III in 6 research trials (1999 to 2001)	18.5% over Birsa Gora in 4 research trials (1981 to 1984)
Gain per year	5.0%	2.6%

***Figure 1.5*. A comparison of the breeding of rice cultivar Ashoka 228 by participatory methods and the conventional breeding of rice cultivar BD 101.**

Annex 2. Summary of promising PPB varieties

Table 1. Increasing availability of varietal choice for the Terai**. Farmer-accepted varieties for the *Chaite* season, 1997 to 2004.**

Variety†	Source (method, country)	Pedigree of PPB varieties	First year tested	First year with > 500 kg seed	Situation
BG 1442[1,2]	PVS, Nepal		1998	1999	MU, ML
Kalinga III	*PVS, India*		*1997*	*1998*	*U*
NDR 97	*PVS, Nepal*		*1997*	*1998*	*ML*
Judi 141F	PPB	KIII/IR64	2002	2003	U
Judi 503	PPB	KIII/IR64	2002	2005	ML
Judi 547	PPB	KIII/IR64	2002	2005	ML
Judi 572	PPB	R32/KIII	2003	2004	ML

† Less popular, niche varieties, in italics
1 Also suitable for upland main-season conditions
2 NARC identified variety originally from Sri Lanka released as Hardinath 1 in 2004 in response to LI-BIRD PVS programme results.

Table 2. Increasing availability of varietal choice for the Terai. Farmer-accepted varieties for the main season, 1997 to 2005. Varieties underlined and in bold were recommended in a National Workshop in July 2004 along with Judi 566.

Variety†	Source (method, country)	Pedigree of PPB varieties	First year tested	First year with > 500kg seed	Situation
Pant Dhan 10	PVS, India[1]		1997	1997	U, MU, ML
PNR 381	PVS, India[1]		1997	1997	U, MU, ML
Swarna	PVS, India[1]		1997	1997	L
Rampur Masuli	PVS, Nepal[2]		1997	1998	MU, ML
BG1442	PVS, Nepal[3]		1998	1999	U, MU, ML
Sarwati	PVS, India[1]		1998	1999	U, MU
Ekhattar	*PVS, Nepal[4]*		*1998*	*1999*	*MU*
Radha 82	PVS, Nepal[5]		1998	1999	MU, ML
IAASR32	*PVS, Nepal[6]*		*2000*	*2001*	*ML*
IAASR16	*PVS, Nepal[6]*		*2001*	*2002*	*MU, ML*
<u>Sugandha 1</u>	PPB	IPB	2001	2002	U
<u>Barkhe 1027</u>	PPB	KIII/IR64	2001	2002	U, MU (drier west)
<u>Barkhe 2001</u>	PPB	IPB	2001	2003	MU, ML
<u>Barkhe 3004</u>	PPB	KIII/IR64	2001	2002	MU, ML, L
Barkhe 2014	PPB	KIII/IR64	2002	2003	MU, ML
<u>Judi 572</u>	PPB	R32/KIII	2002	2003	U (main and bhadaiya)
Judi 567	PPB	R32/KIII	2003	2004	Barind, Bangladesh
Judi 582	PPB	R32/KIII	2003	2004	Barind, Bangladesh
Barkhe 1006	PPB	IPB	2003	2005	U, MU
Sugandha 2002	PPB	IPB	2003	2004	MU
Barkhe 2024	PPB	KIII/IR64	2003	2005	MU, ML
Pipeline varieties					
Barkhe 3015	PPB	Masuli/MT4	2004	2005	ML, L
Barkhe 1019M	PPB	KIII/IR64	2004	2005	U, MU
Barkhe 2045	PPB	Masuli/MT4	2004	2005	MU, ML
Barkhe 3017[7]	PPB	Masuli/Laxmi	2004	2005	ML, L

† Less popular, niche varieties, in italics
1 Indian varieties introduced by LI-BIRD
2 NARC variety released in 1999
3 NARC-identified but non-released variety originally from Sri Lanka
4 NARC-identified but non-released variety from IRRI.
5 NARC-identified but non-released variety from India
6 These are from IAAS, not from NARC, the source of all other Nepalese varieties in PVS
7. Bred initially by IAAS and tested by LI-BIRD.

Annex 3. Assumptions Used

ASSUMPTIONS ON VARIETAL SPREAD IN NEPAL

Example of farmer-to-farmer spread in *Chaite* rice

In the PVS, farmers test varieties on their own fields and preferred varieties start to spread rapidly from farmer to farmer from farm-saved seed. Activities began in Chitwan in the *Chaite* season of 1997 and DTZ Pieda Consulting, Edinburgh, conducted an impact assessment on *Chaite* rice. They found that by the 1999 *Chaite* season there were 35 ha of rice under project-introduced varieties. By 2002 this impact had greatly increased with 1200 ha under one project-introduced *Chaite* rice variety (BG 1442), and 50 ha under other project varieties[†]. This is more than a <u>trebling of area each year</u> in each of the three seasons following 1999.

Studies in Chitwan showed the rapid spread of rice varieties by farmer-to-farmer spread. By this mechanism, rice variety Kalinga III, introduced from India, increased nearly 9 fold in area from the 1997 main season to the 1998 *Chaite* season (see Annex 2). Variety NDR 97, a non-released national programme variety, <u>increased over 30 fold</u> from *Chaite* 1997 to *Chaite* 1998 (see Annex 2). Hence, particular varieties in particular cultivations can spread extremely rapidly.

More recent studies quantified the spread in Chitwan from 2001 to 2002. In these extensive surveys varieties spread at a rate of 1.5 fold to over 20 fold for varieties liked by farmers that are in an early stage of adoption. PPB varieties spread at a rate of over 5 fold from 2001 to 2002.

Examples of farmer-to-farmer spread in main-season rice

In 2001, DADO, Kailali, distributed a total of 300 kg of seed of eight project bred or identified, main-season varieties. By 2002, a survey by DADO showed that a total of about 1.4 t of seed of these eight varieties was seeded in nurseries for the 2002 main season, which is sufficient for transplanting into 28 ha. This represents <u>an increase of over four fold in a single season</u>.

This is a higher rate of spread of main season varieties than was found in the initial years, 1997 and 1998, in Chitwan when only two main-season varieties (Pant Dhan 10 and Swarna) had been identified. Both of these varieties are adapted to specific niches. Pant Dhan 10 is an early variety adopted by vegetable growers - the early harvest allows earlier sowing of vegetables - whereas Swarna is adapted to long-standing water conditions.

[†] Provisional survey data by LI-BIRD and DADO Chitwan

Assumptions made on spread

The two examples above, for BG 1442 in *Chaite* rice in Chitwan and main-season rice in Kailali district, gave an observed rate of spread of over a trebling each year. On the basis of all these examples, we have used the somewhat lower estimates for our scenarios that the project rice varieties increase at rates of a maximum of a trebling in any one year. Whatever rate of increase is assumed, it is reduced to follow an s-shaped adoption curve with a maximum adoption of about 50% of the rice area (note that BG 1442 already occupies 35% of the area after 5 years and is expected to increase again next year).

The assumptions used are generally conservative

We argue that this estimate on the rate of spread is conservative because of several factors:

1. ***Formal seed supply is underestimated.*** The benefits are very sensitive to additional seed supply in early years i.e. a modest additional amount of project-supplied seed early in the adoption process has a large impact on increasing benefits. LI-BIRD, DADOs, and other partners in scaling up the varieties, are expected to supply considerably more seed than the assumed maximum of 7 ha of seed in the higher scenario in each district in the first three years of adoption. The partners in the scaling up (Supplement 6) have increased in number and the Department of Agriculture is using its own resources to supply seed of the varieties that farmers are demanding. (As explained above, this is not considered to be an additional cost when NPV is calculated because DADOs, prior to having project-identified or project-bred varieties, still used resources on front-line demonstrations and minikits of varieties).

2. ***Spillover to new districts is underestimated***: The spread to new districts from the large areas under project varieties has not been included when estimating benefits, although the increased area under new varieties is accounted for in the estimated farmer-to-farmer spread within districts. An estimated total of about 2000 ha of main-season rice under project varieties in 2002[†] represents a very large seed source, in the hands of many farmers, that was not present in previous years.

   In *Chaite* rice there is now 1200 ha in Chitwan of BG 1442. Because of the low average landholdings, about 2000 households are now growing this variety. It is improbable that farmers in these households have failed to give seed of the variety to relatives in other districts. We have found that a major element of the spread of seed from farmer to farmer is among relatives and networks of relatives commonly spread across districts.

[†] In 2002, there were at least 600 ha (LI-BIRD estimate) of project, main-season varieties in Chitwan (DADO estimate is 750 ha or 2.5% of the rice area). There were estimated to be 300 ha of project varieties in Nawalparasi in 2001. If the spread in Nawalparasi is similar to that of Chitwan, then there are 600-700 ha of project varieties in 2002 in Nawalparasi. From field data from collaborating DADOs and NGOs, it is estimated that there is about 500 ha in other districts where the project began interventions in 2001. This gives a total of at least 2000 ha.

Because the quantities of seed given in farmer-to-farmer spread are modest, the quantities of seed in this spillover will also be modest. However, additional small quantities of seed in early years have a large impact on adoption in later years.

3. ***There is a greater varietal choice that matches more of the rice ecosystems:*** The varietal choice that can now be offered has increased dramatically and will continue to increase greatly at least until 2004 (Fig. 6). The varietal choice (Annex 2) is increasingly meeting the needs of farmers. Varieties are now available that fit well to the 60% of the Terai that is rainfed or under limited irrigation.

4. ***Two generations a year of main-season rice can now be grown.*** The *Chaite* season can be used to advance very early duration main-season varieties and the main season can be used to advance *Chaite* rice varieties. However, before 2001 it was not possible to grow two generations a year of longer-duration main season varieties. The PTD projects have identified an area in Nawalparasi where longer-duration main-season rice can be multiplied in the off-season. This was done for the first time in the 2001-2002 winter season (Fig. 3.1). This ability to multiply new main- season varieties in the off-season (two crops a year instead of one) greatly aids seed multiplication and hence dissemination and impact.

6. ***Not all districts are accounted for.*** We have restricted the benefit analysis to the 21 districts in which there has been project-initiated scaling up and to two (Makwanpur and Rupandehi) which border on the projects' districts of Nawalparasi and Chitwan. However, there are several districts, where farmer-to-farmer seed spread is already taking place and in some of the 14 hill districts adjoining the Terai that have a total of 134,000 ha of main-season rice GOs or NGOs have already taken up extension activities on these varieties.

7. ***The start dates for spread are conservative.*** Although some seed will have spread earlier from farmer-to-farmer or by informal intervention by staff from GOs and NGOs, we have assumed the spread only began from project interventions.

Figure 3.1. **Barkhe 2001 in winter season multiplication, May 2002**

Possible overestimates

1. Project-identified varieties may prove unpopular. This is the most sensitive of the possible overestimates, because all of the scenarios assume that the project varieties are preferred and spread from farmer to farmer. However, there is very strong evidence for the high adoption of varieties BG1442 and Swarna. The popularity of other varieties, such as Pant 10, Barkhe 1027, Barkhe 2001, Barkhe 3004 and Sugandha 1, is evidenced by the high rate of their seed distribution by farmers and the positive responses from in-depth interviews. Moreover, evidence for acceptability has been generated by participatory methods (project varieties are the top-ranked entries in mother trials) and all project varieties have undergone organoleptic testing and have good or excellent post-harvest traits.

2. For varieties introduced from India by the project there is the possibility that some of these varieties would have been adopted anyway entirely by farmer-to-farmer spread, as has been the case for many Indian varieties in the past. However, farmer-to-farmer spread of Indian varieties is haphazard (it may not occur at all if no farmer introduces the variety) and (as can be seen from the assumptions of spread in our benefit analysis) without the benefit of an initial, project-supported seed supply it will be extremely slow in the initial stages. Since the analysis has only been taken to 2012, the ‘no-project’ scenario could be expected to have little, or no, benefit from the Indian varieties that have been introduced by the project.

3. For the varieties produced by PPB it is assumed that, in the absence of the project, NARC would not increase the rate of release of varieties for the Terai.

4. For the PPB varieties, it is assumed that there will be some support from NGOs and DADO to maintain a supply of source seed. Costs have been allocated throughout the entire period to allow for this. Moreover, some of the varieties may be officially supported by NARC if they perform well in official NARC trials.

5. It is possible that farmers or NARC could identify new varieties superior to those identified by the project and would thus prevent, or slow, the spread of project-identified or project-created varieties. However, as the adoption ceilings considered are conservative (a maximum of 40 %) then there is plenty of scope for the adoption of non-project varieties.

6. Project varieties may break down to disease. However, all have shown excellent field resistance and resistance in disease nurseries when they have been tested in NARC trials. It is considered more likely that the continuing breakdown of resistance in existing popular varieties, such as CH 45, Masuli and Sabitri that are increasingly disease susceptible, will accelerate the adoption of project varieties, rather than susceptibility of project varieties limiting their spread.

ASSUMPTIONS ON BENEFIT PER HECTARE TO FARMERS

Benefits of new varieties were previously calculated (DTZ Pieda, 1998) on the basis of

- an increased harvest due to the new variety of 500 kg ha^{-1} after any additional costs
- a market price of Rs 9 kg^{-1}
- an exchange rate of Rs 107 per £

This gives benefits of Rs 4500 =£42 ha^{-1}.

We have adjusted these prices to 2001 data of Rs 8 to 9 kg^{-1} and an exchange rate of Rs 120 per £. This gives a benefit that varies from £33.33 to £37.5 ha^{-1}. However, the new varieties, on average, give up to 1 t ha^{-1} more and their grain quality is often superior, sometimes markedly so, to existing varieties so, for most varieties, this is an underestimate of benefits. We have hence used three estimates of benefits of £20, £33 and £46 per hectare.

We have used a discount rate of 10% to estimate net present value.