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Consolidation of Farming Options Developed in Earlier Phases of PARDYP

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Abstract

The Hindu Kush-Himalayan region's diverse social, cultural and agro-climatic conditions and its unique geography and geology mean that a single development approach cannot be applied for the area's sustainable development. PARDYP (the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project) is a research for development project working in the hills of India, China, Nepal and Pakistan on natural resource management. It identifies and recommends practical solutions to local people's problems relating to food, fodder and water. It highlights the potential for increasing farm incomes through the use of appropriate technologies such as drip irrigation, polyhouses, biofertilisers, and high yielding varieties and the growing of off-season vegetables. PARDYP also promotes multipurpose tree and grass species for rehabilitating degraded land. Such interventions can significantly increase production. Drip irrigation is an effective technique for overcoming water scarcity during the dry season. The introduction of fodder trees and grasses has great potential for the ecological rehabilitation of degraded sites. This paper provides a synthesis of the options tested by PARDYP between 1996 and 2002 and discusses their potentials and constraints.

Introduction

The Hindu Kush-Himalayan (HKH) region occupies approximately 4.3 million km^2, and is home to about 140 million people. It is a unique geographical and geological entity with diverse social, cultural, and agro-economic environments. Consequently, a single developmental approach cannot be applied uniformly to the entire region. The People and Resource Dynamics Project, (PARDYP) is looking at the interrelationships between factors responsible for the degradation of the area's resource base. PARDYP is also examining the way communities manage their natural resources. It is taking new technologies and integrating them with traditional knowledge on agriculture and forestry to restore the natural resource base. This paper provides a synthesis of the options tested by PARDYP between 1996 and 2002. The five PARDYP watersheds, with two in Nepal and one each in India, Pakistan and China are described in the introductory paper in this volume.

PARDYP has used participatory rural appraisal and informal meetings with villager and farmer groups to identify the major problems in its watersheds. The PARDYP team members then suggested and tested potential interventions. Technological interventions were made through participatory action research and were aimed at reducing workloads, increasing on-farm productivity, and the overall uplifting of mountain communities.

Technologies to Increase Soil Fertility

Biofertilisers

Biofertilisers are microorganisms that can improve the availability of key soil nutrients either by fixing nitrogen or releasing important nutrients. Biofertilisers are either fungal or bacterial. Only a few are commercially available and many are at the research and testing stages.

Vesicular arbuscular mycorrhiza (VAM) are fungi that live in a harmonious relationship with plant roots. In this symbiosis the fungi provide the plant with extra nutrients from the soil, especially phosphorus and zinc, in exchange for sugars from the plants. These biofertilisers are cost effective, environmentally friendly, and help to naturally maintain soil fertility. Biological nitrogen fixation, a microbial process that converts atmospheric di-nitrogen into a usable form, helps to maintain soil nitrogen reserves. Biofertilisers are particularly important in mountain areas as they can be easily transported. A small packet weighing a few hundred grams can provide the same amount of nutrients for crops as inorganic fertiliser weighing hundreds of kilograms. The limited availability of these biofertilisers to farmers is the major constraint for their wider use.

In India the application to the soil of the biofertiliser *A. chroococcum*, strain:

- W5 increased wheat production by around 14% over a series of 250 trials in four years;
- CBD-15 increased paddy production by around 18%;
- A41 increased finger millet (Madua) production by between 38% and 43%;
- M4 increased maize production by between 21% and 28%; and
- W5 increased production the production of in the vegetable crops tomato, brinjal, pumpkin and capsicum by around 18%.

In India different rhizobium strains also led to up to 42% increased production in bean varieties and leguminous crops. There was an increase in production of between 10 and 42% by applying biofertilisers. The effect differed by place and season. Paddy production increased by around 17% after applying VAM. Rhizobium on leguminous crops showed the best responses of a 43% increase while *A. chroococcum* on cereal crops showed increases of between 11% and 43% (Table 2.1).

In Pakistan, good germination and increased yields came from rhizobium-treated leguminous plants. Improved germination was a feature of rhizobium-treated seeds increasing yield by between 13 and 17% for soyabean (*Glycine max*), and 46.5 to 100% for mung (*Vigna radiata*) (Table 2.1). In the Chinese trials, tea and maize yields increased after inoculating the soil with the biofertiliser Haio. The increases were 22% for tea and 4% for maize (Table 2.1).

The beneficial effect of biofertilisers on plant growth and yield has been reported from other parts of the world on various crops (Pandey and Kumar 1989; Fulchieri and Frioni 1994; Daramola et al. 1994; Pandey et al. 1998; Daly and Stewart 1999). The main challenge remains of how to provide biofertilisers to farmers. Local government and non-government organisations could play a vital role in its distribution.

Bio-composting

The steep slopes and rugged terrain of the Hindu Kush-Himalayas mean that only limited areas are suitable for agriculture. Farmers have developed ways to make the most of this cultivable land based on their local innovations. Amongst their traditional agricultural practices

Table 2.1: **Results of biofertiliser research trials in PARDYP phases 1 and 2**					
Country	**Research trial crops**	**Biofertiliser applied**	**Yield increase (%)**	**Length of trials**	**No. of trials**
India	Wheat, local VL-616, 738	*Azotobacter chroococcum* strain W_5	+11.5 to 17.6	4 yrs	65
	Paddy, local, VL-221	*Azotobacter chroococcum* strain CBD-15	+15.6 to 21.4	1 yr	5
	Paddy, local, Vl-81	Nutrilink (VAM)	+15.9 to 19.8	3 yrs	7
	Madua, local, Vl-149	*Azotobacter chroococcum* strain A_{41}	+38 to 42.9	2 yrs	7
	Bean VL-1 Contender	Rhizobium	+14.2 to 25	3 yrs	20
	Soyabean VL-2	Rhizobium	+21.6 to 38.5	3 yrs	10
	Rajma, VL-63	Rhizobium	+42.8	1 yr	2
	Urad, local	Rhizobium	+11.1	1 yr	3
	Mung, local	Rhizobium	+22.2	1 yr	3
	Maize local, popcorn var.	*Azotobacter chroococcum* M_4	+21.1 to 28.2	1 yr	8
	Tomato	*Azotobacter chroococcum* W_5	+18.5 to 20	4 yrs	75
	Capsicum	*Azotobacter chroococcum* W_5	+17.8 to 22.5	4 yrs	75
	Brinjal	*Azotobacter chroococcum* W_5	+16.2 to 18.5	4 yrs	75
	Pumpkin	*Azotobacter chroococcum* W_5	+12.4 to 14.3	3 yrs	100
Pakistan	Mung	Rhizobium	+42.5-100	1 yr	2
	Soyabean	Rhizobium	+13-17	1 yr	2
China	Maize	Haio	+4	1 yr	3
	Tea	Haio	+22	1 yr	3
Note: trials were carried out with both farmers and groups of farmers					

the preparation and use of farmyard manure is very important. Farmers depend on manure from their livestock to maintain and increase soil fertility for crop production. But there is only a limited use of crop rotation and nitrogen fixing species to augment soil fertility.

Compost is well-rotted organic matter. Composting is largely a biological process in which aerobic (needing oxygen) and anaerobic (not needing air or free oxygen) microorganisms decompose organic matter and lower the carbon-to-nitrogen ratio. The final product is well-rotted manure or compost. Compost is prepared from vegetable refuse, weeds, rice husks, and sugarcane and animal waste.

Traditional farmyard manure is a mixture of cattle dung, urine, plant residues, and leaf litter that is put as cattle bedding. Farmers remove it every few days and dump it in the open to decompose. Many of their nutrients are washed away as these piles are exposed to rain. It is often applied to farmer's fields when only partially decomposed as it can take more than six months to decompose.

PARDYP has been promoting a simple and cheap technology to improve the quality of farm compost. It involves simply placing the material in a pit and covering it with black polythene sheet. This is particularly beneficial for farmers with limited livestock. It helps to maintain soil fertility and improve soil physical and chemical properties and reduces the composting period and the loss of nutrients.

In India, improved pit farmyard manure was tried for vegetable production. In Pakistan, an onion crop was grown with decomposed pine needles composted in a pit and was compared with other traditional types of compost manure and inorganic fertiliser. At the Indian site, the use of this improved compost led to an 8-12% increase in yields and a reduction in the incidence of diseases (especially cutworms). A 78% increase in the onion crop was recorded at the Pakistan site after applying improved compost (Table 2.2). Swift and Palmer (1995), Stewart et al. (1998), Murugappan et al. (2001), and Ojha et al. (2002) have reported beneficial effects of improved compost on different crops and agro-ecosystems in other areas.

Table 2.2: **Improved compost and vermiculture research trials, PARDYP phases 1 and 2**

Country	Trial crops	Intervention	Yield increase (%)	Length of trials	No. of trials
India	Vegetable	Pit compost	8-12	2 yrs	10
Nepal	Bitter gourd	Bokashi	33	2 yrs	1
Pakistan	Onion	Animal, poultry, pine needles, various plant leaves, chemical fertiliser	77.7% increase with pine needles	1 yr	1
China	Maize	Earthworms	5.7	1 yr	3
	Tea	Earthworms	15.6	1 yr	3
India	Vegetables	Earthworms	Positive	1 yr	1

Organic fertiliser

Organic matter takes a long time to decompose and is often applied to fields before fully decomposed which can cause pest and disease problems. Bokashi is an organic manure that can be prepared within about 10 days in summer and 30 days in winter. It is prepared by combining the following ingredients in the following proportions:

- rich organic soil (47%)
- rice husks (13%)
- mustard oil cake (13%)
- chicken manure (10%)
- wood ash (7%)
- rice bran (7%)
- rotten bamboo leaves (0.6%)
- artemisia leaves (2.4%).

The materials are mixed thoroughly and stored under shade to ferment away from direct rainfall or sunlight. Water is added regularly to help decomposition. In Nepal, bitter gourd grown on Bokashi-treated soils gave 33% more yield (Table 2.2).

Vermicompost

Vermicompost is produced by using earthworms to convert biodegradable wastes into compost. Earthworms are vital for soil health and plant growth. The beneficial effect is because earthworms eat up plant material and soil, grinding it down in their digestive tracts and excreting it as small granular pieces. It normally has a black or dark brown colour. The chemical composition of vermicompost is superior to compost made in pits or by bacterial decomposition.

This technology was demonstrated in a few farmers' field in the Indian PARDYP watershed. In China experiments were conducted by applying vermicompost to tea and maize crops. There was a reported 5.7% yield increase for the maize and 15.6% for the tea crop (Table 2.2). Atlavingte and Vanagas (1982), Kale and Bano (1986), Radha et al. (1992), and Clive and Johan (1992) have reported beneficial effects from applying vermicompost to crops.

Technologies to Increase Yields

Improved seed varieties

High yielding crop varieties give higher yields and in some cases are more resistant to diseases than traditional varieties. Farmers often realise more profits from high yielding varieties of grain and vegetable crops compared to local varieties. PARDYP provided the seed of new varieties to farmers in its watersheds. This led to many farmers replacing their old varieties with the new ones.

In India the high yielding wheat varieties VL-738, 616, finger millet (Madua) VL-149); paddy VL-81; maize (Amber Popcorn); and pea (Azad-p1 and Arkil varieties), were distributed to farmers to test. In Nepal, seeds of high yielding varieties of maize (Khumal, Yellow, Rampur Composite, Arun-2, Bioseed), paddy (Pant-10, Sabiti) and 13 pigeon pea varieties were tested for their performance in farmers' field and experimental stations. In Pakistan different varieties of maize (Pahari, Kissan, Azam, Super 3025), wheat (Suleman, Inqilab, Tatara, Gaznavi, Nowshera-96), rice (Jp-5, Basmati-385, Dilrosh-97, Swati-1), cabbage (Golden Axe, Stand-by, Atlas, Darby day, and First of June varieties), tomato (Roma and Condon varieties) and potato (Cardinal variety) have been tested for yield, disease resistance, and early maturing qualities.

Many farmers are adopting these varieties as they are often suited to local conditions and give up to double the yield of local varieties. In India the VL-738 variety of wheat, the VL-149 variety of finger millet (Madua), and Azad-p1 of pea have become popular yielding 14% to 90% more than the traditional varieties (Table 2.3).

Farmers participating in PARDYP's trials in Pakistan preferred Azam and Super 3025 maize varieties. The production of Azam has reached 7.5 t/ha compared to less than 2 t/ha for traditional varieties. Super 3025 gave 243% more yield than local varieties. The Inqilab variety of wheat has given three times the yield, the JP-5 variety of paddy twice the yield, the Swat-1 onion 36% more, and the Roma tomato 69% more than local varieties. They are all becoming popular among Hilkot farmers.

In Nepal four maize varieties have been tested. The Bioseed hybrid variety performed best giving a maximum yield of 7.6 t/ha and a biomass of 9.2 t/ha with a medium crop duration of 105 days. The Arun-2 variety matured rapidly in only 93 days but gave the least yield at

Table 2.3: **High yielding variety research trials in PARDYP phases 1 and 2**

Country	Trial crops	Variety	% yield increase over local variety, or other finding	Length of trials	No. of trials
India	Wheat	VL-616, VL-738	91.6 to 125%	4 yrs	250
	Madua	VL-149	110%	2 yrs	8
	Paddy	VL-221	Matured in 110 days, tastes good	1 yr	2
	Paddy	VL-81	14.2 to 20%	3 yrs	6
	Maize	Amber Popcorn	50.4%	1 yr	2
	Pea	Azad-p1, Arkil	40 to 60%	3 yrs	40
Nepal	Maize	Khumal Yellow, Rampur Composite, Arun-2, Bioseed	Bioseed, 7.6t/ha	1 yr	2
	Paddy	Pant-10	5.4 t/ha	2 yrs	12
	Paddy	Sabiti	3.9 to 5.6 t/ha	2 yrs	10
	Pigeon pea	1 perennial and 7 dwarf varieties	Icp-13055 best	1 yr	2
Pakistan	Maize	Pahari, Kissan and Azam	Azam, 7.5 t/ha	3 yrs	26
	Maize	Super 3025	243% than local	1 yr	8
	Tomato	Roma	69%	1 yr	1
	Potato	Cardinal	4.6-10 t/ha	1 yr	1
	Wheat	Suleman, Inqilab, Tatara, Gaznavi, Nowshera-96, local	Inqilab, 3116 kg/ha, +123.2% than local	3 yrs	50
	Rice	JP-5, Basmati-385, Dilrosh-97, Swat-1 and local	JP-5 +110.7 % more yield than local	3 yrs	12
	Onion	Swat-1 and Desi	Swat-1 +36%	2 yrs	3
	Cabbage	Atlas, Standby, Darby Day, Golden Acre, First of June	Atlas 47 day maturity, 2418 kg/ha production	2 yrs	3

2.8 ton/ha and a biomass yield of 4.7 t/ha. Khumal Yellow and Rampur Composite were medium in yield but took longer to mature and so farmers preferred them least. The farmers accepted the Pant-10 and Sabiti varieties of paddy as they have proved to be high yielding under high inputs suitable for intensive farming. Only seven of the 13 pigeon pea lines flowered. Pea Icp-13055 variety was found the best (Table 2.3). Tandon and Shah 1982, Shah 1997, Singh *et al.* 1997 have all concluded that using improved crop varieties is necessary to fulfil the food demands of people in the Indian PARDYP areas.

Intercropping, multi-cropping, cover crops and crop rotations

PARDYP has worked on intercropping and multi-cropping to increase the productivity of cropping land. It has also tried out alternatives to the traditional winter wheat-summer paddy rotation. One of the benefits of new crop rotations is to prevent the build up of disease and pests and, if a legume crop is incorporated into the rotation, their may also be improved fertility.

In PARDYP's India watershed, some farmers tried growing vegetable crops instead of the traditional winter wheat crop after the paddy had been harvested. In the Pakistan watershed, farmers tried intercropping combinations of leguminous crops amongst their traditional crops with maize grown with mung bean, mash bean (*Vigna mungo*), and soyabean. Off-season pea has been grown with onion, and mung bean with potatoes. In Nepal, maize was intercropped with bush bean, and the system of rice intensification (SRI) practice was tested (Table 2.4). This innovative technique of transplanting single, very young rice seedlings at wide planting intervals – as opposed to the traditional more mature *bunches* of seedlings per closer interval – has given significant yield increases.

Table 2.4: **Results of intercropping research trials in PARDYP phases 1 and 2**

Country	Research Trial Crops	Intercrop	Change	Length of trials	No. of trials
India	pea	tomato, radish	positive	1 yr	2
Pakistan	maize	mung or mash bean or soyabean	> PR 2100-9600/ha when either of these 3 intercropped	1 yr	3
	pea, onion	onion + Vas Pea or onion alone	+ PR 44,725 to 90,550/ha when pea + onion	1 yr	3
	potato	bean	+ 46.7% income	1 yr	2
	wheat or maize	wheat + maize + tomato, wheat + maize + radish , maize + tomato + radish	maize + tomato + radish best	2 yrs	30
Nepal	yellow maize	bush bean	Up to + 42.3% income	1 yr	17
	paddy	SRI practice	+58%	1 yr	1

In India some farmers who planted peas and then tomato before paddy reported increased incomes compared with growing wheat after the paddy. In Pakistan, maize with intercropped legumes yielded between Pakistani rupees (PR) 2,100 and 9,600/ha increased income (US$1:PR 58). Peas grown in a mixture with onions gave an income of PR 190,550/ha against the previous PR 100,000 to 145,825/ha when these crops were grown alone. The farmers reported an income of PR 2700 from a 450m^2 plot, when maize was intercropped with mung beans, against an income of PR 1,840 and 1,200 from a single cropping of potato or maize. The maize (Azam variety)-tomato-radish cropping sequence gave the best yields amongst those tried (Table 2.4).

In Nepal, farmers who followed PARDYP's suggestion to grow maize with beans earned more than Nepalese rupees (NR) 25,000/ha per season (US$1:NR 74 in December 2003). Growing these crops singly realised only NR 4600/ha for maize and NR 10,380/ha for beans. The application of SRI rice cultivation increased paddy yields by up to 58% (Table 2.4). Robert (1985), Pilbeam et al. (1999), Sabirin and Hamdan (2000), Zhardhari (2000), and Ojha et al. (2002) have also reported how crop rotations and intercropping have increased yields and soil fertility management in indigenous agriculture systems.

Disease control

Crop diseases are a major problem for most farmers causing reduced production and reduced incomes. Borers and cutworms are major pests in India in all seasons. In Pakistan, defoliating beetles and borers are major problems. For farmers in Nepal's Jhikhu Khola watershed the main problems are plant borer, late blight of tomato, and potato wilt.

In India, well-decomposed farmyard manure checked the problem of cutworms and a 1% solution of the pesticide Sevin greatly reduced borer and cutworm infestations (Table 2.5). In Pakistan, a 1% solution of Sevin was effective against cutworms, and light traps helped control cocciferous beetles (*Anomola dimediata*).

Table 2.5: **Results of disease control research in PARDYP phases 1 and 2**

Country	Trial crop	Disease control application	Change	Length of trials	No. of trials
India	borer	Sevin	1% solu. effective	3 yrs	10
Nepal	tomato, fruit borer	10% solution of titep ati (*Artemisia vulgaris*), andil (*Ricinus communis*), bakaina (*Melia azaderach*), *Vintex negundo* (simali)	+ 58-112% better result compared to control	2 yrs	2
	late blight of tomato	lemon grass, 1:5 & kantakari, 1:25	+65%, and +95% disease control respectiv ely	2 yrs	2
	potato wilt	Ketuki (*Agave americana*) 1:5, kantakari 1:25	kantakari best	2 yr	2
	late blight	plastic tunnel	+ 17% protection	2 yr	2
Pakistan	cockchafer beetles	light traps	useful	1 yr	1
	borers	1% Sevin	100% control	2 yrs	10
	wheat grain	Phostoxin	100% control	2 yrs	10

In Nepal a 1% solution of titepati (*Artemisia vulgaris*), andil (*Ricinus communis*), bakina (*Vintex vigundo*), and simali (*Melia azedarach*) were separately tested against tomato fruit borer. Andil extract was the most effective. For late blight of tomato, lemon grass (*Cymbopogon flexuosus*), kantakari (*Solanum xanthocarpus*), and plastic cloches were tried and kantakari gave the best protection. Potato wilt was successfully checked using a 1:25 solution of kantakari (Table 2.5). Other researchers have reported plant extracts and microorganisms controlling plant diseases (Dubey et al. 1984, Mishra et al. 1988, El-Abyad et al. 1993, Kothyari et al. 1993, and Kothyari 1997).

The use of extracts from locally available plants to control crop pests shows promise. However, it has not been adopted by farmers as the process is time consuming and technical. Pesticides like Sevin are more attractive as they are readily available, cheap, easy to use, and apparently non-toxic.

Income Generating Activities

Low temperatures in the winter in hill areas mean that few vegetables are produced. The low temperatures and frost delay seed germination, slow down growth, and lead to high plant mortality. Associated problems include poor plant quality and lack of uniform plant size.

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Many of these problems can be overcome by covering the crops with polythene in pits, trenches, and polyhouses. Polypits are made by digging pits – usually at least 2.5 ft deep – and covering with a polythene sheet supported on a frame. During warm days the polythene is partly or completely removed to allow sunlight in and maximise photosynthesis. The pits are covered and sealed at night.

PARDYP has also encouraged farmers to use polyhouses for growing winter vegetables. In the Indian watershed, off-season vegetable production was introduced by using polyhouses, polypits, and poly trenches. Vegetable seedlings are raised in the protected structures during winter and then transplanted to the fields as temperatures rise in the spring. This means that the crops are ready for harvesting two to three week earlier than if raised by planting seeds in the open. In Pakistan turnip and in Nepal bitter gourd have been raised as off-season vegetables.

These techniques are gaining popularity in PARDYP's Indian watershed as some farmers are earning more than Indian rupees (IR) 10,000/year by selling seedlings and produce like tomato, capsicum, pumpkins, and brinjal in the off-season when there is a shortage of vegetables (US$1:IR 46) In Pakistan the introduction of turnip as an off-season vegetable has meant that farmers get eight times more income from the same piece of land compared to growing the traditional wheat crop. In Nepal, the introduction of bitter gourd as an off-season vegetable has provided more than NR 9,000/ha from one crop (Table 2.6). Dass et al. (2002) have reported vegetable production as a way of improving livelihoods amongst tribal people in India.

Table 2.6: **Results of off -season vegetable research trials in PARDYP phases 1 and 2**

Country	Trial crops	Product	Change	Length of trials	No. of trials
India	tomato, capsicum etc.	seedling and fruits	>IR 10,000/yr	4 yrs	25
Pakistan	turnip	leaf	> 8 times	2 yrs	2
Nepal	bitter gourd	fruit	> NR 9,000	2 yrs	3

Value Addition and Other Supporting Activities

Water harvesting technology and drip irrigation

Water shortages caused by fluctuations in rainfall can seriously damage crops and reduce yields. Long dry spells lead to root and stem wilting and can lead to plant death. Farmers need to irrigate their crops to supplement the often inadequate rainfall. PARDYP has promoted drip irrigation. It is a simple technology that helps overcome water shortages. Its application ensures a uniform water supply to plant roots resulting in better growth and higher yields. An upland farmer using drip irrigation fed from a small water source can easily produce off-season vegetable in lean periods. The drip system typically uses only 60% of the water used by irrigating with buckets. In Pakistan and Nepal this technology has been tested with off-season production of tomatoes, bitter gourd, and cauliflower.

It has shown positive result in all tested plots leading to a doubling of profits for some farmers in Nepal (Table 2.7). Smajstrla and Locasio (1990) and Marr et al. (1993) reported increased vegetable production from using drip irrigation in the USA.

Table 2.7: **Results of drip research trials in PARDYP phases 1 and 2**

Participating country	Research trial crops	Intervention	Change	Length of trials	No. of trials
Pakistan	tomato	drip irrigation	positive	1 yr	1
Nepal	bitter gourd	drip irrigation	> 2x profit	2 yrs	3
	cauliflower	drip irrigation	> NR 250-300/ha	1 yr	1

Management and improvement of wasteland

Large areas of land in the hills of the Hindu Kush-Himalayas have become low output grazing and wasteland. Such areas are generally used to produce grass during the monsoon season (mid-June to September) and are left open for grazing during the rest of the year. This land is not being used to its full potential. It is the lack of technical know-how that prevents improvement of these mismanaged lands. These areas could be better used to increase production and minimise environmental degradation.

In PARDYP's Indian watershed, a number of types of fodder trees and grasses were tried out on degraded community land by villagers as demonstrations. Tea cultivation, vegetable seed production and the production, of fruit trees have been tried out in the Pakistan watershed. In the Nepal watershed a number of species have been tested on degraded sites and nutrient poor degraded red soils for biomass production and improving soil nutrient status.

In India, all tested species performed well. Among the tree species *Dalbergia sissoo* performed the best with *Grewia oppositifolia* and *Bauhinia retusa* as the next best. Among the grass species *Thysanolanea maxima* was the best followed by Napier grass. These produced significant amounts of biomass and increased the fertility of soil and reduced the workloads of women.

In Pakistan in 2000, tea was planted over four hectares in the PARDYP watershed with the help of the Lever Brothers Company and tea growing experts. It is performing well. In other areas farmers are earning good money from vegetable seed and fruit tree plant production on previously barren lands.

In Nepal, the long-term rehabilitation experiments on degraded lands are giving interesting results. The growing of sunflower (*Helianthus annuus*), sunhemp (*Crotolaria juncia*) and pigeon peas (*Cajanus cajan*) in carbon-deficit soils has helped increase the soil carbon pool. Lemon grass (*Cymopogan citrates*), stylo (*Stylosanthes guianensis*), Guatemala and Thailand creeper grass have performed well on red soils under different conditions (Table 2.8). Aronson et al., (1993), Babu et al. (1993), Kothyari et al. (1996a, 1996b, Rebafka et al. (1993), and Muller et al. (1998) have worked on similar lines with restoring degraded lands with many benefits realised.

Table 2.8: **Results of rehabilitation research trials in PARDYP phases 1 and 2**

Country	Trial	Species planted	Effects	Length of trials	No. of trials
India	rehabilitation	*Dalbergia* sp., *Grewia* sp, Oak sp., *Alnus* sp., *Bauhinia* sp.	*Dalbergia* sp. performs best.	4 yrs	20
	grass	*Thysanolanea maxima* , Napier, *Pennisetum* sp.	*T. maxima* best	4 yrs	20
Nepal	rehabilitation	sunflower, sun hemp, pigeon pea	carbon increased	4 yrs	1
	red soil	lemon, *Setaria*, Stylo, Thailand creeper	lemon grass best	4 yrs	1
	grass trial	11 types of grass	Guatemala best	4 yrs	1
	fodder trial	7 grasses for fodder & composting	Napier, molasses best	4 yrs	1
Pakistan	tea		positive	1 yr	2
	seed production	onions, vegetables	positive	4 yrs	3
	fruit nurseries	apples, peaches, nuts, etc.	good earning	2 yrs	5

Constraints

There are no local dealers within the PARDYP watersheds or nearby where farmers can purchase biofertilisers, high yielding varieties of seeds, or drip irrigation systems. Farmers depend upon the PARDYP teams to get hold of these items. The process of preparing plant extracts for disease control has proved to be too time consuming to be adopted. A further problem is that the plants may not be available at the time of disease incidence and farmers do not know how to preserve them for out-of-season use.

Conclusions

The sustainable management of cropland, forests and barren land can contribute much to improving natural mountain ecosystems. Many traditional management practices are centuries old and well-established. Good people's participation is needed to successfully introducing new practices. Also, technologies may return promising trial results, but success depends upon the willingness of farmers to use them. Routine demonstrations and on-site training on their use is necessary to increase farmers' confidence and help wider acceptance. Providing integrated training programmes on soil, water and, crop, and pest management are needed to enhance cash crop production among the upland cultivators of the Hindu Kush-Himalayas.

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