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Participatory paths to conserving and utilizing plant biodiversity in India

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Tribal communities in India and some other countries remain the custodians and conservators of the rich plant genetic resources that reside in habitats that are away from the reach of modern development. Compelling circumstances, however, are making it increasingly difficult for them to continue this activity, and consequently there is progressive erosion of precious plant genetic resources and their traditional knowledge that could be used for developing food and agricultural resources. Dr. Arunachalam has spent three decades in India studying plant genetics and breeding including areas of conservation, documentation, and utilization. This paper is an adaptation of and an update on a paper presented at the Global Biodiversity Forum, South and Southeast Asia in October 1999. In it Dr. Arunachalam stresses the value of promoting the voluntary participation of rural and tribal farmers, as equals with scientists, in conservation and plant breeding programs.

Plant genetic resources for food and agriculture are an integral part of biodiversity conservation and utilization programs. The importance of an in-depth knowledge of plant genetics, on-farm conservation and improvement of these resources, empowerment of local communities in such activities, participatory plant breeding, and development of underutilized species has been well recognized. The Global Plan of Action, for example, is a FAO initiative that is following the directives of the Convention on Biological Diversity by emphasizing the full participation of farmers and local communities in such programs. The World Food Summit Plan also echoes similar proposals "to pursue through participatory means, sustainable, intensified and diversified food production" (Cooper et al 1998).

There is a general opinion that the "green revolution" varieties are fatigued and can no longer meet the needs of an ever-increasing population. However, given that yields of major crops have risen dramatically over the past four decades, it would be difficult to push the already high productivity further up through conventional plant improvement techniques. Interestingly, a study by Plucknett of Consultative Group on International Agricultural Research (CGIAR) has made a conciliatory inference that many developing countries have room for improvements, and that the waiting limit in farm yields has not yet been reached (Holmes 1993).

> *Participatory strength is defined by a joint effort in which formal scientists and farmer breeders function as equal stakeholders.*

The adoption of modern varieties has been partial and gradual in many areas. Farmers' requirements for both their seed and food in genetically rich tribal areas reflect a range of criteria. For example, tribal farmers prefer diverse traits that include cooking quality, resistance of plants to environmental stresses, use in feed and food production, varietal maturity to suit their cultivation modes, and the like (McGuire et al 1999). These characteristics are not readily available in the modern high-yielding varieties (HYV) that are often based on a restricted genetic base. Also, most of the HYV are not suited to the *local* ecological conditions, and their cultivation is expensive. Thus, in spite of the vigorous promotion of "green revolution" varieties, farmers' specific preferences and their various needs have led to a wide diversity of local varieties and landraces still being grown in tribal areas. See Table 1 to see the specific

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Rice Variety	Predominant Quality	Festivals	Time of Maturity (Month)
Kalakrishna	Scented	All festivals	January
Tulsi	Scented	Chaitra Parva	April
Machhakanta	White slender short grains, good taste	Manabasa and Lakshmi Puja	November
Mer	Black grains with medicinal properties	Annual ceremony of forefathers	November
Haladichudi	White slender long grains, good taste	Shakti Puja	December
Deulabhoga	Bold and short grains, reddish tinge on cooking with mild scent preferred during worship at temples	Temple Deities	December

Table 1
Some valuable land types or Rice varieties preserved by Orissa tribal farmers in India for use in their religious functions

varieties of Rice, *Oryza sativa*, for example, that are grown for use in cultural and religious functions. Unfortunately, *in-situ on-farm* conservation of genetic diversity is currently under increasing threat for various reasons. This is particularly true in genetically rich but resource-poor tribal areas.

THREATS TO *IN-SITU* CONSERVATION OF GENETIC DIVERSITY

One example of the loss of on-farm conservation is in the rich minor millet tribal areas of South India. Here the farmers are slowly abandoning the cultivation of minor millet species. Minor millets need de-husking, an arduous job that is done manually (mostly by women). Wherever transport and communication facilities have been established, Rice-hulling machines have now become available. Therefore, despite the high nutritive value of millets, tribal farmers have switched over to less nutritive Rice. In addition, the new possibility of leasing their land for commercial cultivation of remunerative crops like Tapioca in lieu of cash payments has emerged. Though such incentives are grossly incommensurate to the gains made, farmers accept them and thereby shun risk-prone agriculture and lack of marketing facilities in their areas. In essence, the cost-benefit ratio is too high for them to persist with cultivation of diversity-rich crops.

Such instances illustrate the reasons behind the fast depletion of biodiversity in tribal areas:

- Compulsion for increased income to meet increasing cost of living;
- Non-availability of small farm implements to relieve farmers of work drudgery;
- Economic improvement, which is led by the desire for an easier life;
- Poor benefit-cost ratio to pursue cultivation of genetically rich crops; and
- Emerging alternatives to earn easy income from their lands.

HYVs and modern technology - Are they pro-biodiversity?

During the last 40 years, the "green revolution" decades, government institutions or those supported by the government in India had a sharp and narrow focus on increasing productivity and production in order to feed more people effectively and efficiently. The first aim led to vertical improvement of single traits (for example, grain yield) and the genetic avenues were sophisticated but narrow. For instance, the "green revolution" in Wheat and Rice was based on dwarfing genes, initially one or two in number. The dwarf varieties entailed a correlated response for productivity and thus achieved the goal. It was consolidated on appropriate cultural, agronomic, and soil inputs, such as irrigation, chemical fertilizers, optimal plant population, plant protection, and fertile soils. This technology accompanying the HYV was extended to those farmers who had enough land and financial resources.

The second aim of increasing production enabled extended development of HYV in other crops and the adoption of a cropping system approach. This encouraged multiple- and inter-cropping. A varietal cafeteria offered an optimal choice of varieties to suit seasonal fluctuations. However, over time, one or two major cropping systems like Rice-Wheat (with assured irrigation) dominated production over the other combinations (particularly, dryland pulses and oilseeds). Gradually, with the fatigue of the soil and the stagnant benefits of the predominant Rice-Wheat rotation, sustaining productivity is becoming increasingly difficult.

Yet, HYV technology has remained, in general, a boon and saviour of countries like India predicted to a doomsday in food production. With HYV technology India passed from a subsistence level of food production through a surplus level and finally to an export level. Because more grain can be harvested from the same amount of growing space, HYV has also saved huge tracts of arable land that would have otherwise been utilized in producing food for the growing millions. In turn, then, more land becomes available for conserving and using biodiversity. An estimate shows that, worldwide, the same 6 million square miles of land are cropped as in 1960 but 80% more people are being fed a diet that has more than twice as many grain-equivalent calories (Avery 1997). Even though the calories are higher, these grains do not necessarily provide the full nutrition that is needed.

Despite these positive factors, HYV technology remained far from biodiversity-friendly. Breeders were able to develop more HYVs by using earlier HYVs and their own breeding lines in crosses. Such methods led to a narrow elite germplasm base in crop improvement. Despite yield improvement, resulting HYVs became genetically vulnerable to newly developing, virulent biotic stresses such as pest attack and diseases. Dependence on chemical control led to environmental degradation. Looking for a growing environment optimal for HYV expression led to narrow adaptation and the avoidance of genotype X environment interaction.

On the other hand, if local varieties that express their yield potential in a tribal environment were improved at the site by farmer-scientist participatory action, they would show enhanced yield expression at that environment. In other words, breeders could exploit genotype X environment interaction for optimal expression. It must be emphasized that the environment consisting of a site's soil, climate, and ecology is a major factor influencing expression. HYV breeders select environments where HYVs express optimally. That means they avoid sites (environments) where the HYVs do not express; in other words, they avoid genotype X environment interaction.

Indirectly such HYV technology became biodiversity-unfriendly. It provided impetus for sustaining production in relatively rich environments. Measures of amelioration were thus evolved for generating and maintaining ideal environments for HYV. For example, irrigation facilities were improved in both natural areas (river, rainwater etc.) and others (drylands, watersheds etc.). Such measures began to marginalize other improvement avenues. Large rainfed areas could not gear up to improving productivity; HYV technology did not fit them cozily. Large tribal areas that were out of the reach of institutional development mechanism remained confined to traditional cultivation modes. This failed to provide tribals with avenues to improve their income to meet the demands of a competitive existence. Due to a scarcity of essential inputs, including seeds of local varieties and landraces, necessary funds for cultivation, and alternatives to insulate themselves from regular risks, tribal farmers gradually veered away from the conservation of genetic diversity. Instead, as mentioned earlier, they began to accept biodiversity-unfriendly avenues, such as leasing their land for commercial exploitation. In a way, formal improvement technologies dominated farmer-preferred genetic improvement. However the continued farmer-preference for specific traits and consequent low spread of HYVs are still sustaining site-specific biodiversity. But such biodiversity is comparatively low and under increasing threat of extinction. The local adaptive paradigm is friendlier to the farmer, consumer, and environment but goes against the commercial motive of preferring a handful of cosmopolitan varieties.

In essence, therefore, any technology or intervention that directly or indirectly counters sustaining or improving biodiversity in a target area can be termed biodiversity-unfriendly. HYV falls into this category. What if HYV technology were extended to tribal areas with the aim of developing one or two farmer-acceptable varieties with high benefit-cost ratio, meaning that cultivation of such varieties would provide more benefit in terms of income compared to the cost of cultivation? If those varieties were saturated across those tribal areas, and if farmers were encouraged to crop such varieties in the entire area, certainly, genetic diversity would diminish over time to the extent of extinction. The depletion of varietal diversity in non-tribal HYV areas supports that concern. The following components of HYV technology are detriments to the conservation of biodiversity:

- failure to learn from farmer-knowledge on cultivation

COUNTRY	CROP	VARIETY	METHOD	REMARKS	
NEPAL	Rice	MP3	PFS	Sel. in F5	Sthapit et al (1996)
NIGER	Pearl Millet	ICMVIS 92222	PFE	Preference to released population	Baidu - Forson (1997)
RWANDA	Beans Phaseolus vulgaris	Land races	PFS	Arresting genetic erosion	Sperling and Sheidegger (1995)
BRAZIL	Beans	Breeder's material	PFS	Selection in segregating population	Sperling and Ashby (1997)
SYRIA	Barley	Breeder's material	PFS	Selection in segregating population	Sperling and Ashby (1997)
INDIA	Rice	Released varieties	PFE	Enhanced productivity through green manuring with Sesbania	Behera et al (1997)
	Pearl Millet Maize Chickpea Blackgram	Population	PFE PFE PFE PFE	Selection in prereleased and released lines	Joshi and Witcombe (1996, 1998)

Table 2
Published success cases of Participatory Plant Breeding. PFE = Participatory Farmer Evaluation, and PFS = Participatory Farmer Slection

practices, seed selection, seed maintenance, and farmer skill in trait selection;

- a dominant desire to introduce formal methods on farmer sites;
- inability to discover pro-biodiversity and farmer-friendly methods;
- failure to restructure formal methods to suit farmer needs;
- voluntary or compulsive urge to demonstrate short-term improvement;
- strong dependence on formal material (varieties, segregating populations, breeding methods) for farmer progress;
- insensitivity to knowledge sharing and knowledge empowerment;
- vulnerability to increased spread of pests and diseases (due to narrow genetic base); and
- corporate paradigms that foster a few cosmopolitan HYV varieties and high agrochemical inputs with *in situ* and *ex situ* effects.

ONE SOLUTION: INTERFACING FORMAL AND FARMER APPROACHES

One solution to finding biodiversity-friendly breeding and growing techniques is to integrate modern scientific methods (formal) with traditional tribal methods (informal). The hypothesis that HYV seeds and plants would fare well in any environment is now held to be invalid. Adaptation of local varieties and land races to specific geographic niches and expression of favoured traits only under specific cultivation and cultural practices have been cited as the major reasons (Worede and Mekbib 1993; Caccarelli et al 1996; Rasmusson and Phillips 1997). Since tribal environments do not duplicate in breeders' research stations, custom-bred varieties for farmer-sites are also not a viable proposition. In essence, formal breeding strategies *per se* may not suit farmer sites though formal breeding concepts would still remain valid. It is then appropriate that pro-biodiversity technologies are generated through intensive formal-farmer association.

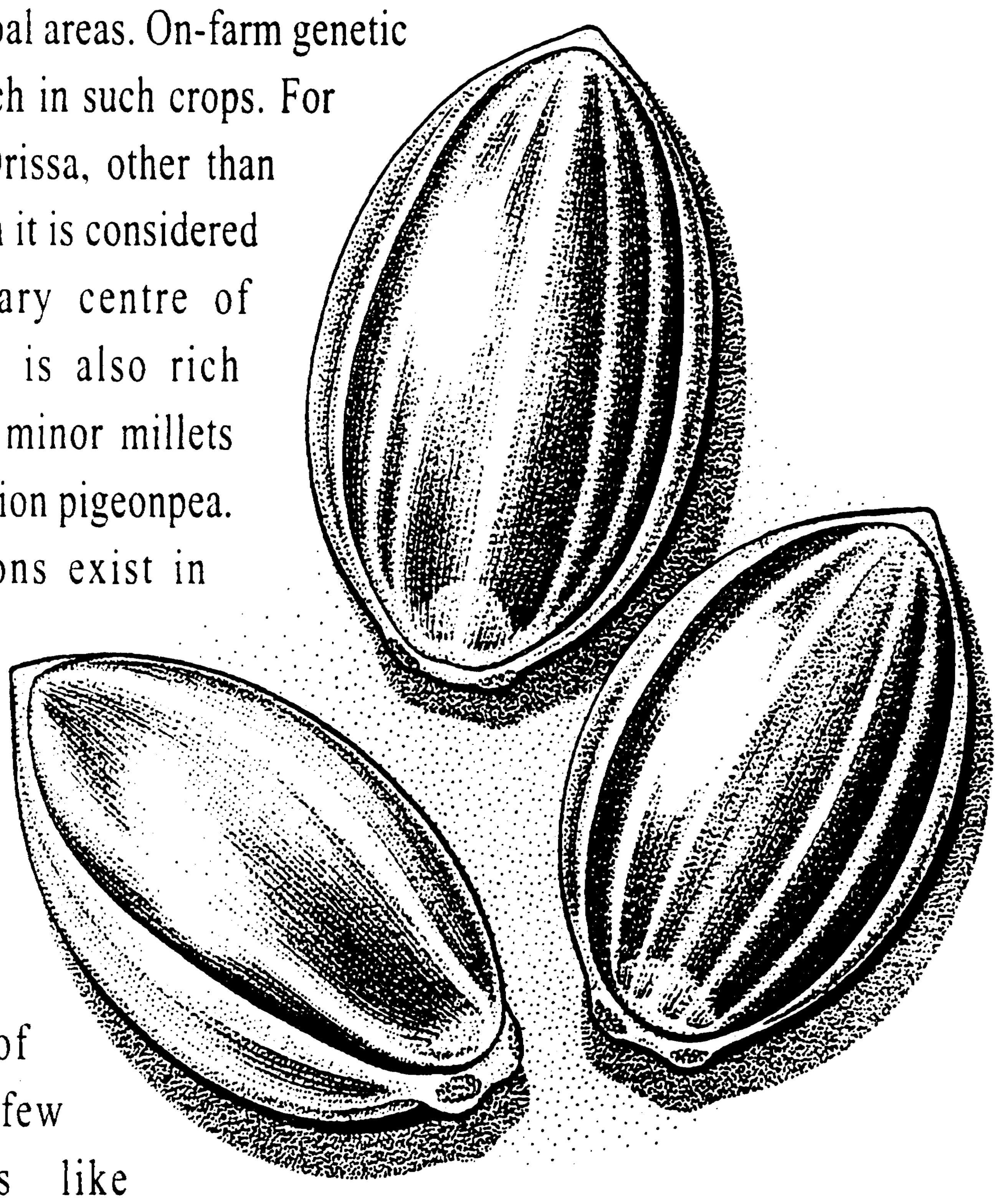
Published case histories have commonly used participatory varietal selection as a method of yield improvement in farmers' plots. Broadly speaking, segregating populations (which are new genotypes that have arisen out of recombination in the second and later filial generations from formal experiments) are tested in farmers' plots and the farmers then select desired plants (Table 2). Although this method provides a short-term avenue to achieving relatively high yields, it does not aim at conservation of biodiversity at farmer locations. Such selections would improve farmers' incomes (assuming marketing or buy-back facilities exist) but may not cater to the multi-trait preferences of the farmer.

Another reason for combining formal and informal knowledge and practices is to take advantage of several informal farmer-practices that have formal implications. Formal-farmer interaction can fine-tune these techniques and be a catalyst for significant mutual benefits. Three examples substantiate this idea:

1. Farmers favour planting a mixture of varieties, whether the crop is self- or cross-pollinated. In cross-pollinated systems, unconscious open pollination between and within varieties would result in recombinational variability for farmers to select on further. In both self- and cross-pollinated crops, growing mixtures can produce synergistic competition effects that can work as an effective insurance against various risks such as disease incidence, water stress during various stages of crop growth, and diverse ramifications of other variety-environment interactions. The underlying basis is well documented in formal literature particularly in developing composite and synthetic populations. But it is common to find formal systems advocating genetic homogeneity in a bid to ensure stability of yield. In contrast, farmer practices (tuned to risk-prone cultivation in marginal lands where it is difficult to sustain yield stability anyway) would recommend the use of a mixture of varieties. This area is open for participatory research to set strategies, appropriate to options available at a site, of seed production, a view commonly found in published literature (see, for example, Almekinders et al 1994; McGuire et al 1999). Use of a number of diverse crop varieties provides good insurance against crop failures.

2. Farmers like to obtain both grain and fodder yields from the risk-prone crops. Hence they prefer to grow tall varieties that have less tillering (suckering), a practice also conducive to economic water use. Their cultural methods are driven by site infrastructure and their economic strength. For instance, farmers in the state of Orissa, which is located between $82^0 - 87^0$ E longitude and $18^0 - 22.5^0$ N latitude in East India and occupies an area of about 156,000 sq km, broadcast Rice in upland and medium land areas on undulated land with sub-optimal preparation. They sow the seeds on specific days and in the months they know to be the best from their traditional wisdom; in most cases, they expect seasonal rain to follow these dates. Formal knowledge would make it possible for farmers to select from a range of varieties. For instance, one might choose a variety that suits a certain time of sowing with a few of the other desired traits like plant height, tillering potential, capacity to tolerate mid season drought, maturity, and harvest index. In other words, contingent planning can effectively be made to suit site factors including seasonal and climatic variation. Farmer-scientist interaction will then enable appropriate action plans.

3. Un- and under-utilized crops are a special strength of tribal areas. On-farm genetic diversity is rich in such crops. For instance, in Orissa, other than Rice for which it is considered as a secondary centre of origin, there is also rich variability in minor millets and long duration pigeonpea. Such situations exist in other tribal areas too. Globally, formal breeding has concentrated on methods of improving a few major crops like Wheat, Rice, and Maize. These formal methods have yet to find appropriate application in crops like minor millets already growing in site-specific environments of tribal areas. Here again formal and farmer sectors can work together on a range of crops to optimize benefits.



Millet seeds, *Panicum miliaceum*, as viewed under a microscope. Through participatory plant breeding and conservation, we can begin to diversify our food sources. At present Rice, Wheat and Maize account for 60% of the world's calories and 56% of protein from plants. One example of where such diversification could begin is in the rich minor millet tribal areas of South India.

The Question of Incentives: It was pointed out earlier that farmers do not find it easy to continue conserving plant biodiversity specific to their areas. One option is to offer direct incentives to farmers for this activity. Incentive is a broad term that encompasses everything that motivates or stimulates people to act (Geiger 1999). The basic argument is that incentives will help small-scale farmers who are too poor to take any risk to take action on behalf of long-term biodiversity. The counter argument is that incentives discourage people to help themselves, and oftentimes strategies are handed down to farmers with no or minimal input from them, making them finally ineffective. Geiger (1999) has analyzed a number of case histories before concluding that most of the incentive-driven practices did not yield sustainable or replicable results.

On the other hand, well-conceived indirect incentives have been successful. For example, in a Joint Farm Management program, the communities around forests in 16 states of India derived at least 25% of their income

Conventional Plant Breeding	Participatory Plant Breeding
Works on favourable and robust environment with assured inputs	Has to work on a heterogeneous and fragile environment with low / inadequate inputs
Can be cost-intensive	Has to be cost-effective
Aims at widely applicable methods (Wide horizon)	Has to focus on site-specific methods (Narrow horizon)
Can work on a high-tech mode	Has to work on the principle of learning to scale-up downstream technologies
Can invest high technical skill	Has to tone up local skill
Has unrestrained options	Is constrained to farmer preferences
Can rest on an innovative and theoretical base	Has to be practical for popular acceptance
Narrow genetic base, in general	Wide options to utilize intra- and inter-specific genetic diversity in sites
High productivity is the usual target	Farmer preferred traits, sustainability of production (though moderate), and local preference are targets
Breeds varieties and then fits them to environments (avoidance of genotype x environment interaction)	Should develop environment-specific varieties (exploitation of genotype x environment interaction)

Table 3
Salient differences between Conventional and Participatory Plant Breeding

from timber harvests and non-timber forest products like leaves, fallen branches, mushrooms, and grasses. This indirect incentive has succeeded in the community protecting degraded public land in those areas (Poffenberger 1996).

Another project on food security in Zimbabwe identified farmers' needs and means of satisfying them based on farmers' local knowledge. Earlier research agencies had undertaken, in vain, trials that were too rigid and based on complex designs with inputs the farmers could not afford. In contrast, new farmer-friendly trials, which were set up and controlled by farmers themselves, led to significant success (Critchley et al 1996). Essentially, then, the success of incentives lies in supporting farmer-led processes of innovation to remedy site-specific maladies and finding farmer- and environment-friendly productive technologies.

Participatory strength is defined by a joint effort in which formal scientists and farmer breeders function as equal stakeholders. Formal methods would seek effective application and benefit demonstration while farmer knowledge would absorb innovation and reinforce traditional skill to generate sustainable gains. In a way, it would be a synergy between scientific will and traditional skill.

Of the many possibilities of such participatory efforts, participatory plant breeding and participatory conservation are persuasive biodiversity-benign paths to both the conservation of and sustainable and profitable use of biodiversity. The two activities are outlined in some detail to highlight possible achievement of the twin goals of biodiversity conservation and farmer prosperity (particularly of tribal poor).

PARTICIPATORY PLANT BREEDING

Unlike formal plant breeding, PPB has both open and restricted options (see Table 3). The emphasis in PPB is on *voluntary* participation. Thus the agenda for improvement and the priorities must originate from farmers' needs, site status and infrastructure, cultivation practices, and the farmers' knowledge and perceptions. A project on participatory improvement in a Rice crop initiated in Orissa has provided a case study.

Tribal farmers in Orissa grow Rice in three different growing situations: upland (areas located about 900 m above mean sea level), medium land (areas located about 600 m above mean sea level) and lowland (areas in flat plains). Because the areas are rainfed, farmers plant the crop with the onset of monsoon, which is highly variable across the areas. Hence the same local variety is sown on differing dates with as much as 50-60 days between sites. The duration of the initial rains is short, so farmers are left with limited options to prepare the land to the required tilth.

A number of deficiencies in raising the Rice crop were observed in farmers' plots:

- Poorly prepared land;
- Poor quality seeds;

- Direct seeding with high seed rates (60-80 kg/ha) to compensate for substandard viability;
- Plant stands that were not uniform in height and posed hurdles in weeding, plant protection, and other operations
- Lack of resources to monitor optimal crop growth
- Lack of knowledge about the techniques of benefit optimization (i.e. not knowing which are the best benefits to choose to work on)

As a first step, farmers were empowered with formal knowledge on the basics of raising a good crop. This was followed by demonstration plots that rectified farmer deficiencies noted above. The plots were laid out and managed by the farmers themselves with the participation of scientists. Formal practices extended to farmers included 1) application of farmyard manure at least a month before planting, 2) raising a Rice nursery in levelled land and with sufficient moisture, 3) line sowing with proper spacing between and within rows, 4) selection of well-filled seeds for sowing, and 5) setting rows in a north-south direction for maximum interception of sunlight by plants. Farmer-plots, managed with formal practices, have established a healthy crop with good uniformity, high tillering, and good seed setting. These practices involved no extra cost to the farmers but improved the yield of varieties during 1999 up to 70% when compared to those obtained by farmer practices, as seen from Table 4. When compared to the yields in 1998, the benefit realized was still higher. The data revealed that the yield of some varieties like Machchakanta, for example, fluctuated widely during the years 1998 and 1999 due to highly erratic weather conditions (cyclone, uneven rainfall, and at times, flood). The improvement in upland varieties was marked in both the years. Further the farmers saved about 75% of seeds in the formal method of sowing (15 to 20 kg/ha under formal compared to 50 to 80 kg under farmer practices). The key to the success of formal methods of cultivation is the participatory rural appraisal (PRA), farmer consultation, and joint implementation at every step of activity. Farmers were highly cooperative and willing to learn and implement formal techniques as the PRAs helped them to gain confidence in scientific farming.

This technological solution is a first step, and there are other areas that will also have to be addressed soon. These areas include 1) community-centered generation of seeds and of crosses between selected parental Rice varieties followed by participatory advancement of generations, 2) participatory selection to lead to new varieties, 3) development of rural markets through the initiative of communities, and 4) the attainment of self-sufficiency in the production of good seeds of appropriate local varieties and landraces.

PARTICIPATORY CONSERVATION STRATEGIES

As mentioned earlier, conservation for conservation's sake in the wake of increasing pressures for economic prosperity is no longer a viable proposition. Likewise direct incentives are not a healthy substitute. Simple interventions, like the project in Orissa, can only encourage farmers to stay within these practices as far it benefits them. These observations imply a need to link conservation of biodiversity with a participatory plant breeding program.

Participatory conservation represents a synergistic plane

Land type	Variety	Av. Yield (Kg/ha)				FO/FA	FO/FP
		1998	1999				
		FP	FO	FA	@		
Lowland	Machchakanta	2189	1671	1418	0	1.2	0.76
	Bayagunda	1755	3679	2321	2	1.6	2.10
	Gadakuta	1352	1524	961	2	1.6	1.13
	Barapanka	1643	3438	2533	2	1.4	2.09
	Kalachudi	1309	2562	2007	2	1.3	1.96
Medium land	Bodikaburi	1261	2838	1736	2	1.6	2.25
Upland	Pandakagura	393	1188	1178	0	1.01	3.02
	Paradhan	562	1028	622	1	1.7	1.83
	Matidhan	839	1199	1133	0	1.06	1.43

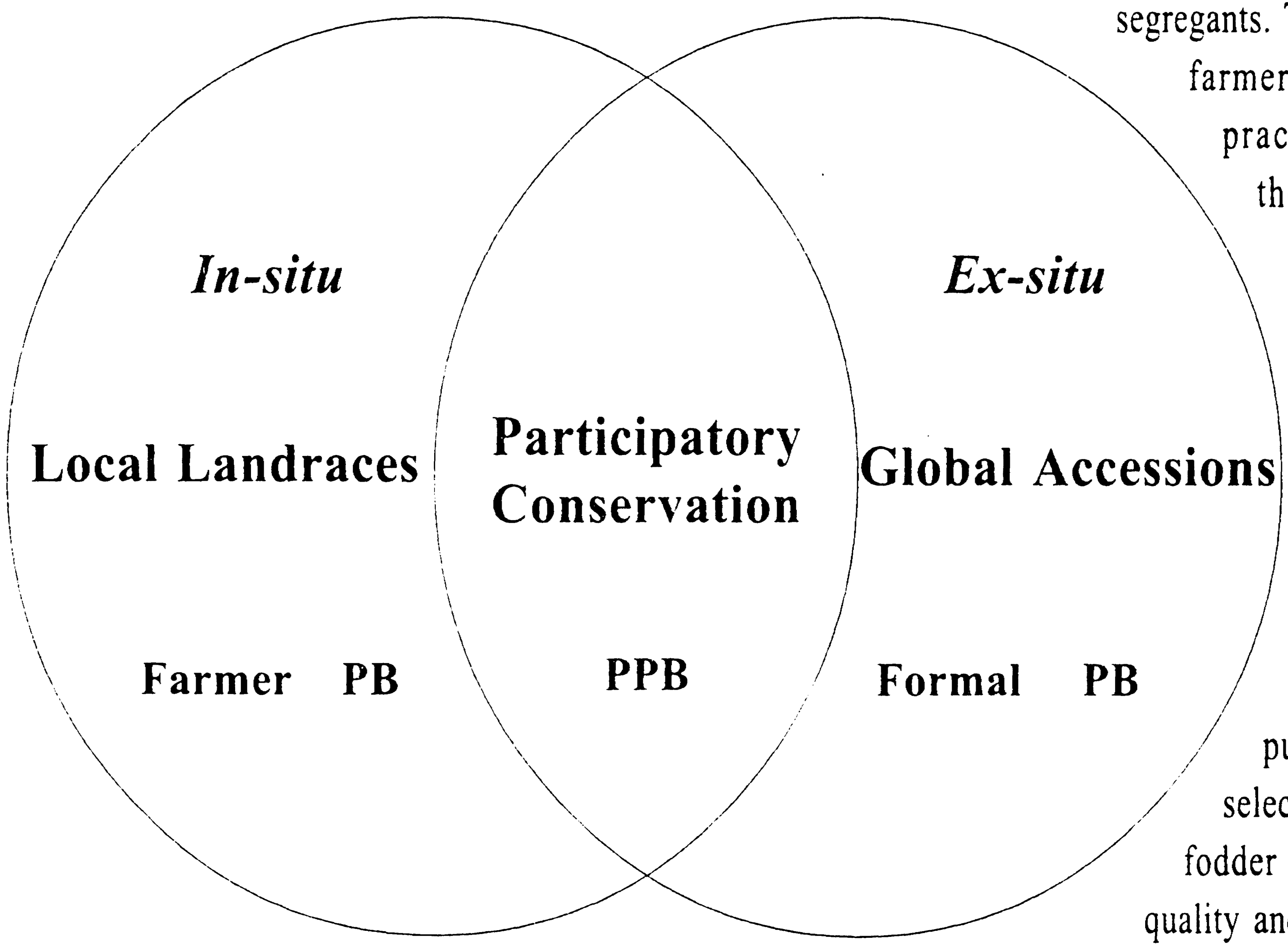
FO - Formal; FA - Farmer; FP - Yield in 1998; @ - No. of locations out of three in which significant differences were observed between formal and farmer plots

Table 4
Comparative benefits of formal over farmer practices in a participatory plant breeding experiment in the Jeypore tract.

of intersection between formal breeding techniques and particpatory (informal) ones (Figure 1; Arunachalam 1999). Based on published case studies (see, for example, Boef et al 1993; Eyzaguirre and Iwanaga 1996; Arunachalam 1998a, b; McGuire et al 1999) and our experience, the following participatory plant breeding options deserve an initial trial, and are being implemented with the participation of tribal farmers in Orissa.

- **Disruptive ecological selection**: No opportunities exist for tribal farmers to test local varieties adapted to one site at any other. Since there is a broad commonality in the type of land areas, climatic regime, and traditional practices of cultivation, it is possible that local varieties from one site may perform much better in another site. Such a "disruptive ecological selection" could become a safe short-term avenue for enhancement of production. For example, Veliyan, an improved variety grown for its grain yield by tribal farmers in Kerala, was found to do extremely well for fodder yield when introduced in the Jeypore district of Orissa during 1999. More confirmatory evidence from large-scale testing in farmer plots will be collected in future seasons.
- **Participatory genetic enhancement**: Genetic divergence between local landraces and varieties in various sites is large. This could be estimated and evaluated. Usually government mechanisms exist to release, for general cultivation, region-specific HYVs under assured inputs. Genetic enhancement may then aim at two types of initiating crosses: Local X Local and Local X HYV.

Figure 1
Participatory Conservation and Genetic Enhancement.



Local X Local cross is suggested to take advantage of substantial genetic diversity among the local cultivars and landraces. The recombinants from Local X Local crosses would be adapted to the target area and free from genotype X environment interaction. Depending on the choice of parents, preferably those genetically divergent for yield and farmer-preferred traits, this process can help to develop lines relatively higher in yield but with a range of traits meeting desired quality and consumer preference.

Local X HYV cross is a potential avenue to introgress, or to incorporate genetically, genes for high yield from the HYV while still retaining the desired quality traits of the local variety. Supporting evidence is found in a participatory plant breeding project on Bean in which a variety from a Local X HYV cross was ranked by farmers at the top on its preferred grain quality though it yielded lower than other HYVs (Kornegay et al 1997).

Participation in F1 seed production [F1 = a cross between two varieties]: The F1 seeds of such crosses can then be obtained on a participatory mode. Farmers, both men and women, can be trained in emasculation-pollination techniques. They would generate F1 seeds under scientific supervision. In addition to generating a large quantity of F1 seeds economically, the method would give a feel of scientific research participation to the farmers and enhance the chances of the sustainable and continued application of other participatory plant breeding methods.

Participatory Varietal Selection: Large F2 populations can then be grown in farmers' fields at several target areas and the farmers can be encouraged in selecting desirable segregants. This would provide a basic understanding of farmers' methods of selection. When farmers' practices were blended with established theoretical principles of selection, genetic advances could improve substantially. Such selection processes can also be continued through further generations to develop a site-adapted variety on a participatory mode.

Such participatory processes can also be extended to seed production—the development of visually and genetically pure, healthy, and well-filled seeds. Farmers select for "other" desired traits besides grain and fodder productivity. They also select for cooking quality and consumer preference. Their skill could be blended with scientific yardsticks of seed production, maintenance, and commercialization on a knowledge-sharing anvil. This would satisfy the quality seed requirements of farmers and also provide a mechanism for commercial profits. When firmly established, such avenues could be used to establish "seed villages" with a regular role of seed production and commercial distribution.

The Participatory Varietal Selection envisaged here differs from such a selection reported in published literature. The essential difference is that the tribal farmers experiment and select from populations (based on local varieties and landraces) that are adapted to their environment. This is a great advantage over material that is developed in the rich "controlled" environments (usually utilized in research institutions and universities) and then tested in poor (tribal) environments.

In the participatory plant breeding practices mentioned so far, site adaptation and varietal development using local germplasm are the main frame on which development software is mounted. Such practices exploit genotype X environment interaction favourably to ensure sustainability. Though these practices are farmer-friendly, they need to be meshed into a wider participatory conservation process. Only then can the twin goals of conservation and utilization be achieved in a synergistic mode.

WORKING FROM THE BOTTOM UP

Participatory conservation bridges farmer (indigenous) knowledge and formal (scientific) theory with the aim of improving conservation, sustainable use, and benefit sharing. Being stakeholders in benefit-sharing activities like participatory plant breeding and conservation activities, farmers have already learned, by tradition, the techniques of conserving their genetic resources taking into account vital plant characteristics, such as pollinating system, flowering time, tillering capacity, biomass accumulation, disease and pest incidence, seed size and maturity. Now is the time, though, to formalize their knowledge, so that it is recognized and used in such activities.

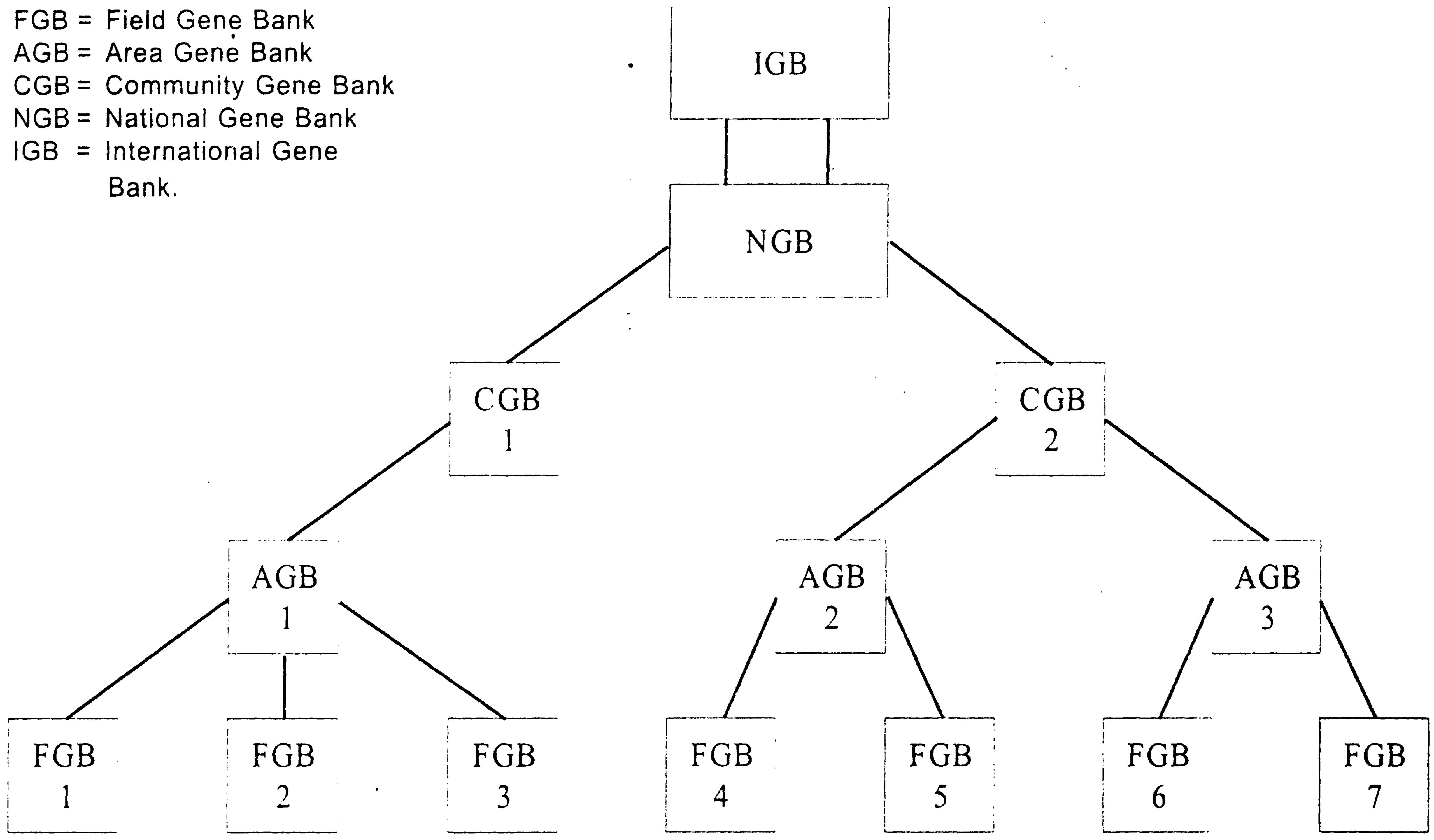
Here's how participatory conservation might work on a larger scale. Village bodies, such as village panchayats, could identify a few good plots on a rotational basis for growing germplasm specific to their locale and its growing conditions. If farmer plots were located with access to a nearby source of water like a pond, live irrigation channel, or lift irrigation, villages could then avoid crop failures due to scanty rainfall or uneven spread. There are a variety of other traditional small-scale water storage and conservation techniques that could be drawn upon. In such situations, the irrigation could be used as a back up. Germplasm to be conserved could then be planted in such plots, and a formal-farmer participatory effort would then ensure the harvest of high-quality type seeds of each germplasm accession. The seeds could be stored in a small structure such as a farmhouse that could be called a Field Gene Bank. Such field gene banks could be set up in each village or groups of villages, as convenient, and in tribal areas located in a high altitude, they would not even need temperature control because the climate would be cool enough to preserve seeds for a few seasons.

Scientists could train the farmers in keeping and updating records on ownership, passport data, and diagnostic traits of the varieties. The records would be of tremendous advantage in cases where decisions need to be made about the intellectual property rights associated with the variety should it become commercial. Field gene banks could be

Plant Breeding Basics

When you make a cross, you get the seed of first filial generation, F1. If grown again, it will give rise to F2 that will segregate into parental types and recombinant types. Hence we employ selection techniques. There are breeding processes to be followed to raise F3, F4, F5 generations etc. When recombinants are selected across generations to become high-yielding genetically uniform plants, their seeds can be bulked to get what is popularly know as a variety (HYV etc.). (Actually some varieties are genetically diverse, formed by open cross pollination.) The crossing of HYVs with varieties adapted to local environments, farming, and food/fodder uses, is one of the avenues discussed in this paper. The second avenue is true voluntary participation of farmers with scientists in carrying out varietal breeding by farmers in their fields in cooperation with scientists, rather than breeding varieties in rich controlled plots by non-farmers at sites often distant from where they will be used in the future.

Figure 2
Organizational Set-up of Participatory Conservation



of variable size depending on the sites and the number of germplasm accessions to be conserved. A few field gene banks could be linked to an Area Gene Bank (AGB).

The AGB could be managed by a committee made up of representatives from all contributing villages. This committee could also be vested with the conciliatory responsibility whenever intellectual property right issues or disputes crop up. If some local germplasm accessions were lost due to natural or other causes, the AGB could be a rescue seed source. These centres could also serve as genetic enhancement centres. At AGBs scientists and farmers could work in the area, hand in hand, to expand the utility of landraces and local varieties by generating high yielding populations (pure lines, mixtures, or open-pollinated varieties) carrying farmer-desired traits. They could even take up plant improvement based on specific molecular techniques, if adequate funding were made available. (The successful case histories of *Hevea* and Sugarcane employing "portable [molecular] laboratories" provide encouraging evidence for the latter idea [Lenaud and Lebot, 1997].) AGBs would also provide insurance in cases of long-term droughts and consequential seed variety losses.

Participatory conservation as conceived here would (a) provide a network to rescue and regenerate site-specific genetic resources and (b) make valuable genes available to participatory breeding efforts to enhance productivity. Thus both participatory conservation and plant breeding would help farmers by giving them avenues for secure and sustainable livelihoods.

The AGBs could, in turn, be linked to a Community Gene Bank. A Community Gene Bank would be located in a NGO or other institution serving the interests of the farmers contributing to the local field gene bank areas. It would be situated within the easy reach of AGBs and would be equipped with long and medium storage facilities and other documentation and networking channels. They would help in providing an indirect link between the very bottom level of conservation effort (the Field Gene Banks) and the National and International Gene Banks (See Figure 2). Participatory conservation with such a bottom-up approach has been acknowledged to provide singular benefits to farmers (Worede and Mekbib 1993).

From all of these concepts, case histories, views, and strategies—examined in the light of participatory action with farmers—I suggest that a biodiversity-friendly plan be piloted in identified genetically rich tribal/rural farmer sites. These sites should be within the reach of a research organization like a government institute, university or NGO. (See Figure 3 for a schematic representation of the plan.)

I have no doubt that the results would be favourable and would thus act as a catalyst for governments to replicate such plans in their countries. In the event of such a development, participatory paths to farmer prosperity will light up not only on the food front but on other spheres of their life as well.

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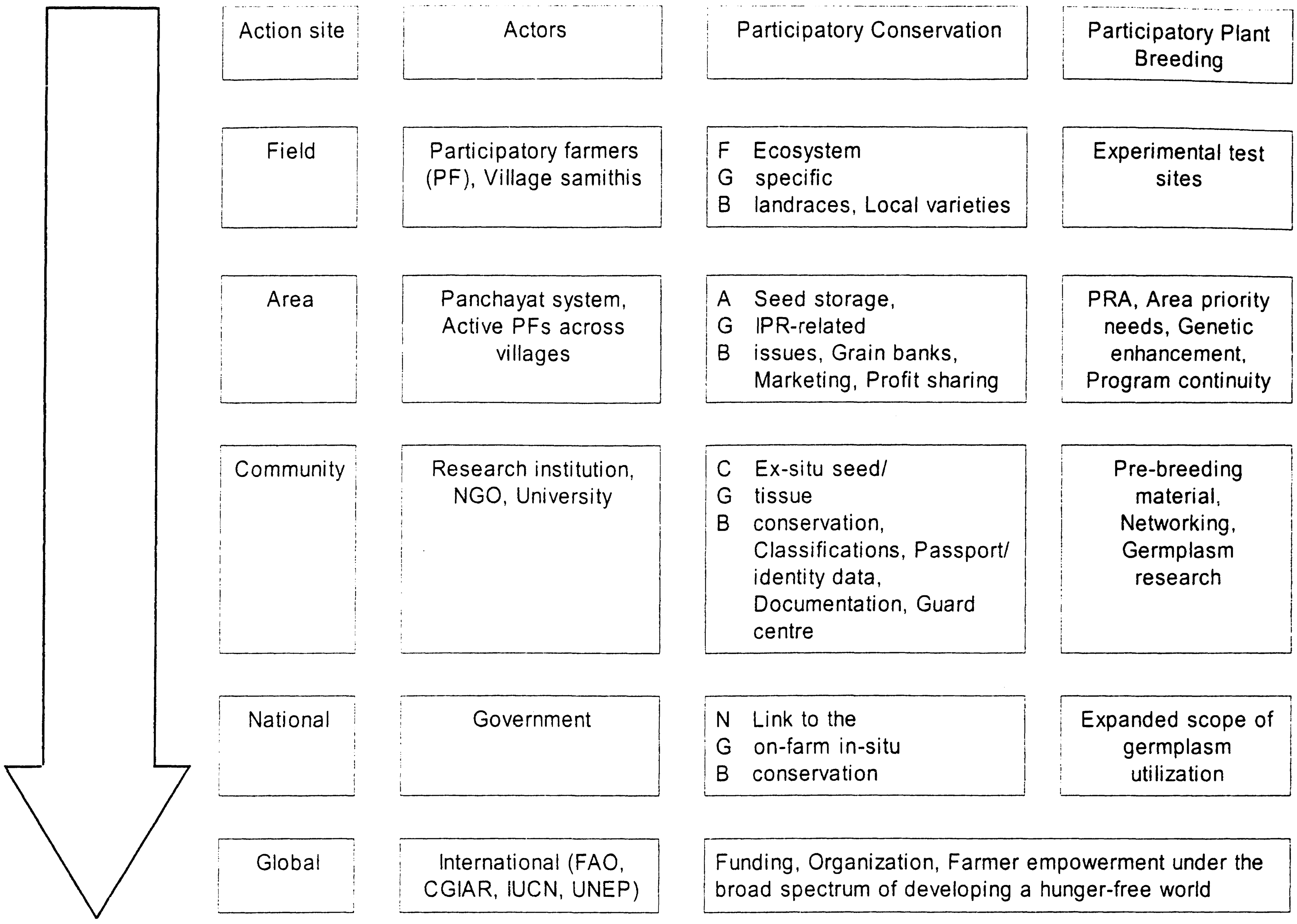

Figure 3
A possible biodiversity-friendly plan of action.

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Farmer and scientist jointly setting field layout for sowing Rice in Orissa.

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A tribal woman farmer with a farmer-raised Rice nursery showing early yellowing of plants. The inset picture shows poor plant growth from yellowed seedling.

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Farmers easily uprooting Rice seedlings from formal nursery in Orissa. The inset photo shows healthy seedlings.