Participatory Biodiversity Assessment

Enabling Rural Poor for Better Natural Resource Management

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Background

Biological diversity is the very foundation of human welfare. It hosts many species that supply products for food, medicine, building materials, cultural artifacts, genes for breeding programs and genetic technology, trade as well as for the processes and functions that support productive ecosystems. Biodiversity provides many opportunities for supporting or enhancing livelihoods, especially of poorer sections of the society. Communities on the margins of the market economy often depend far more on products harvested from the wild than richer groups for subsistence, barter and trade yet these resources are often undervalued in national accounting systems. Biodiversity also provides them crucial safety nets in the context of external shocks such as droughts, floods and collapse of market prices.

The Well Being of Nations report, published in cooperation with the International Union for Conservation of Nature and Natural Resources (IUCN), Switzerland in 2001, confirms that human and ecosystem wellbeing are intimately entwined, and validates the need to plan and manage ecosystem protection and human development simultaneously (Prescott-Allen 2001). The measures used by the report are unique in that they give equal weight to human development and environmental conservation in ranking the wellbeing of nations. Out of the 180 countries ranked, only 37 are close to striking a good balance between a healthy population and a healthy environment. But to truly achieve this balance all countries enjoying high standards of living must greatly improve their environmental efforts.

While only 2–10% of all the species on Earth are known to science, scientists recognize that full surveys of biodiversity are not feasible owing to time and resource constraints. They also recognize that even among scientists there is a lack of agreement about which assessment methodologies should be applied, and the various indicators that might act as proxies for biodiversity. This reflects not only the variety of biological context, and how to represent them within one assessment, but also differences in viewpoint about what is important (Lawrence 2002).

Much conventional biodiversity assessment (CBA) has been species-based but increasing attention is being paid to the functional aspects of biodiversity, enshrined in the 'Ecosystem Approach'. There are several methods for measuring genetic diversity; however, many of these remain costly and time-consuming and consequently are applied only in very specific contexts.

There are differing opinions in terms of the components of biodiversity that need to be focused. There is some participatory biodiversity assessment (PBA), all related to local management. The CBA provides a framework in which local and indigenous perspectives on biodiversity should be accommodated. To date more progress has been made with scientific biodiversity assessments because these are built on centuries of biological exploration methods. After the Earth Summit at Rio in 1992 the Global Biodiversity Assessment was initiated, and published in November 1995. This was an enormous job involving 13 teams of scientists, led by Vernon Heywood, and is described as 'an independent, critical, peer-reviewed, scientific analysis of all the current issues, theories and views regarding biodiversity, viewed from a global perspective.' Complementing the scientific focus of this book, another book entitled "Cultural and spiritual values of biodiversity" (edited by Darrell Posey) was published in 2000, representing an important step in recognizing ethnically differentiated perspectives in biodiversity.

Why Participatory Biodiversity Assessment?

There is a need for multiple indicators for biodiversity, including aspects of ecosystem function and services. The United Nations Environment Programme (UNEP), together with World Resources

Institute and other major international institutions, are now coordinating the Millennium Ecosystem Assessment which links biodiversity and ecosystem assessment, and recognizes the need for multi-scale, multi-stakeholder assessments. In addition to the focus on ecosystem assessment, there has been increasing interest in the involvement of non-scientists such as members of stakeholder communities, local and indigenous communities, and ethno-botanists in biodiversity assessment. Thus, PBA is increasingly being adopted to involve the stakeholder community in conserving the biodiversity.

Participatory biodiversity assessment provides a way of reconciling the need for national assessment, monitoring and reporting with increasing focus on involvement of all relevant stakeholders, particularly indigenous/local communities. Participatory biodiversity assessment, ie, biodiversity assessment by and with non-scientists can provide short-cuts to scientific assessments; provide data which is useful to local resource managers; establish links to access scientific information which is relevant to local needs; and enhance inclusiveness of decision-making.

There are different reasons for PBA, and varying information needs. Most national or regional decision makers expect information in quantitative, spatially comparable forms. Participatory processes may not supply this so readily (or efforts to quantify may distort local perceptions) but may provide qualitative information of different and complementary value. It is very important to match objectives with methods and stakeholders, rather than apply a blanket set of recommendations to all situations, which appear to need a participatory approach. Assessment is affected by value judgments, regardless of who is conducting the assessment. It is often assumed that local people value only useful species but research reveals spiritual, cultural and ethical values and that species or habitats with non-material values may be at least as important as those with uses.

Prerequisites for Participatory Biodiversity Assessment

Participatory approaches take more time and different skills compared with scientific surveys, but there are benefits that are worth this cost. The potential for real synergy between different actors depends not only on good communication but also on realistic understanding of the costs and benefits of involving different actors in such assessments, and above all ensuring that local people can take part in analysis and decision-making. The process of negotiating, observing and analyzing indicators may bring about more change than the data gathered itself, and in particular can enhance benefit-sharing as well as be more sustainable than externally led processes. However, to achieve this, changes in education, training of scientists and institutional networking are needed.

Participatory Biodiversity Assessment for Better Natural Resource Management

Since mid-1990s numerous watershed development projects came in operation throughout India. However, in majority of cases ecosystem approach was missing. The ecosystem approach is a strategy for integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. The term 'ecosystem' does not necessarily correspond to the term 'biom' or 'ecological zone' but can refer to any functioning unit at any scale (Ramakrishna et al. 2000). Development of about half of the 90-ha common grazing land in Govardhanpura under Thana watershed in Bundi district of eastern Rajasthan, India is an example of ecosystem approach through the participation of the local herders and grazers. This report summarizes the process the community adopted to restore the degraded common grazing land and delineates the methodology in getting the community to evaluate their collective endeavor through PBA technique.

The Setting

Thana, Govardhanpura and Gokulpura cluster of villages in Bundi district, eastern Rajasthan are covered under the Tata-ICRISAT-ICAR project "Combating Land Degradation and Increasing Productivity in Madhya Pradesh and Eastern Rajasthan" funded by Sir Dorabji Tata Trust, Mumbai, India. The soils here are degraded and represent shallow to medium deep clay loams and silt loams. The terrain is undulating and lands are highly degraded due to high grazing pressure in this hot semi-arid area. The total geographical area covered under this watershed is 1356 ha, of which forest area is 195 ha and common grazing land is 95 ha. Over time the common grazing land has degraded and is bereft of good quality fodder to support the ever-increasing population of livestock, the mainstay of livelihoods here. The only source of open grazing, the 95-ha common grazing land was so degraded that most fodder and grasses that grew there were neither palatable nor sufficient to the cattle.

The Process

BAIF Institute of Rural Development, an NGO that is implementing the project here initially recognized the problem and engaged the community to discuss about what could be done to improve the situation. The people reciprocated positively and agreed to part with half of the common grazing area for rehabilitation. The village stakeholder community consisting of grazers, herders and farmers through *panchayat*, resolved to erect stone fence around the 45-ha grazing land and not allow any cattle to graze in that area. Thus the area was fortified with physical and social fencing. The stakeholders agreed to take up rehabilitation of the grazing land in half the area initially so that the other half was accessible to common grazing. Villagers contributed their labor to erect stone fencing, and construct soil and rainwater conservation structures to arrest runoff and increase infiltration. Over 200 staggered trenches, 290 percolation pits and 6 gully plugs were constructed across the grazing land. Once the in situ rainwater harvesting structures were in place villagers planted useful grasses and saplings all over the area. The degradation was so severe that the mortality of the saplings was very high. Then came the idea of putting up stone bench terraces, contour trenches and catch pits for in situ moisture conservation. This resulted in excellent soil and moisture conservation and aided establishment of vegetation. Despite consecutive droughts from 2000 to 2003, the area turned lush green in stark contrast with gray area across the fence.

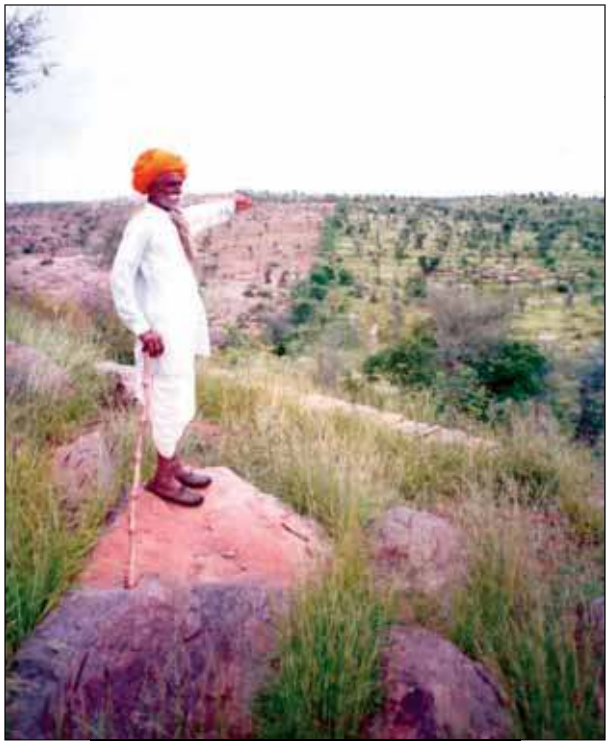

Figure 1. A villager showing the difference in vegetation on either side of the fence.

There was a perceptible improvement in the density of vegetation in the protected grazing land in contrast to the unprotected land (Fig. 1). The density of vegetation including grass has attracted many birds and animals to this part of the grazing land. Prominent among these are blue bulls. The effort of the villagers and the *panchayat* for over 6 years has brought out remarkable changes in the flora and fauna of this piece of land. The whole episode has brought out valuable learning for all

those involved in the project and helped enhance the confidence level of the villagers. It was precisely at this juncture that the project staff thought of getting the whole process recorded and evaluated by the very people who were instrumental in the success of the project. Thus came the idea of getting the villagers to assess the biodiversity in the rehabilitated grazing land in contrast with land not rehabilitated. The objectives of this exercise were to:

- Let the community know the worth of the efforts put in by collective action.
- Create an awareness in the community about the importance of community action in natural resource management.
- Create a sense of ownership among the community so that the conservation and management of natural resources by the community go beyond the project period.

The number of species of useful grasses and fodder has increased tremendously. Besides the flora, even the fauna was rehabilitated in this area. This area is a safe haven for nilgai [a species of wild cows (blue bulls)], adults and young ones. Rabbits, hares, jackals, foxes, mangooses and a host of bird species are found in this area. A biodiversity assessment was undertaken recently with the community participating actively in enumerating and listing the uses of the various herbs, shrubs and grasses that have been rehabilitated in this area (Fig. 2).

Figure 2. The PBA team with a blue bull calf.

Methodology

The entire area of 45 ha area was divided into six blocks considering the topography, soil type and vegetation in consultation with the project staff (Fig. 3). The project staff that had detailed information about the entire grazing area helped characterize the blocks. Besides, they also named each block to connote the best identification in the local dialect.

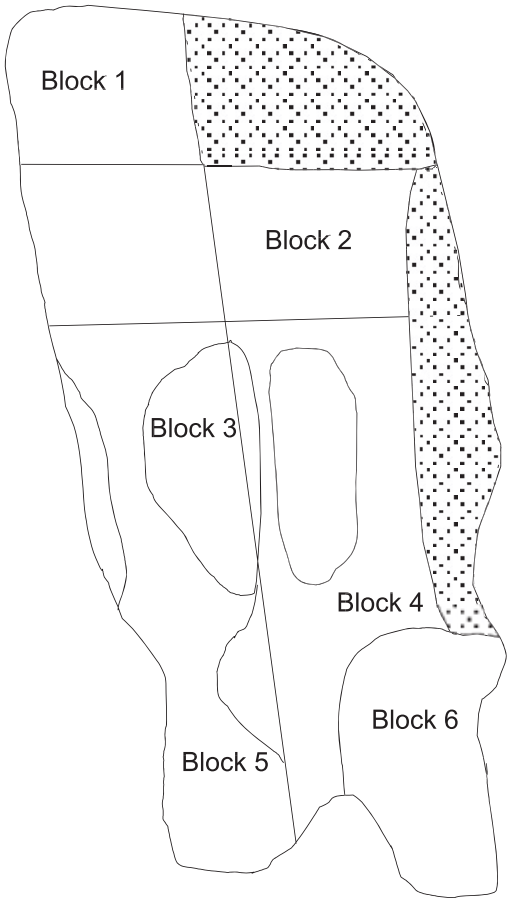

Figure 3. Sketch of rehabilitated grazing land.

Block 1: *Aadibali* is an elevated area with a gentle gradient on all sides. It has shallow soil spotted with white stones. The area is covered with mostly *dhaman* grass and the native *khejri* species.

Block 2: This is same as the above except that it has a gentle gradient.

Block 3: *Tapariwala Dhala Bardi* is a fairly flat land with shallow soil and white stones.

Block 4: *Nala Bardi* is a valley with a small stream running across it. It has fairly flat land with deep soils and good vegetation.

Block 5: *Dev Dungari* is a highly stony and steep hillock. It has very good cover of plants due to the stone bench terracing for in situ moisture conservation.

Block 6: *Lamdi Guddi* has sparse vegetation and has little or no soil on it. It has stone sheets running beneath.

After naming the blocks, the next step was to put peg marks around a prominent place in each block and write the block number near the peg so that the group concerned could go around for enumerating the plants in the area.

Six project staff and six villagers who had a fairly good knowledge about the local flora and fauna were grouped into a team of two members each. Each team consisted of a villager and a project staff and was randomly allotted to one block in the grazing land. The villager was administered a simple questionnaire (Appendix 1) by the project staff before setting out to enumerate the species in the block.

Once the farmers responded to the questionnaire, they were taken around the block assigned to the team (Fig. 4). The team spent over 4 hours going around the area, listing the names of herbs, shrubs and grasses and their uses. The details of the participatory survey are provided in Appendix 2. Besides this exercise, a group led by an ecologist carried out an independent assessment of the biodiversity assessment.

Figure 4. Villagers participating in PBA.

Assessment

For the purpose of the study, the biodiversity observed has been grouped as 'diversity above the ground' and 'diversity below the ground'. The aboveground biodiversity was assessed both by participatory methods as well as conventional methods. The results of participatory assessment of the biodiversity are presented as PBA outcome and those of conventional assessment are presented as CBA outcome. The findings of studies on below ground biodiversity are presented as 'diversity below the ground'.

PBA outcome

All the respondents agreed that the common grazing land was covered with local vegetation and that there was abundant grasses and fodder available in the area. They all felt that the reasons for its degradation were increased pressure of human and livestock population, frequent droughts, cutting of trees and no replanting and no protective measures from the community. All of them, however,

agreed that there was greater awareness about rehabilitation of degraded lands in the community. The villagers also suggested measures like erecting physical and social fencing and stall-feeding. They also suggested that the benefits of conservation initiatives should reach all the sections of the communities so that the community participates in such efforts.

CBA outcome

Since biodiversity is sum total of different kinds of diversities, eg, species diversity, genetic diversity, life form diversity, floristic diversity, functional diversity and cultured diversity, it was not possible to evaluate every constituent. To discuss biodiversity in present silvi-pasture we took floristic diversity and species diversity of woody and herbaceous vegetation and dominance-diversity (d–d) curves of herbaceous vegetation. Beta diversity (between habitat diversity), dominance concentration (Cd) and species diversity index (H') were calculated following Whittaker (1975), Simpson (1949) and Shannon and Wiener (1963), respectively. Also, an attempt was made to assess 'diversity below the ground', ie, soil microbial diversity, in the rehabilitated grazing land in contrast to the degraded land.

Floristic diversity

Because variety is "the spice of life", diversity must surely be a "good thing" (Moore 1985). In general, biodiversity obviously implies wealth of species (richness). But it also means that most of the species are fairly represented. The present developed silvi-pasture expressed reasonably good development of floristic diversity. Twenty species of woody taxa were enumerated in the area (including outside open land). Maximum number (25%) of species belonged to the family Leguminosae/Mimosoideae. Rest of the woody species (including those enumerated across the stone fence) were distributed among 11 families/sub-families. Thus, the woody species in the area were distributed among 12 families/sub-families.

Thirty-six herbaceous species were found in the rehabilitated grazing land. These were distributed among 24 families. Family Cyperaceae represented maximum percentage of herbaceous species. Rest of the families had either one or two herbaceous species. Thus, rehabilitated grazing land was rich in floristic diversity as it contained 54 plant species, while there were only 9 plant species in open degraded area.

Species diversity

Sagar and Singh (1999) considered species diversity as approximate proxy of biodiversity. Whether the term is 'biodiversity' or 'species diversity', it means, at first instance, in general, the number of different species found in a given area. However, when we talk of species diversity, it must take into account the relative abundance of all the different species. The species richness or alpha diversity is simply the number of species. The richness of woody species varied in different habitats on rehabilitated grazing land ranging from 3 to 11. Beta diversity for tree layer was found to be 2.2. When Cd and H' were worked for different habitats for woody species in developed silvi-pasture, an interesting picture emerged. Maximum Cd was observed on Guddi site, but the site also supports good diversity. Maximum H' was found on Eastern Upland site; however, the H' value was also comparable in Dev Dungari site. Minimum H' within the developed pasture was recorded on Entrance Gate-upland site. Perhaps due to main entrance point of this developed silvi-pasture, this site experienced some sort of biotic pressure, which in turn did not allow sufficient diversification of woody vegetation. The high Cd and low H' values on open degraded area reflected the heavy exploitation of woody biomass.

In case of herbaceous vegetation, species richness or alpha diversity varied from 13 on Guddi site to 20 on Plain Land site within the developed silvi-pasture. Beta diversity of herbaceous vegetation was 2.32. Within the developed silvi-pasture, Cd was maximum on Plain Land site and surprisingly this site had also highest species diversity. The very high numbers of herbaceous species were responsible for such high diversity. In general, all the sites/habitats of developed silvi-pasture had H' value >3.0. On open degraded land Cd value was relatively much higher and value of H' was relatively quite low. This indicated the heavy degradation of herbaceous vegetation outside the developed pasture. Moore (1985) stated that micro-climate substantially affects the species diversity and further emphasized that even little variation in micro-climate is enough to alter diversity patterns in small areas (like that of present developed silvi-pasture at Bundi watershed). Plain Land site, which was located in little depression, supported maximum herbaceous biomass as well as species diversity. It was obvious that due to better topographical situation and maximum runoff retention zone, this site has the ability to retain moisture for longer period and that too in good quantity, which in turn provided conducive conditions for better germination, growth and development of herbaceous vegetation. On an average, the species diversity was 3.437 and Cd was 0.124. These values clearly reflected a very high degree of diversification of herbaceous vegetation on entire developed silvi-pasture.

Dominance-diversity curves

Dominance-diversity curves were developed for herbaceous vegetation on the basis of relative biomass values for all the sites and also for open degraded land. With exception of Open Degraded Land site, the d-d curves on all the sites exhibited similar log normal distribution. This indicated that several herbaceous species were sharing relatively low importance values (biomass) or similar range of importance values. The log normal or curves approaching to log normal, in fact, indicate relatively stable population. The d-d curve of Open Degraded Land site is more closer to geometric series. Whittaker (1972) opined that communities having low diversity exhibit geometric series. In open degraded land ruthless exploitation of herbaceous vegetation has resulted in tremendous loss of biodiversity.

Biodiversity below ground (microbial biodiversity)

Undifferential biomass carbon (C) and nitrogen (N) is a direct measure of soil biological activity. In this study, biomass C and N were estimated using chloroform fumigation and incubation method (CFIM) using top 15 cm depth soil samples collected from developed and normal control area. The diversity below the soil was assessed by collecting samples from 0–15 cm layer of the ground from both the degraded and rehabilitated areas of the grazing land. Soil samples from the degraded lands were collected from outside of the rehabilitated part of the grazing area. Each category of samples represents approximately 50 × 50 m^2. The total number of bacteria, fungi and actinomycetes and biomass C and N were estimated in the soil samples collected.

Media

Different media were used for the estimation of microbial populations like bacteria (nutrient agar), fungi [potato dextrose agar (PDA)] and actinomycetes (actinomycetes isolation agar, HI-media). These media were prepared according to their composition and were sterilized in the autoclave at 121°C under 15 lb pressure $inch^{-2}$. After sterilization these media were dispersed into disposable petri

plates (100 mm diameter × 15 mm height) for solidification by observing the following method:

- 10 g soil sample was weighed, added to sterile 90 ml blank and placed in the shaker for 45 min to obtain 10^{-1} dilution.
- After 45 min the 90 ml blanks were removed and further diluted to 10^{-6} by serial dilution technique for enumeration of microorganisms following spread plate method.
- Microorganisms were enumerated using dilution and plate method by spreading 0.1 ml of desired dilution on the media surface using sterilized glass triangle.
- The inoculated plates were incubated in an inverted position at specified temperature and duration (Table 1).
- After incubation colony forming units (cfu) were estimated and were calculated per gram of the soil.

Table 1. Temperature and incubation period for different organisms.

Organism	Incubation temperature (°C)	Period (days)
Bacteria	25	3
Fungi	25	5
Actinomycetes	30	14

Characterization of bacteria

Out of all these samples collected few samples (group Y, group S and 6 NTGC) were selected and were checked for bacterial diversity. Colonies having different morphologies in the plates were selected. These isolates were considered to be pure strain after three consecutive transfers without the evidence of other microorganisms. These isolates were given accession numbers and were exposed to different staining techniques and biochemical tests to identify the genus they belonged to.

Pure cultures were transferred to nutrient agar slants with accession numbers and were stored at 4°C in the refrigerator. The bacteria were then isolated on nutrient agar plates from the slants. All microscopic slides prepared were studied at 40x and 100x under Axioskop 2 Routine Microscope (ZEISS).

Characterization of fungi

Soil samples were assessed for the counts of fungi and the colonies were isolated and were purified by repeated plating. The colonies isolated were studied for the identification of the genera and the species. The microscopic slides for fungi were prepared by picking up the necessary portion of hyphae, conidiophores and other relevant structures and were studied under Axioskop 2 Routine Microscope (ZEISS). Temporary mounts were made in cotton blue lactophenol (SD Fine Chem Limited, Mumbai) and warmed on a heater to drive away air bubbles. The slides were sealed with quick fix. Each slide was labeled and was given accession number and was observed under the microscope.

Pure cultures were transferred to PDA slants with accession numbers and were stored at 4°C in the refrigerator. Fungi were isolated on PDA plates from the slants. All microscopic slides prepared were studied and photographed (MC 80 DX Microscope Camera) at 40x and 100x. These slides were preserved in slide boxes to prevent them from dust.

Results and Discussion

Microbial biomass C in soil samples collected from developed/treated rehabilitated area was 460 µg C g^{-1} soil which is 32% higher than the biomass C in soil samples from untreated/degraded common grazing area. Similarly biomass N was also 37% higher (37.8 µg N g^{-1} soil) in rehabilitated area soil samples than the biomass N content in soil samples from degraded common grazing lands (Table 2). Biomass C and biomass N values for rehabilitated sites were 32% and 37% higher when compared to those in degraded sites.

Table 2. Biological parameters in soil samples collected from rehabilitated and degraded grazing lands.

Parameters	Soils in rehabilitated area	Soils in degraded area
Biomass C (µg C g^{-1} soil)	460.1	287.8
Biomass N (µg N g^{-1} soil)	37.8	25.4
Bacteria (cfu g^{-1} soil)	10×10^4	88×10^4
Fungi (cfu g^{-1} soil)	37×10^3	15×10^2
Actinomycetes (cfu g^{-1} soil)	57×10^3	35×10^3

The population of bacteria (10×10^4 cfu g^{-1} soil) when compared with that of actinomycetes (57×10^3 cfu g^{-1} of soil) and fungi (37×10^2 cfu g^{-1} soil) in the rehabilitated grazing lands was 43% to 96% higher than that in the samples obtained from degraded grazing land (Table 2). The population of bacteria was 12% higher in the samples obtained from rehabilitated grazing lands than that in soil samples of degraded grazing lands. Population of fungi was 59% higher in rehabilitated grazing lands than in the degraded grazing lands. Population of actinomycetes was 39% higher in rehabilitated grazing lands than in degraded grazing lands (Table 2).

Bacteria

Soils in rehabilitated area

Isolates from soil samples collected from rehabilitated grazing lands recorded higher diversity than those observed in the soil samples of degraded grazing land. A total of 21 strains were isolated from the soil samples of rehabilitated grazing lands, purified and assigned lab identification. All the isolates from rehabilitated grazing land were gram negative with a majority of them in bacilli category (52% of the isolates were bacilli, 28% were coccobacilli, 3 isolates were bacilli in chains and 1 isolate was cocci) and 86% of the isolates showed capsule-forming capacity.

Extracellular enzymatic activities were also tested for all these isolates. Reports indicated that 91% of isolates were positive for the production of amylase and catalase. This was followed by gelatin production (86%), caseinase (47%) and urease hydrolysis (19%) (Table 3).

To predict the presence of *Enterobacteriaceae* family IMViC tests (indole, methyl red, Voges-Proskauer, citrate utilization test) were performed. All the 21 isolates reported negative for indole production. Only 14% of isolates reported positive for the production of strong acids from glucose (methyl red test). Eight isolates reported positive for the presence of diacetyl, the oxidation product of acetoin. Citrate utilization test reported 57% of the strains positive.

Production of hydrogen sulfide was not observed for any of the isolates. Test for motility reported 62% isolates were motile. To check the fermentation carried out by bacteria, triple sugar ion test was performed and majority of the isolates utilized sucrose/lactose (47%) as a carbohydrate source followed by glucose (42%). Only one isolate could not ferment any of these three sugars.

Soils in degraded area

A total of 18 isolates were obtained from the samples and were purified and assigned lab identification. External morphology of all these isolates were recorded and exposed to staining methods. Staining reports indicate that all the isolates were gram negative with majority of them bacilli (73%), followed by coccobacilli (16%) and cocci (11%). Of the 18 isolates, only 27% reported positive for the capsule formation.

Different biochemical tests performed with these isolates revealed that 94% of these isolates were positive for catalase production and 33% for starch, casein and urease hydrolysis. Only 22% organisms were positive for gelatin hydrolysis. No isolate was reported positive for the indole test. Of the isolates, a higher percentage (44%) of organisms was positive for the citrate utilization (IMViC test), followed by presence of diacetyl (38%), the oxidation product of acetoin (Voges-Proskauer test), and 27% of organisms reported the production of strong acids from glucose (methyl red test).

Motile organisms were higher in these soil samples (77%) than in the soil samples of rehabilitated grazing land (62%). Isolates utilizing sucrose/lactose as the carbohydrate source were higher (50%) in these samples. Only 5% of isolates could not utilize any of these three sugars (Table 3).

Table 3. Biochemical analysis of soil samples collected from rehabilitated and degraded grazing lands.

	% of +ve isolates for the biochemical tests performed	
Parameters	Rehabilitated area (21 isolates)	Degraded area (18 isolates)
Amylase production (Starch hydrolysis)	91	33
Caseinase (Casein hydrolysis)	47	33
Urease hydrolysis	19	33
Gelatin production	86	22
Catalase production	91	94
Indole production	–[1]	–[1]
Methyl red test	14	27
Voges-Proskauer	38	38
Citrate utilization	57	44
Production of hydrogen sulfide	–[1]	–[1]
Motility test	62	77
Glucose utilization	42	44
Sucrose/lactose utilization	47	50

1. All the isolates were negative.

Fungi

A very good diversity of genera was observed in the soil samples collected from rehabilitated grazing land in contrast to that in the samples of degraded grazing land. *Aspergillus* (32% g^{-1} soil) was the predominant genus followed by *Penicillium* (25% g^{-1} soil) whereas other genera like *Absidia*, *Alternaria*, *Badarisama*, *Cladosporium*, *Fusarium*, etc constituted 30%.

Torula and *Periconia* isolated from soil samples of rehabilitated grazing land were mostly found on decaying plant debris and other plant materials. *Trichoderma*, which is known for its antibiotic properties, was also isolated from soil samples of rehabilitated grazing land. *Trichoderma* controls many seedborne and soilborne pathogens. The abundant occurrence of this fungus is suggestive of new industrial applications particularly in the agricultural industries (Vasant Rao et al. 2004). *Stachybotrys*, which is isolated mostly from wet degrading plant materials, was also isolated from these soil samples. *Aspergillus* is used to produce enzymes in many industries. *Penicillium* produces mycotoxins as well as antibiotics.

Common species of fungi were observed in the soil samples of degraded grazing land. *Aspergillus* was the most predominant among them. However, higher species diversity within *Aspergillus* was observed in the samples of degraded land. Over 70% fungi consisted of *Aspergillus* while other genera like *Alternaria*, *Cladosporium*, *Fusarium*, *Mucor* and *Penicillium* accounted for the rest. List of species isolated is given in Appendix 3.

Further Initiatives

More emphasis is needed to empower the community by blending local knowledge with better biodiversity protection and management techniques. Community-level biodiversity centers need to take charge of education and empowerment of the rural poor who depend on the natural resources for their livelihoods.

Identification of native bacteria and fungi could provide important insights into the transformation of C, N, sulfur and other nutrients. Additional long-term benefits of this research could include discovering a biological control for soilborne pathogens or detecting beneficial strains that encourage plant growth. A better understanding of soil biota will enable farmers to depend less on modification of the natural environment and place greater emphasis on using biological processes to optimize nutrient cycling, minimize the use of purchased inputs and maximize the efficiency of their use. However, molecular techniques and the application of functional gene probes now offer the opportunity for rapid gains in evolutionary, ecological and biodiversity knowledge.

Soil-living organisms also play a key role in the release of carbon dioxide, methane and other greenhouse gases from the land to the atmosphere. Understanding and unraveling the role of these humble creatures and life forms in the so-called "carbon cycle" may help the land absorb more greenhouse gases.

Summary

In traditional rural setting of the country almost in majority of villages or in cluster of few nearby villages, village folk maintain a part of land for grazing livestock. The grazing lands are essentially common pool resources (CPRs) that are on the brink of degradation. However, due to ever increasing anthropogenic pressure throughout the country, common grazing lands are degraded in every part of the country to an alarming state.

Looking at the functional attributes of such CPRs, about 45 ha grazing land has been developed at Bundi watershed under Tata-ICRISAT-ICAR Project. Results of enumeration of floristic diversity, assessment of species diversity indices and development of d-d curves clearly pointed towards the tremendous enhancement of aboveground plant biodiversity in the rehabilitated grazing land. As open degraded land and rehabilitated pasture belong to the same land formation, the loss of biodiversity of

aboveground vegetation on open land is the outcome of continuous degradation of vegetal resources due to tremendous biotic and abiotic pressure, and partly also due to inappropriate management. The grazing land at Bundi watershed was rehabilitated through community participation right from inception. The community and scientists together assessed the impact of the participatory biodiversity conservation and found that there was a very significant improvement in the diversity of flora in the rehabilitated grazing land. This exercise was gratifying to the entire stakeholder community including scientists.

The bacterial isolates from the rehabilitated and degraded grazing lands were tentatively identified as organisms, which belong to the genera *Azatobacter*, *Rhizobium*, *Pseudomonas*, *Xanthomonas*, *Enterobacter*, *Azospirillum*, *Streptomyces*, *Bradyrhizobium*, *Nitrosomonas*, *Nitrobacter*, *Klebsiella*, *Erwinia* and *Serratia*. Higher diversity was observed with the fungi isolated from these soil samples. The occurrence of *Aspergillus* species was high both in degraded and rehabilitated grazing lands. Diversity of genera was more in rehabilitated grazing land. This may be due to the reduction in soil degradation as a result of the measures adopted in this area. The microbial population in general was also high in rehabilitated grazing land.

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Appendix 1: Questionnaire on PBA to Village Elders

1. Can you identify the useful plants growing in this area?

Name of the plant (as told by the respondent)	Uses
a	
b	
c	
d	
e	

2. How was this area in terms of vegetal cover about 20–25 years ago?

3. Can you remember the names of useful plants and animals that existed then?

Name of the plants	Uses	Name of the animals

4. What in your opinion are the causes of degradation of the vegetation?
   a
   b
   c
   d

5. Do you believe that such efforts of conservation can change the situation for better?
   Yes/No

6. If yes, what are your suggestions for future course of action?
   a
   b
   c
   d

Appendix 2: Local and Botanical Names of Plants

Local name	Botanical name	Use
Khejri	*Prosopis cineraria*	Fodder, timber and fuel
Kher	*Capporil decidua*	Fodder
Neem	*Azadirachta indica*	Fodder, medicine and timber
Dhallar	*Dichrostachys cinerea*	Fuel
Khair	*Acacia catechu*	Fodder and timber
Dhokada	*Anogeissus latifolia*	Prepare agri-implements
Goya	To be identified	Fodder
Dasoon	To be identified	Prepare agri-implements
Sailooni	To be identified	Prepare agri-implements
Khejada	*Acacia leucopholia*	Bullock cart part
Subabul	*Leucaena leucocephala*	Fodder and fuel
Sisam	*Dalbergia sissoo*	Timber
Lapada	*Aristidia funiculata*	Fodder
Charchada	To be identified	Fence
Aandhi jhada	To be identified	Anti-venom
Doodhi	*Euphorbia lirta*	Fodder
Jaal	To be identified	Medicine
Ber	*Ziziphus* spp	Fruit and fodder
Pattar suli	To be identified	Fodder
Dhaman ghas	*Cenchrus setigerus*	Fodder
Koli kanda	To be identified	Medicine
Malich ghas	To be identified	Fodder
Ksheen ghas	To be identified	Fodder
Chidiya ki kakadi	To be identified	Wild fruit
Chirphoti	*Physalis minima*	Fence

Appendix 3: Fungi Isolated from Soil Samples Collected from Degraded and Rehabilitated Areas

Degraded area	Rehabilitated area
Alternaria alternata	*Absidia cylindrospora*
Aspergillus aculeatus	*Alternaria citri*
Aspergillus amstelodami	*Aspergillus cervinus*
Aspergillus caespitosus	*Aspergillus foetidus*
Aspergillus cervinus	*Aspergillus fumigatus*
Aspergillus fischri	*Aspergillus niger*
Aspergillus fumigatus	*Aspergillus sclerotiorum*
Aspergillus nidulans	*Aspergillus terreus*
Aspergillus niger	*Badarisama sojae*
Aspergillus niveus	*Cladosporium cladosporioides*
Aspergillus ochraceous	*Cladosporium herbarum*
Aspergillus repens	*Cladosporium sphaerospermum*
Aspergillus sclerotiorum	*Drechslera papendorffi*
Aspergillus sydowii	*Fusarium semitectum*
Aspergillus terreus	*Fusarium solani*
Cladosporium herbarum	*Gilmaniella humicola*
Fusarium tabasium	*Mucor racemosus*
Mucor racemosus	*Mucor rouxianus*
Penicillium chrysogenum	*Penicillium chrysogenum*
Penicillium thomii	*Penicillium citrinum*
	Penicillium miczynskii
	Penicillium thomii
	Periconia clitoriae
	Rhizopus nigricans
	Scopulariopsis brevicaulis
	Stachybotrys pulchera
	Syncephalastrum racemosum
	Thermomyces lanuginosus
	Torula teristris
	Trichoderma koningii
	Trichoderma viride