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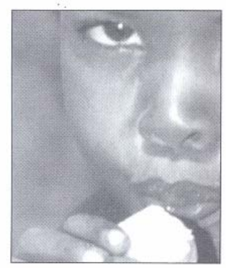

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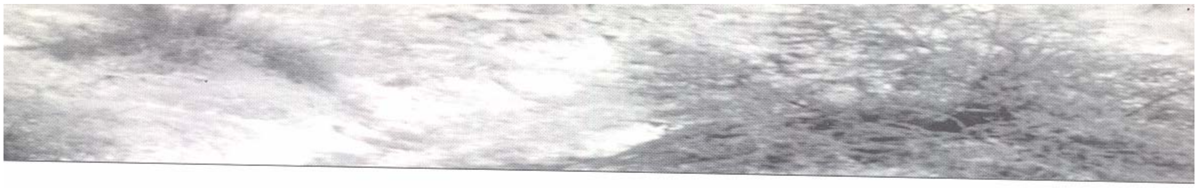


Agroforestry in watershed management:

Adoption and economic perspective from the central plateau and hills region of India

C.R. Hazra and Dipankar Saha

Faced with unproductive soils, rocky and degraded terrain, a community in Uttar Pradesh State of India has made nearly uninhabitable land productive using simple agroforestry technologies. The result? More farm produce to eat and sell, an increasing awareness about conservation, and a mushrooming of rural-based industries.

The collapse of traditional village institutions and the absence of a national policy on common lands have accelerated the degradation process

Estimates are that about 175 million hectares—53 percent of land—in India is severely eroded and degraded (Mukherjee and others 1985). The area subject to water erosion is about 111 million hectares, and 39 million hectares is affected by wind erosion. Another 25 million is also affected and degraded by agents such as waterlogging (6 million), ravines and gullies (4 million), shifting cultivation (4.4 million) and riverine torrents (2.7 million). Indiscriminate use of land resources and deforestation are the major driving forces behind destruction. Reports indicate that through soil and water erosion, the country loses over 8.4 million metric tons of soil nutrients annually.

The central plateau and hills region of Uttar Pradesh State in India is an agroecological zone rich in biodiversity. Geologically the whole region is made up of coarse-grained rocks. The formation consists of massive granite rocks traversed by gigantic quartz reefs that make up the hill ranges. The terrain is undulating with rocky outcrops, with considerable variation in soil type, colour (often red), texture and depth. The climate is semi-arid with a mean annual precipitation of 900–1000 mm that is highly erratic, and evapotranspiration is high (1516 mm). Over 90 percent of the annual precipitation is received between mid-June and mid-September. The region is subject to erratic rainfall and periodic drought, especially affecting steep, barren slopes where runoff is high.

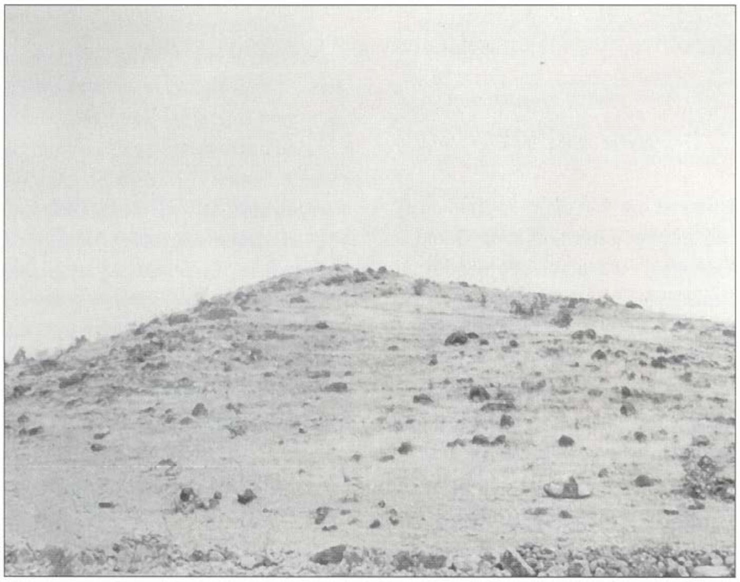
The forests are transitional between the southern and the northern tropical dry deciduous forests (Champion and Seth 1968). Four main subtypes are found in the region:

- dry teak forest
- *Anogeissus pendula* forest
- *Anogeissus pendula* scrub forest
- southern and northern dry mixed deciduous forest

The problem

In our studied watershed area the *Anogeissus pendula* forest and *A. pendula* scrub forests are the characteristic vegetation in association with species such as *Acacia catechu, Anogeissus latifolia, Lagerstroemia parviflora, Diospyros tomentosa, Aegle marmelos, Bauhinia racemosa* and *Butea monosperma* in the former and *Ziziphus xylopyrus, Butea monosperma, Acacia catechu, Cassia carandus, Holarrhena antidysenterica* and *Nyctanthes arbor-tristis* in the latter.

Increasing population coupled with unemployment and poverty has imposed a lot of stress on the land and vegetation resources of this region, and the natural resources have deteriorated markedly. Further, the collapse of traditional village institu-



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Increasing population, overexploitation of natural resources and poverty resulted in highly degraded hills at Kharaiya Nala watershed.

tions and the absence of a national policy on common lands have accelerated the degradation process. In summer, hills and hillocks are virtually bereft of vegetation, particularly of any trees or shrubs, and one is struck by the brown and arid landscape of the region. When the monsoon breaks on these bare hills and hillocks, which were once forestlands or are common lands, coarse soil particles and scree wash down onto the agricultural land below. Over the years, the deposits of scree from hill slopes have adversely affected the productivity of previously fertile agricultural lands, sometimes making them unfit for cultivation. Such sediment measured at a few locations had reached a depth of 36 cm (Hazra and Singh 1992).

Because the forest has been destroyed, the land is no longer able to store the rains as they fall, which would provide a steady supply of water. Accordingly, an approach to land management has been adopted that aims to improve the watershed, with agroforestry integrated as one component of the management system. The aim is to green the village common lands.

A community approach

In one effort to do this, a watershed (5395 hectares) was evaluated that consisted of seven microwatersheds in the Kharaiya Nala (a catchment area with small streams), situated 50 km from Jhansi City. In these seven microwatersheds, the extent of privately owned degraded land ranged from 36 to 63 hectares and common lands from 20 to 340 hectares. The area was chosen because its crop productivity was low; the demand for fodder, fuelwood and small timber was greater than the area could supply; and the need was great to relieve pressure on the little forestland that remained, which was already highly degraded.

A holistic strategy of village resource development was adopted, based on an understanding of the socioecology of the region and local village communities. It embraced taking measures to conserve soil and water, improving crop production through better technology, regenerating the hills and hillocks that constituted the village common lands, and creating a management plan that would be able to institute these changes. The aim was to create both a much-needed natural resource base and avenues for self-employment for rural poor and marginal farmers. The steps taken at each microwatershed were based on the natural resource data available and on fieldwork ascertaining the Village Resource Management Committee's views regarding choice of species to be planted, the kind of soil and water conservation measures to be adopted in agricultural fields, the arrangement to be made for protecting and managing rehabilitated common lands, and the likely benefits that would accrue to the community. The watershed plans were put into action, starting from the crest of a hill that sloped

(8 to 30 percent) down to agricultural land. Soil and water conservation measures were applied to the entire watershed area.

Staggered contour trenches were dug on the hillslopes for moisture conservation, each trench being 3 m long, 45 cm wide and 40 cm deep. The distance between trenches was 3 m. Where soil depth was not adequate for making trenches, larger planting pits of 60 x 60 cm were dug. The gullies were treated with loose rubble check-dams or by gully plugs planted with *Agave sisalana*.

Check dams are also called stop dams or anicuts, and are walls constructed with earth or bricks and cement across the deep gullies or small streams for the purpose of collecting and storing rainwater or run-off water. Similarly, gully plugs are also made of soil usually constructed across the embankments blocking the active and erosion-prone gullies in order to stabilize them. Vegetation is allowed to grow in the gully beds reducing silt load going down stream. This helps in water retention and storage in the gully beds.

At suitable locations in the gully beds, pits 3 m long, 2 m wide and 1 m deep were also made for water harvesting.

In addition to tending rootstock of different tree species naturally growing in the area, suitable exotics were planted to enrich the flora in the area: *Emblica officinalis* (aonla), *Albizia lebbek* (siras), *Aegle marmelos* (bel), *Morus alba* (shahtut), *Azadirachta indica* (neem), *Derris indica* (syn), *Pongamia pinnata* (karanj), *Leucaena leucocephala* (subabul), *Carissa carandus* (karonda). The space in between the rows of staggered trenches was seeded with grasses and legumes like *Cenchrus ciliaris* (anjan), *Pennisetum pedicellatum* (dinanath grass), *Sehima nervosum* (pavan), *Chrysopogon fulvus* (phulwa) *and Stylosanthes hamata.*

All agricultural fields were treated with soil and moisture conservation measures such as contour bunding, submergence bunds and field bunds on contours. Grasses along with trees were planted on field bunds and gully plugs. To augment their income, villagers took up fish farming wherever surface water collected in suitable pools. To stop the migration of the landless poor to urban areas, the project network included a training component. Villagers were taught how to make baskets from branchlets of Lantana camara, which is locally plentiful, and plates from leaves of the tree Butea monosperma.

Villagers were taught how to make baskets from branchlets of Lantana camara

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Seven years later, through soil and water conservation measures and agroforestry practices, the degraded hills at the Kharaiya Nala watershed had been rehabilitated.

Many benefits

The effect of regenerating the vegetation on hillslopes by taking measures to conserve soil and water is clearly shown by the reduction in water loss from runoff, soil loss and sediment yield (table 1). Tree species like *Leucaena leucocephala, Hardwickia binata* and *Acacia nilotica* were found useful for improving degraded soils through silvipastoral practices in this red soil of central India (Hazra 1992, 1994). Grasses like *Cenchrus ciliaris* and legumes like *Stylosanthes hamata* and *Clitoria ternatea* are successfully grown in association with trees (Hazra and Saha 1998). Although the herbage yield from grass and legume pasture (without trees) was higher than yield recorded under silvopasture, the overall soil productivity was much better with silvopasture (table 2). A small addition of nitrogenous fertilizer (20 to 40 kg of nitrogen per hectare) helped to a great extent to produce the higher herbage yield (table 3). Adopting soil and water conservation measures coupled with afforestation on ridges not only helped conserve soil and water; it also significantly contributed towards augmenting both surface and ground water available in the agricultural lands. The water table rose to an average of 6 m in the initial years of watershed development. The table level was subsequently maintained at a depth of between 2 and 9 m, depending upon the season and how much water was used for irrigation. Before, the depth of water table ranged from 6 to 15 m. The overall increased availability of water for irrigation led to increasing the cropped area by 25 percent, and consequently, cropping intensity increased by 69 to 172 percent. Crop yield was substantially increased, to 5.2 metric tons per hectare per year. Productivity of individual crops increased by 200 to 600 percent. Similarly, the amount of fodder available annually increased to 17 980 metric tons—in contrast to the previous 5648 metric tons.

The water table rose to an average of 6 m in the initial years of watershed development

After fodder and feed resources improved, composition in livestock species changed dramatically (table 4). Increased buffalo population coupled with improved feed and fodder resources almost doubled milk production in the watershed area. Planting in village common lands greatly helped the villagers meet their fuelwood requirement. The amount of fuelwood available annually before the watershed development activities were initiated was 319 metric tons in the watershed, which was only 11 percent of what the villagers required. But it greatly improved to an annual, sustainable harvest of 2443 metric tons from the third year onwards.

The ecological benefit that has accrued from this network can be summed up as 1) reduction in runoff water, soil loss and sediment yield from hills, hillocks and wastelands, 2) rise in the groundwater table, 3) increase in crop productivity and cropping intensity, 4) increase in forage and firewood production from field bunds and common lands, 5) change in livestock composition (40% reduction in milch cattle; 120 percent increase in female buffalo; and a decrease in sheep and goat population by 62 percent because of lack of free grazing land), and as an added bonus, 6) increase in farmyard manure that could be used as biomanure.

Table 1. Runoff water loss (percentage of annual rainfall), soil loss (metric tons per hectare per year), and sediment yield (metres) before and after treatment

Characters	Before treatment	After treatment First year	Second year	Third year
Runoff water loss				
Barren hills & hillocks	70	52	35	22
Foothills	48	30	23	16
Soil loss				
Barren hills & hillocks	41.0	18.5	9.5	1.9
Foothills	20.5	14.0	5.5	0.9
Sediment yield	0.36	0.16	0.07	0.01

An economic analysis of the area treated with soil and water conservation measures was made, as well as individual costs for each of the seven microwatersheds: water harvesting, seeding of grasses and legumes, planting of trees and shrubs, and protection. The total cost of afforestation and pasture development in 665.23 hectares of hills and hillocks of the total area for a period of three years was US$92 000. In returns during the three-year period, the discounted value of the forest produce (forage, firewood, seeds of grasses, legumes and leaves) was US$81 000. A comparison of the total discounted expenditure incurred on regenerating common lands (US$81 328) and the discounted income (US$81 000) that they generate shows that virtually the entire expenditure incurred on establishing agroforestry practices and adopting the associated network was recovered within three years.

Additional benefits from regenerating the hills and hillocks are 1) increasing crop productivity in lands adjoining the foothills, which were otherwise being rendered useless as scree was being deposited from the hillslopes, 2) increasing milk production due to sustained fodder supply, 3) instituting aquaculture in the form of fish farming by impounding water runoff that was otherwise being lost, 4) creating self-employment opportunities in basketmaking for the unemployed members of 412 families (the discounted value of these benefits from the base year 1990–91 was US$65 000), and 5) giving the environment a chance to recover through its natural resilience by adopting an agroforestry-associated network, which provided ecological, economic and sociostructural benefits for the entire watershed areas.

Conclusion

The microwatershed development network in central India, which relies on developing and using village resources, has become a successful cost-effective model for greening the barren hills and hillocks that presently make up so much of the common lands. The important lesson to keep in mind is to ensure grassroot participation. This will ensure that the model of this pilot project can be adapted to other agroclimatic conditions or different situations; then the workers themselves who are in the watershed management programme can make site-specific technological modifications.

continued

Table 2. Effect of different tree species under silvopasture and legume pasture on fertility and other physico-chemical properties of soils after three years of treatment

Treatment	*Organic carbon (%)*	*Availlable nitrogen (kg/ha)*	*Available phosphorus (kg/ha)*	*Available potassium (kg/ha)*	*Pore space (%)*	*Bulk density (g/cc)*	*Field capacity (%)*	*Infiltration rate (cm/hr)*
Leucaena leucocephala[a]	0.67	253	17.1	241	46	1.38	15.0	7.8
Hardwickia binataa	0.49	229	15.6	207	42	1.47	13.7	6.7
Acacia nilotica[a]	0.56	239	15.3	228	44	1.42	14.6	7.3
Pasture	0.40	202	12.7	189	41	1.51	13.3	6.2
Degraded grassland[b]	0.21	89	8.6	143	31	1.78	11.5	3.8

[a] *Cenchrus ciliaris* was a common grass species in all cases.
[b] *Heteropogon contortus, Eremopogon foveolatus* and *Aristida* sp. were among the initial grass species.

	Nitrogen levels (kilograms per hectare)							
	0		20		40		Mean	
Vegetation	Without tree (t/ha)	With tree (t/ha)	Without tree (t/ha)	With tree (t/ha)	Without tree (t/ha)	With tree (t/ha)	Without tree (t/ha)	With tree (t/ha)
Cenchrus ciliaris	3.50	4.02	4.88	4.90	5.79	5.62	4.72	4.85
C. ciliaris + *Macroptilium atropurpureum*	6.78	6.29	8.01	7.14	8.41	7.65	7.73	7.03
C. ciliaris + *Stylosanthes hamata*	6.22	6.99	8.18	7.48	8.78	7.85	7.96	7.44
C. ciliaris + *Clitoria ternatea*	7.64	6.90	8.43	8.00	9.07	8.38	8.38	7.76
Mean	6.21	6.05	7.37	6.86	8.01	7.37	7.20	6.77

Table 3. Effect of nitrogen application on different pasture and legume species on annual dry forage production in metric tons per hectare (average of three years)

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Kind of livestock	Before (no.)	After (no.)
Cattle		
Female	1036	626
Male	3268	5240
Subadult	345	210
Buffalo		
Female	370	815
Male	12	16
Subadult	101	215
Small ruminants		
Sheep	370	25
Goat	507	306

Table 4. Composition of livestock species before and after the watershed treatment