Ecosystem services from ravine agro-ecosystem and its management

V. C. Pande[1,*], P. R. Bhatnagar[1], D. Dinesh[1], Raj Kumar[1,2] and Gopal Kumar[3]

[1]ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Vasad 388 306, India
[2]Present address: ICAR-Central Soil Salinity Research Institute, Karnal 132 001, India
[3]ICAR-Indian Institute of Soil and Water Conservation, 218, Kaulagarh Road, Dehradun 148 195, India

Ravine agro-ecosystems are characterized by degraded gullied lands formed over the years due to several natural and anthropogenic factors, surrounded by the adjacent table lands cultivated for the production of food and fibre for humans and livestock. These potential lands not only support the livelihood of marginal and smallholder farmers, but are host to various plants and grass vegetation providing a cushion to the local environment. A two-way relationship exists between the human settlements and ecosystem services in these agro-ecosystems. While the ravines support plants, grasses and human settlements in these agro-ecosystems, the same biophysical pressures over time degrade the ecosystem leading to ecosystem services loss, if not managed sustainably. The present pilot study conducted in the Mahi ravines, Gujarat, India, has examined these issues from the local socio-ecology perspectives and suggests management options for participatory management.

Keywords: Ecosystem services, gullied land, livelihood, participatory management, ravines.

RAVINE agro-ecosystems encompass spatially and functionally coherent parcels of agricultural land along riverside, including living and non-living components as well as their interactions. While these ecosystems support plants, grasses and human settlements, the same biophysical factors when managed unscientifically degrade the ecosystem. The two-way relationship between human settlements and ecosystem services in these agro-ecosystems, and for that matter any natural capital around the world, is crucial not only for the local dwellers but also the environment at large[1–4], and the farmers practising agriculture are at the centre of the sustainable management of these agro-ecosystems[5].

While the cultivated land supports provisioning services, the gullied land with conservation interventions supports regulating, supporting and cultural services, in addition to provisioning services such as fuel, fodder and non-timber forest produce (NTFP; bamboo poles). The trade-off among these ecosystem services brings in complexity in the management of ravine ecosystems, as a part of the ravine lands is under the control of the locally elected governing bodies and a part under private ownership[6,7]. This makes it legitimate to analyse the perception of farmers about management of agro-ecosystems and draw policy implications for the region[8,9]. Perceptions of local dwellers is a pre-requisite to provide insights into observations, understandings and interpretations of the socio-ecological dimensions of conservation efforts, the legitimacy of conservation governance and social acceptability of the interventions for sustainable management of ravine agro-ecosystems[10–19]. Perception is the way in which the local dwellers observe, understand, interpret, and evaluate ravine agro-ecosystem management and its impact in their livelihoods[20].

Ravines and gullies are distributed over 3.98 m ha area in India, and four major areas of severe ravine erosion have been reported[21]. The present pilot study was taken up in the Mahi agro-ecosystem, Gujarat, India. The Mahi basin, particularly the lower basin is known for ravine erosion[22,23]. The Mahi ravine ecosystem comprises of 20,256.9 ha gullied land and 1855.7 ha degraded land associated with the river, while 311.7 ha is table land[24]. This study addresses the issue of ecosystem services and suggests policy interventions in sustainable management of ravine agro-ecosystems in India.

The study area lies between 22°16′N and 72°58′E in the lower basin of Mahi river catchment (Figure 1). Two sets of villages having adjacent ravine land treated with plantation and conservation measures as well as without treatment were identified through field surveys and discussions with local farmers. Three villages, viz. Sarnal, Prathampura and Khorwad have revenue gauchar (grazing) lands partly treated (i.e. villages with partly managed ravines) by TGCS. On the other hand, Pratappura, Manekla and Rajpur villages have degraded ravines without treatment measures undertaken (villages without managed ravines) (Table 1). Three sets of farm holdings, viz. (a) those located in the ravine, (b) those adjacent to ravine and (c) those away from the ravine land were identified from survey number maps (cadastral map) with field validation. The list of farmers owning these lands was collected and categorized into marginal (land holding less than 1 ha size), small (1–2 ha), and medium (2–10 ha). Based on the number of farms located in different ravine locations, proportionate number of farmers in each category such as marginal, small, medium and large farmers was selected in each location of farm holding in each village. A list of 150 farmers (marginal – 127 nos, small – 15 nos, medium – 8 nos) was finalized for field-data collection.

The data collection included both primary and secondary data. Biophysical and farmers' surveys were conducted to collect primary data in the six villages during 2015–16. Socio-economic survey focused on the general characteristics of the farmers (age, gender, farming), their farms (size, predominate agricultural land-use), farm

*For correspondence. (e-mail: vcpande64@gmail.com)

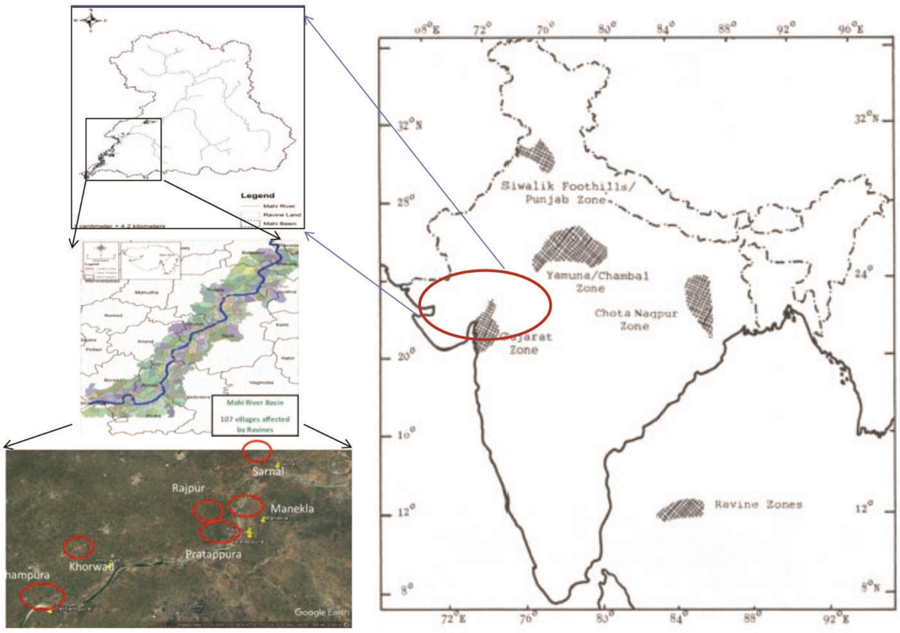

Figure 1. Major ravine areas distribution in India and location of the study area (adapted from Sharma[21]).

Table 1. Profile of selected villages in Mahi catchment, Gujarat, India

Village, District	Khorwad, Anand	Sarnal, Kheda	Prathampura, Anand	Rajpur, Vadodara	Manekla, Vadodara	Pratappura, Vadodara
Village land (ha)	612	209	309	355	137	197
Cultivated land (ha)	350	159	177	305	110	163
Ravine affected land (ha)	250 (40.8)	60 (28.7)	66 (21.3)	22 (7.2)	20 (18.1)	12 (6.1)
Households (no.)	850	620	725	127	118	473
Households BPL (no.)	230 (27.0)	164 (26.5)	215 (29.6)	60 (47.2)	47 (39.8)	265 (56.0)
Livestock (no.)	1100	462	359	280	500	700

asset, livelihood patterns and their familiarity about the ecosystem services. Besides, data on the perception of farmers about ravine ecosystems and the benefits drawn from them, the importance of ravine in their livelihoods, and familiarity about 'payment for ecosystem services' were collected.

Statistical tools, viz. regression analysis for biophysical data, Likert-scale analysis for perception data[20] and economic analysis for ecosystem services valuation were used for analysis and drawing inferences. The growing stock of trees was measured for biomass and carbon stock assessment in the ravines. The characteristics of tree, viz. height, girth diameter at breast height (DBH), diameter of branches and tree height were measured and volume was calculated according to standard methodology[25,26]. Soil samples were collected through one transact demarcated across each village. The soil samples collected were bulked, air-dried and sieved for physical and chemical analysis using standard procedures. Destructive sampling was done to assess the vegetation biomass above ground following standard methodology and below-ground biomass was estimated by multiplying with 0.25. The carbon stock was taken as 50% of the total biomass and multiplying this value with 3.67 gave the amount of carbon sequestered. The soil organic carbon content was determined by wet digestion method. The total sequestered carbon was multiplied with market price of carbon (US$ 3.5/t).

Economic value was estimated as the difference between gross value and extraction cost for the products obtained from the ravines[27]. Gross value was estimated as the product of the number of rural households collecting fuelwood from ravine in last 365 days and average value of collection. Extraction cost was estimated as the product of rural households (nos) collecting fuel/fodder and total annual time cost of collection per household valued at 15% of the average agricultural wage rate. Timber value was estimated as the difference between stumpage value and cost of raising forests in ravines. The annual benefit of NTFP was estimated as NTFP collected per year per household multiplied by the number of households (value to be used was the relevant price in the nearest local market). The annual cost of collecting NTFP was the number of rural households multiplied by the total annual time

Table 2. Assessment of ecosystem services in treated and untreated ravines

Ecosystem benefit/services	Treated ravine (Rs/ha)			Untreated ravine (Rs/ha)		
	Annual benefit	Annual cost	Net annual value	Annual benefit	Annual cost	Net annual value
Timber	152.7	86.7	66.0	71.1	40.4	30.7
Fuel wood	44,251.2	18,438.0	25,813.2	20,607.4	8,586.4	12,021.0
Fodder	118,831.2	18,330.0	100,501.2	55,338.0	8,500.0	46,833.0
Non-timber forest product (bamboo)	9,105.7	4,727.7	4,378.0	–	–	–
Carbon – vegetation	6,256.0	*	6,256.0	2,754.0	*	2,754.0
Carbon – soil	28,662.9	–	28,662.9	19,182.0	–	19,182

*No annual cost considered.

cost of collection per household valued at 15% of average agricultural wage rate.

Majority of the farmers were marginal (87%) and small (10%), and educated up to high school (38.3%). Farmers with mid-level school, primary school and no education were 36.3%, 20.2% and 5.2% respectively. Agricultural labour (36.3%) was reported as the primary source of earning, followed by crop production (31.8%), animal husbandry (14.3%), jobs (14.3%) and other occupations like small enterprise, shops, etc. (3.3%).

The provisioning services, viz. fuel, fodder and bamboo poles (NTFP) were the major benefits reported by farmers from the adjacent ravine land; only a part of it was collected from the fields. In addition, NTFP was available from the ravine wasteland plantation by the village society, such as bamboo, grasses, babul pods, kankodi (vegetable), ber (fruit) and gum[28]. However, the major benefits derived by the beneficiary community were fuel and fodder. On an average, 9.6 kg fuelwood per household per day and 46.5 kg fodder were obtained from the ravine area. For majority of farmers (82.5%), provisioning services (fuel and fodder) were available nearby (less than 0.5 km from their village). Regarding the importance of provisioning ecosystem services, the responses varied from important (44.7%) to very important (46%) (median = 2, SD = 0.67). The low variability in responses indicated that the respondents, by and large, were unanimous in their perception. Only 9.3% respondents expressed them to be least important. The provisioning services provided by the ravines directly affected the livelihoods of majority of the respondents (96.7%). On the other hand, regulatory services indirectly affected the livelihoods of only a few farmers (3.3%). The difference between respondents from two sets of villages, with partly managed and unmanaged ravines, was not much.

The timber volume of trees in treated ravines varied from 769 kg/ha at Sarnal to 970 kg/ha at Khorwad. In untreated ravines, it varied from 177 kg/ha at Pratappur to 385 kg/ha at Rajpur. On an average, the timber volume, biomass and carbon stock in treated ravines were recorded four times more in comparison to untreated ravines. Soil nutrient and carbon stock were similarly estimated and the analysis revealed that treated gullies recorded higher soil organic carbon stack (SOCS) (89.1–97.1 t ha^{-1}) compare to untreated ravine (66.7–76.9 t ha^{-1}). Similar trend was recorded in carbon dioxide (CO_2) equivalent carbon. With respect to available nutrients, available phosphorus pooled stock was recorded marginally higher in treated ravine (74–161 kg ha^{-1}) than untreated ravine (109–132 kg ha^{-1}); available potassium pooled stock was recorded higher in treated ravine (2.77–3.41 t ha^{-1}) compared to untreated ravine (1.67–2.14 t ha^{-1}). The values of ecosystem services in treated ravines were estimated to be roughly double that in untreated ravines (Table 2). This indicated the potential of maintaining the ecosystem services by proper management of ravine lands. Extrapolation and valuation of these services revealed that the Mahi ravine ecosystem provided services of fodder and fuelwood worth Rs 2836 million per annum and Rs 1096 million per annum respectively. The timber and NTFP (bamboo poles) benefits were estimated as Rs 3.74 million per annum and Rs 15.5 million per annum respectively. The indirect benefits such CO_2 carbon and soil nutrients in the soil were worth Rs 216 million per annum and Rs 8 million per annum respectively. However, there was trade-off between direct and indirect benefits. In absence of proper ravine management, extraction of direct benefits would adversely affect the indirect benefits.

A sustainable policy intervention towards enhancing ecosystem services warrants sustainable ravine management through viable payment/incentivization mechanisms. Based on farmers' responses, observations during surveys and the literature, a framework of ecosystem services payment for participatory management of ravine ecosystems has been suggested[29] (Appendix 1). The framework involves identification of ravine ecosystem managers, both present and future, ecosystem beneficiaries and ecosystem degraders, the relevant opportunities for ravine ecosystem service and incentives/disincentives for relevant actors in the Mahi ravine ecosystem. The ravine land ownership in Mahi includes private ownership (60%), village panchayat (21%) and State Government (19%). So, the issue of participatory management largely revolves around incentive/payment to ecosystem managers, fee/levy from ecosystem services beneficiaries and penalty from ecosystem services degraders. The

Annexure 1. Framework for participatory ravine management (adopted from Rode *et al.*[29])

Analysing ravine ecosystem services (ES) and management issues

Relevant issues (fuel collection, cattle grazing, fodder collection)

Role of ravine ecosystem in addressing the issues (ravines support fuel/fodder; however, due to over-stocking and excessive harvesting, apart from population increase, ecosystem services are declining)

Trade-offs between ecosystem services and their importance to different stakeholder groups (excessive harvest and cattle stocking are adversely affecting environmental benefits)

Understanding the relationship between stakeholders and ravine ES

Fuel/fodder/non-timber forest produce/ravine tourism

ES providers	ES beneficiaries	ES degraders
Present (Gram panchayat/Tree Growers Cooperative Society) Future (Ecoparks/nature parks/biodiversity park owners/milk cooperatives)	Small and marginal farmers Ecopark/nature park owners Farm-house owners	Over-exploitation by farmers Stone quarry owners

Examining the gaps between ravine ES providers, beneficiaries and degraders

ES providers	ES beneficiaries	ES degraders
Bear the cost for providing ES ✓ Plantation cost: Rs 34,409–68,500/ha ✓ Cost of grassland development: Rs 14,000–21,000/ha	Get ES freely Fuelwood (10–11 kg/day/Hh), fodder (5–40 kg/day/Hh)	Not held responsible and liable for penalty

Identification of ravine ES opportunities

ES providers	ES beneficiaries	ES degraders
Rewarding for benefits generated and costs incurred by them 80% cost (Rs 33,000–68,000/ha) – cost of plantation/maintenance in ravine land (TGCS) – most (80% – SWC) can be met from other sources	Making them pay for the costs in accordance with benefits drawn	Penalizing for over-exploitation of ravine services

Ecosystem business opportunities Ecoparks/biodiversity park incentivization for conservation

Selecting suitable incentive/payment/compensation mechanism for ravine conservation

ES providers	ES beneficiaries	ES degraders
Payment for services Subsidies in ravine conservation/ravine maintenance Plantation: Rs 28,000–55,000/ha Grassland development: Rs 11,000–17,000/ha	Collection of charge in terms of taxes, fees, labour contribution for maintenance Willingness to pay: Rs 360–1200/household/annum	Fee/lump-sum payment, fines for greening of ravines. Farmers: Firewood Rs 0.80/kg Grass: Rs 0.12/kg Quarry owners: Rs 5000–16,000/ha/annum – amortization cost of grassland and plantation

Ecosystem business opportunities
(Ecopark/biodiversity park/nature part/wind power/solar power generation unit)

Incentives, micro credit/finance, land lease for eco-tourism, eco-biodiversity park development

beneficiaries were identified as farmers and ecotourism-based entrepreneurs; the degraders included, apart from farmers, quarry owners who operated sand and stone quarries in the vicinity. Further, the future/probable ecosystem services providers included eco-park/biodiversity park owners, Tree Growers' Cooperative Societies, milk/dairy cooperatives in the Mahi ravines. The relevant payment/incentive mechanisms identified included subsidized funds provision for grassland and forest development by creating a special purpose vehicle (SPV) or green fund (Environment Action Fund of State Departments). The cost of plantation, inflated to 2016–17 prices using an inflator based on All-India Consumer Price Index (CPI) for Agricultural Laborer (base 1960–61 = 100), varied from Rs 26,000 to 45,000 per ha at different sites. Also, 70% of the cost, largely comprising wages in plantation and maintenance, could be compensated from Government initiatives like MGNREGA, NABARD, etc. Further, service providers (Tree Growers' Cooperative Societies) may be provided incentives through cost of grassland management, by creating a SPV or green fund. The Cooperative Society, in turn, may collect fees for grass collection and/or grazing of animals in the ravines. In addition, incentivizing probable service providers such as eco-park/biodiversity park owners through finance, legal provision of land lease and levying appropriate fees/charges from ecosystem services beneficiaries and penalty for land degradation from ecosystem services degraders would help sustain the motivation of relevant actors in ravine ecosystem management. Ecosystem services degraders such as quarry owners mining stone/sand must be liable to compensate more towards the green fund/investment on greening around mined areas (Rs 5000 and 16,000 ha^{-1} $annum^{-1}$ based on the amortization cost of grassland and forest land management respectively). In fact, eco-restoration must be a part of the terms of license for mining/stone quarrying.

The ecosystems not only support the rural livelihood of local dwellers, but are also threatened by anthropogenic activities. The ravine ecosystem, which meets a part of their requirements, is exploited due to population pressure, and the absence of sustainable institutions for management. This adversely affects the flow of different ecosystem services in turn affecting small and marginal farmers. Involvement of institutions as well local farmers and other stakeholders is crucial. Besides, probable ecosystem services providers can be incentivized to participate in the sustainable management of ravines. Part of the plantation/maintenance cost (70–80%) of the ravines may be met from different sources, or land-based activities under different Government initiatives may be converged with ravine development schemes[30–32]. Environment Action Fund of State Departments may be appropriately linked with ravine management. The other opportunities include nature-based tourism, solar power and wind power generation firms with appropriate energy purchase, distribution and land lease support. In fact, eco-restoration must be a part of the terms of license for mining/stone quarrying.

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Effect of different essential oils on enzymatic activity of oyster mushroom (*Pleurotus florida*)

Manjari* and Ram Chandra

Department of Mycology and Plant Pathology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 221 005, India

An experiment was carried out to study the effect of different essential oils on enzymatic activity of stored oyster mushroom (*Pleurotus florida*). The harvested fruiting body was treated with four essential oils, i.e. lemongrass oil, citronella oil, mint oil and clove oil at two different concentrations – 5 and 10 μl – to test the total phenol content (TPC) and activity of three important enzymes, viz. phenylalanine ammonia lyase (PAL), peroxidase (POD) and polyphenol oxidase (PPO) that are involved in post-harvest quality preservation of mushrooms. TPC (0.286 mg/g), PAL content (0.038 μM/g), PPO content (0.042 U/mg) and POD content (0.38 U/mg) were found significant in mint oil-treated mushroom at 10 μl concentration. TPC and PAL content were higher in essential oil-treated mushrooms compared to the control samples, whereas PPO and POD contents were lower in the treated samples, signifying that essential oils treatment had a positive impact on the quality of harvested mushrooms. This preservative technique will help in increasing the shelf-life of harvested fruiting bodies.

Keywords: Enzymes, essential oils, fruiting bodies, *Pleurotus florida*, preservation.

POST-harvest quality is a major concern among mushroom-growers. Mushrooms are a highly perishable commodity that are not suitable for long-term storage and long-distance transportation[1]. Several methods have been developed to increase the post-harvest shelf-life of mushrooms, but only a few have achieved success. Use of essential oils in the storage of mushrooms is a new concept, but has shown positive results in improving quality attributes of harvested fruiting bodies.

The most important quality parameter for assessing the marketability of mushrooms is the colour of the fruiting body which is degraded upon storage due to activity of enzymes such as polyphenol oxidase (PPO), phenylalanine ammonia lyase (PAL), peroxidase (POD), superoxide dismutase (SOD) and secondary metabolites like phenols and ascorbic acid. The use of essential oils in the preservation of mushrooms is a new concept which is gaining appreciation because of its easy application and negligible side effects. Essential oils are natural volatiles obtained by distillation and have the characteristic aroma of the plant from which they are obtained[2]. Essential oils act on the biochemical processes of mushrooms, and suppress or enhance the concentration of enzymes and secondary metabolites which are involved in quality preservation[3].

Fumigation of the fruiting bodies of mushroom (*Agaricus bisporus*) with three essential oils (clove, cinnamaldehyde and thyme) recorded changes in browning index, weight loss, firmness, percentage of open caps, total phenolics, ascorbic acid, microbial activity and activity of important enzymes such as PPO, PAL and POD. All essential oils inhibited the post-harvest degradation of mushrooms, of which cinnamaldehyde oil (5 μl) was found to be the most efficient[4]. Different concentrations of essential oils of cinnamon, mint, winged prickly ash and eucalyptus improved the post-harvest quality of oyster mushroom (*Pleurotus ostreatus* and *Pleurotus florida*). Cinnamon and mint oil (20 μl) were found to be the most effective against post-harvest microbial losses[5]. Essential oils

*For correspondence. (e-mail: mishramm1596@gmail.com)