Ecosystem services from ravine agro-ecosystem and its management- Farmers' perceptions

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Abstract

Ravine agro-ecosystems are characterized by degraded gullied lands, formed over the years due to several natural and manmade factors, surrounded by the adjacent table land cultivated for production of food and fiber for human and livestock. These potential lands not only support the livelihood of marginal and small holder farms but are host to varied plants and grass vegetation providing cushion to local environment. A two-way relationship exists between the human settlement and ecosystem services in these agro-ecosystem services. While ravines support plants, grass and human settlement in these agro-ecosystems, the same bio-physical pressures, overtime, degrade the ecosystem leading to ecosystem services loss, if not managed sustainably. The pilot study conducted in Mahi ravines examined these issues from local socio-ecology perspectives and suggested management options for participatory management.

Key words
Ecosystem service, Gullied land, Livelihood, People's participation, Institutions

1 Introduction

Ravine agro-ecosystem encompasses spatially and functionally coherent parcels of agricultural land along the riverside including the living and nonliving components as well as their interactions. While these ecosystems support plants, grass and human settlement, the same bio-physical factors, managed unscientifically degrade the ecosystem. The two-way relationship between the human settlement and ecosystem services in these agro-ecosystems, and for that manner any natural capital around the globe, is crucial not only for the local dwellers but also the environment at large[1,2,3,4] and the farmers practicing agriculture are at the center for the sustainable management of these agro-ecosystems[5].

While the cultivated land support provisioning services, the gullied land with conservation interventions support regulating, supporting and cultural services, in addition to provisioning services such as fuel, fodder and non-timber forest produce (bamboo poles). The tradeoff among these ecosystem services[6,7] brings in complexity in the management of ravine ecosystems as part of ravine lands are under the control of locally elected governing body and a part, under private ownership. This makes it legitimate to investigate the perception of farmers about management of agro-ecosystem[8,9] and draw policy implications for the region. 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 the social acceptability of the interventions for sustainable management[10,11,12,13,14,15,16,17,18,19] of ravine agro-ecosystems. Perception has been referred[20], as the way the local dwellers observe, understand, interpret, and evaluate the ravine agro-ecosystem management and its impact in their livelihood.

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 pilot study was taken up in Mahi agro-ecosystem. The Mahi basin, particularly the lower basin is conspicuous for ravine erosion[22,23]. Mahi ravine ecosystem comprises of 20256.9 ha gullied land, 1855.7 ha degraded land associated with river and 311.7 ha is table land[24]. The study attempts to address the issue of ecosystem services and suggest policy interventions in sustainable management of ravine agro-ecosystem in India.

Material and Methods

The study area lies between $22^0$16' N and $72^0$58' E in lower basin of Mahi river catchment (Fig. 1). Two sets of villages having adjacent ravine land treated with plantation and conservation measures as well as without treatments 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 ravine land were identified from survey number maps (cadastral map) with field validation. List of farmers owning these lands were 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 locations 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. 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 asset, livelihood pattern and their familiarity about the ecosystem services. Besides, data on perception of farmers about ravine ecosystem and benefits drawn, ravine importance in their livelihood, 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 ravines. The characteristics of tree *viz*., height, girth diameter at breast height (DBH), diameter of branches and tree height was measured and volume was

calculated as per the 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 value 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 ($ 3.5/t).

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

Results

Characteristics of Farmers

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 labor (36.3%) was reported as the primary source of earning, followed by crop production (31.8%), animal husbandry (14.3%), job (14.3%) and other occupation like small enterprise, shops (3.3%).

Farmers perception about Ecosystem Services

The provisioning services viz., fuel, fodder, bamboo poles (non-timber forest product) were the major benefits reported by the farmers from adjacent ravine land, only a part of it was collected from fields. In addition, there were non-timber products available from the ravine wasteland plantation by village society such as bamboo, grasses, *babul* pods, *kankodi*(vegetable), *ber*(fruit), and gum[28]. However, major benefit derived by beneficiary community was fuel and fodder. On an average 9.6 kg fuel wood per household per day and 46.5 kg of fodder was obtained from 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 provisioning ecosystem services' importance, the responses varied from important (44.7%) to very important (46%) (Median=2, s.d.=0.67). The low variability in responses indicated that 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 livelihood of majority of the respondents (96.7%). On the other hand, regulatory services indirectly affected the livelihood of only few farmers (3.3%). The difference between respondents from two set of villages, with partly managed and without managed ravines, was not much different.

Vegetation biomass, carbon stock and soil nutrients

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, carbon stock in treated ravines was recorded four times more in comparison to untreated ravines. Soil nutrient and carbon stock was similarly estimated and the analysis revealed that treated gullies recorded higher soil organic carbon stack (SOCS) (89.1 to 97.1 tha^{-1}) compare to untreated ravine (66.7 to 76.9 tha^{-1}). Similar trend was recorded in Carbon Dioxide (CO_2) equivalent carbon also. With respect to available nutrients, available phosphorus pooled stock was also recorded marginally higher in treated ravine (74 to 161 kg ha^{-1}) than untreated ravine (109 to 132 kg ha^{-1}); available potassium pooled stock was recorded higher in treated ravine (2.77 to 3.41 t ha^{-1}) as compared to untreated ravine (1.67 to 2.14 t ha^{-1}). The values of ecosystem services in treated ravines were estimated to be roughly double of the quantity in un-treated 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 Mahi ravine ecosystem provided the services of fodder and fuel wood worth Rs 2836 million $annum^{-1}$ and Rs 1096 million $annum^{-1}$, respectively. The timber and non-Timber Forest produce (bamboo poles) benefits were estimated as 3.74 and 15.5 Rs million $annum^{-1}$, respectively. The indirect benefits such carbon CO_2 and soil nutrient in the soil were worth Rs 216 million $annum^{-1}$ and Rs 8 million $annum^{-1}$, respectively. However, there is tradeoff between direct and in direct benefits. In absence of proper ravine management extraction of direct benefits would adversely affect indirect benefits.

Ravine land management

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 literature, a framework of ecosystem services payment for participatory management of ravine ecosystems has been suggested[34] (Appendix II). The framework involves identification of ravine ecosystem managers, both present and future, ecosystem beneficiaries and ecosystem degraders, the relevant ravine ecosystem services' opportunities and relevant incentives/ dis-incentives for relevant actors in 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 degraders. The ecosystem beneficiaries were identified as farmers and ecotourism-based entrepreneurs, the ecosystem degraders included, apart from farmers, the quarry owners who operated sand and stone quarries in the vicinity. Further, the future/ probable ecosystem service providers included eco-park/ bio-diversity park owners, tree growers' cooperative societies, milk / dairy cooperatives in 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 between 26,000 – 45,000 Rs ha^{-1} at different sites. 70% of the cost, largely comprising of wages in plantation and maintenance, can be compensated from government programme viz., MGNREGA, NABARD. Further, service providers (tree growers' cooperative) may be provided incentives in the form cost of grass land management, by creating a Special Purpose Vehicle (SPV) or green fund. The cooperative society, in turn, may collect fee for grass collection and/or grazing of animals in ravines. In addition, incentivizing probable service providers such

as eco-park/ biodiversity park owners through finance, legal provision of land lease and levying appropriate fee/ charges from ecosystem beneficiaries and penalty for land degradation from ecosystem degraders and would help sustain the motivation of relevant actors in ravine ecosystem management. Eco system degraders such as quarry owners mining stone/ sand must be liable to compensate more towards green fund/ investment on greening around mined area (Rs 5,000 and 16,000 ha^{-1} $annum^{-1}$ based on the amortization cost of grass land and forest land management, respectively). In fact, eco restoration must be a part of the terms of license for mining/ stone quarrying.

5 Summary and conclusion

The ecosystems not only support the rural livelihood of local dwellers but are also threatened by the anthropological activities. The ravine ecosystem, which meets a part of their requirements, are exploited due to population pressure, absence of sustainable institutions for management and this adversely affect the flow of different ecosystem services affecting, in turn, small and marginal farmers. Involvement of institutions involving local farmers and other stakeholders is crucial. Besides, probable ecosystem providers can be incentivized to participate in the sustainable management of ravines. Part of the plantation/ maintenance cost (70-80%)[35,36,37] of ravines may be met from different sources or land-based activities under different programme such as mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA, National Bank for Agriculture and Rural Development (NABARD) may be converged with ravine development schemes. Environment Action Fund of State departments may be appropriately linked with the programme with ravine management. The other opportunities include nature based tourism, solar power and wind power generation firms with appropriate energy purchase, distribution, land lease support. In fact, eco restoration must be a part of the terms of license for mining/ stone quarrying.

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Table 1: Profile of selected village in Mahi catchment

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

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

Ecosystem benefit / service	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	1,18,831.2	18,330.0	1,00,501.2	55,338.0	8.500.0	46,833.0
NTFP (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

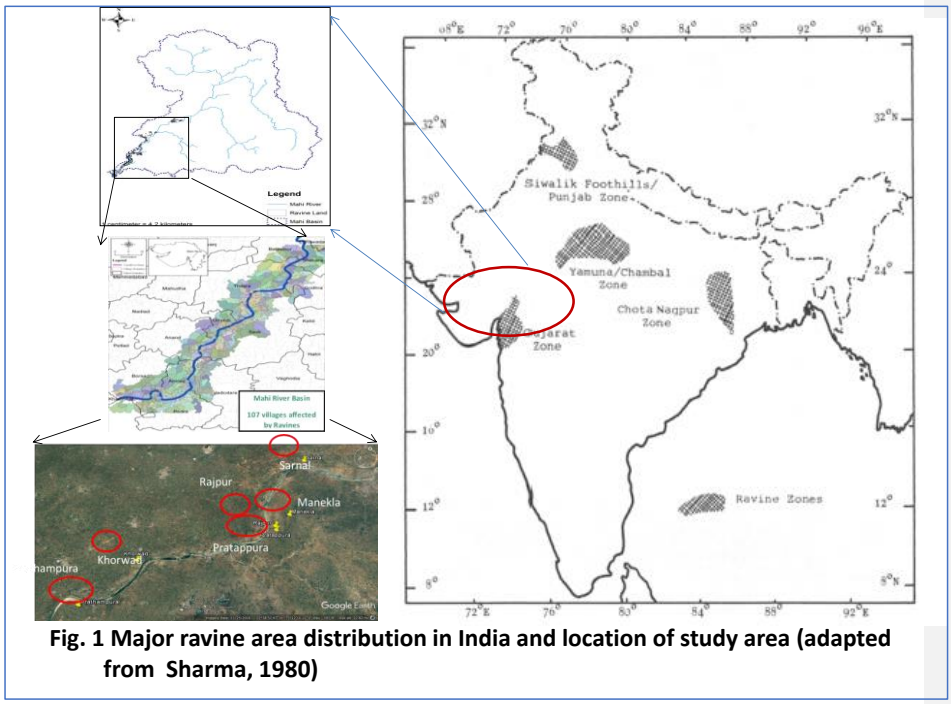

Fig. 1 Major ravine area distribution in India and location of study area (adapted from Sharma, 1980)

Annexure II

Framework for participatory ravine management (adopted from Rode et al, 2016)