A quantitative analysis of plant use as a component of EIA: Case of Narmada Sagar hydroelectric project in Central India

A. M. Dixit[*,#,†] and C. P. Geevan[#]

*Wildlife Institute of India, P.O. Box #18, Dehra Dun 248 001, India
[#]Present address: Gujarat Institute of Desert Ecology, Patwadi Naka, Bhuj (Kachchh) 370 001, India

In this study we have examined the impacts of Narmada Sagar multipurpose hydroelectric project on the ethnobotanical resource base in the Central Indian dry deciduous forests. Impacts have been assessed using an objective approach by developing certain indices, marking a departure from traditional EIA studies. The approach presented here is an attempt to integrate heterogeneity in plant distribution and variation in their uses into impact assessment criteria.

In the two zones of impact – both primary and secondary – 69 woody species that are utilized by local communities were recorded from the sample plots through a random sampling procedure. Each species was assigned minor or major use-values on the basis of utilization pattern by the local communities.

The use of indices developed shows that even when ethnobotanically important species are well represented almost equally both within and outside the project area, varying degrees of impacts can be expected to occur. The indices developed here may be used to advantage in similar EIA studies in cases where ethnobotanical losses are likely.

Plants belonging to food, fuel, medicinal and miscellaneous categories were found highly vulnerable to post-dam impacts. Impacts are also expected to occur in the availability of useful species such as *Tectona grandis, Butea monosperma, Diospyros melanoxylon* and *Cassia fistula*.

ONE of the major reasons for declining forest cover in India is the diversion of forest lands for developmental projects[1,2]. Narmada Valley Development Project (NVDP) is one such large project envisaging the construction of 30 major, 135 medium and about 3000 minor irrigation schemes in the entire stretch of the densely-forested Narmada river basin. At completion, NVDP is expected to provide irrigation to 4.8 million hectares (m ha) of land and generate 2700 MW of electricity. It will submerge 0.35 m ha of forests and also displace about a million people, majority of whom belong to culturally diverse tribal groups. These forest-dwelling communities substantially depend on their surrounding forests for food, fodder, fuel, medicine, fibre, dyes and timber. However, in the case of NVDP, this fact was grossly overlooked during the project formulation phase, including resettlement plan for the affected people[3]. These displaced people (also termed as 'ecosystem refugees' by Gadgil[4]) are thus liable to face various social, economic and environmental uncertainties in the future[5].

While several attempts have been made to assess the impacts of various water resource projects on species and ecosystem diversity[6–8], impacts on ethnobotanical values have often been ignored. Since the forests of the Narmada basin are well known for their high ethnobotanical values[9–12], it is assumed that any developmental activity in and around these forested tracts would result in serious ecological and ethnobotanical consequences.

Usually, ethnobotanical studies tend to be qualitative, often ending up with mere documentation. Recently, some new approaches have been developed to quantify ethnobotanical values[13,14]. Nevertheless, there are only few attempts of applying such approaches in EIA studies. Similarly, the traditional EIA studies adopt one or a combination of descriptive methods like checklists, matrices, networks and spatial data overlays[15].

This study goes beyond the qualitative approaches and proposes a quantitative analytical framework for EIA using ethnobotanical values as the assessment criterion. In this paper, we propose new indices for measuring the impact of a development project on the useful plant species and major use-categories. The proposed indices combine the abundance of plants with their uses and utilization pattern. We use these indices in objectively assessing the impacts of the Narmada Sagar Project (NSP) – one of the major dams planned under NVDP.

Study area

The study area is a part of the Narmada river basin and falls between 22°08 ¢to 22°28 ¢N latitude and 76°10 ¢to

[†]For correspondence. (e-mail: arunmdixit@hotmail.com)

76°55′E longitude. Predominantly undulating terrain is interspersed with perennial and ephemeral streams of different orders. The altitude of the area varies between 180 and 460 m above mean sea level. The average annual rainfall is about 1300 mm and the average temperature varies between 17.9°C in winter and 33.6°C in summer.

From the study area, 369 plant species of 256 genera representing 76 families were identified[16]. However, none of them belonged to any category of threatened plants of India as documented by Jain and Sastry[17]. The forest has been classified as a southern tropical dry deciduous forest with teak (*Tectona grandis*) as the most dominant species[18]. *Anogeissus latifolia, Diospyros melanoxylon, Hardwickia binata, Lagerstroemia parviflora, Terminalia tomentosa* and *Zizyphus xylopyra* are the other co-dominant species. Based on multivariate classification techniques, Dixit[19] identified and discussed 11 different vegetation communities from the study area.

A significant proportion (36%) of human population in the study area belongs to the socially disadvantaged and economically weaker sections of the society, viz. scheduled castes and scheduled tribes[20]. The population density of the area is about 88 persons/km^2. While agriculture is the dominant occupation (68% of total families), the proportion of daily wage labourers is also high (18%). However, the entire population across the occupation types, are significantly dependent on biomass resources, placing considerable pressure on the forests[16,21].

Narmada Sagar Project (NSP)

The NSP located in the Khandwa district of Madhya Pradesh (22°17′N latitude and 76°28′E longitude) is about 40 km upstream of another proposed hydroelectric project – the Omkareshwar Project (OMP). The NSP is expected to generate 1000 MW of electric power and irrigate 0.123 m ha of land in Khandwa and Khargone districts. The NSP reservoir will submerge 91,348 ha of land, including 40,332 ha of forest and 254 villages, affecting approximately 1,30,000 people, of whom about 30,000 belong to tribal communities. The salient features of the project are presented in Table 1.

Table 1. Salient features of the Narmada Sagar Project

Height of the dam	91.4 m
Length of the dam	574 m
Full Reservoir Level (FRL)	262.13 m
Total area to be submerged	91,348 ha
Forest area to be submerged	40,332 ha
Cultivable area to be submerged	44,363 ha
Irrigation potential	1,23,758 ha
Power generation (installed capacity)	1000 MW
Number of villages to be affected	254
Number of people to be affected	1,30,000

Methodology

Zoning of study area

The study area covers the two impact zones – primary and secondary – of the project. The primary impact zone is the area that will be converted into a reservoir once the dam is completed. This zone covers 40,332 ha of forest area (Figure 1) and is termed as the 'submergence zone' (SZ).

The secondary impact zone includes the forest areas lying outside the reservoir limits of the dam and covers 40,880 ha. These forests, being contiguous to the SZ, hereafter referred as 'Contiguous Forest Zone' (CZ), are highly susceptible to project-induced secondary impacts like construction of roads and residential colonies and biomass collection. Under these circumstances and on account of it being a major source of many useful plant species, the study of this area assumes greater significance.

Data collection and analysis

For obtaining relevant information on various uses of plants from the two study zones, knowledgeable and reliable informants from different villages of the area were identified. Information on uses of different plant species known by their local names and their parts was compiled through interviews. Cross-checks on species were undertaken during field visits.

Plants and their products were classified into eight use-categories, viz. construction (huts and agriculture implements), fodder, food, fuel, medicinal, religious, commercial, (i.e. sold in the local market) and miscellaneous (which includes fibre, thatching, fencing and poison for hunting). Use scores of 1.0 and 0.5, respectively, were assigned to the major and minor uses of each species. Assessment of 'major' and 'minor' uses and assignment of scores were based on an ordinal measure of the relative utility of species to the local population as revealed in the data and, in some cases, by subjective rating during the field check. Those species that have multiple uses were assigned a use-score of either 1 or 0.5 in each use-category. Use-value for each species was determined by adding different use-scores.

A random sampling procedure was adopted to obtain a representative sample of woody species of the study area. 115 forested grids of 1 km × 1 km area were randomly selected from the entire study area (61 in SZ and 54 in CZ). The grids with more than 50% forest cover were considered as forested. Within each selected grid, five sampling plots of 0.1 ha size were randomly

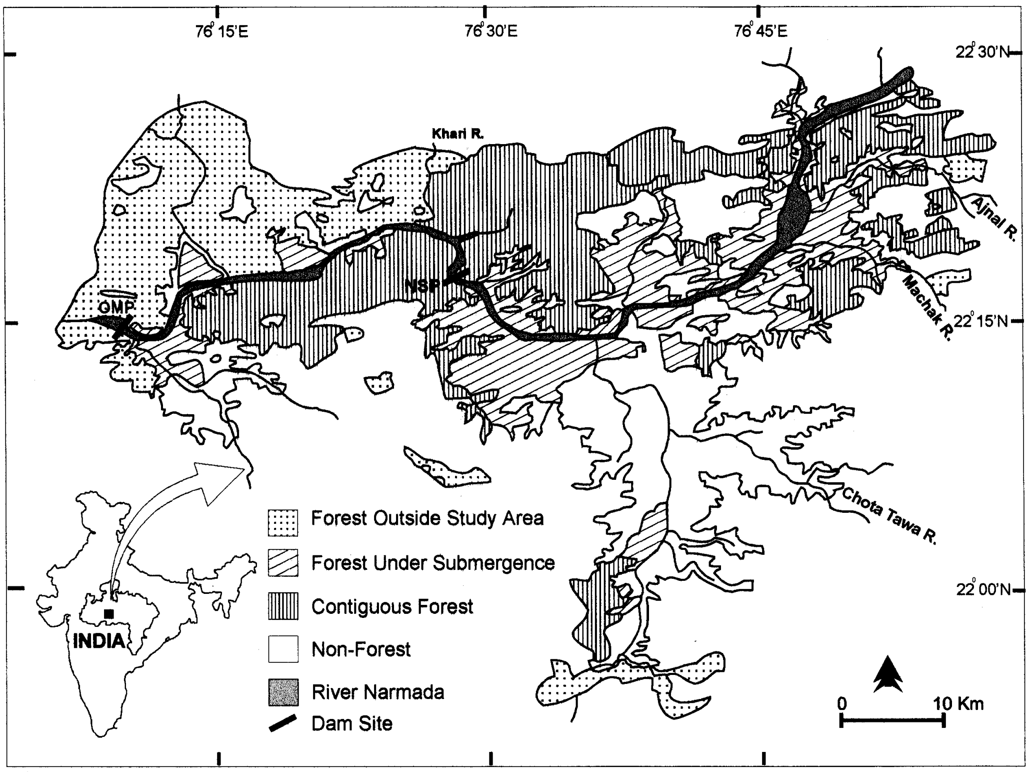

Figure 1. Location of the study area showing primary (submergence) and secondary (contiguous forest) zones of impact.

located at every 250 m interval along its diagonal. In this way, a total of 288 plots, (i.e. 28.8 ha) from the SZ and 265 plots, (i.e. 26.5 ha) from the CZ were sampled. In each sample plot, the all-woody plants with more than 50 cm height were counted. The species–area curve indicates a steady increase in the number of species that starts flattening after 16 and 24 ha of sampling in the two study zones (Figure 2). This suggests that sampling has been done adequately to record the woody species richness of the area.

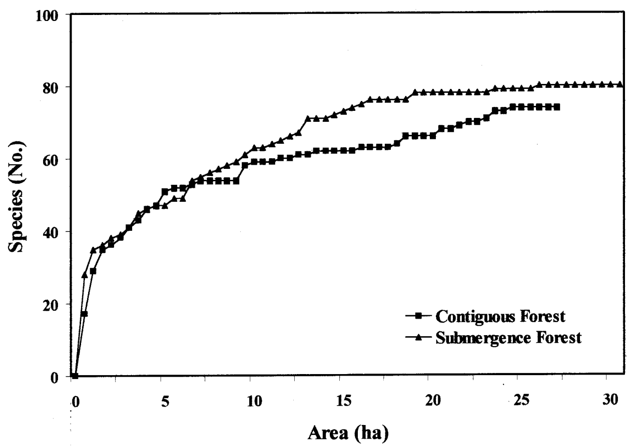

Figure 2. Species–area curve for the two study zones.

Indices for measuring impacts

The impacts on different use-categories are quantified by different measures. One of them takes into account the number of plants in each use-category to be reduced after submergence and impacts are expressed in terms of density difference. Absence of significant difference will imply negligible impact. However, this measure does not account for either the use-value or relative utility of different species. Species of little use and those with high values are not differentiated.

To incorporate the use-values and the relative abundance of plants, another measure is contemplated – Cumulative Use-Values (CUV). For each use-category, CUV is calculated by taking into account both the density of plants (number per hectare) and the use-score of each species. Use-score is an ordinal measure of the relative ethnobotanical utility of the species on a uniform scale and is not a measure of the actual quantum of extraction. The CUV was calculated separately for the SZ, CZ and for the entire study area using the following equation:

$$\mathrm{CUV}_j = \sum_{i=1}^{n} u_i \cdot d_{ij},$$

where CUV_j is the CUV of a use-category (e.g. construction, food, etc.) in the area; j is the SZ or CZ or the entire area; u_i is the use-score of species i for the use-category; d_{ij} is the density of plants (no/ha) of species i in study zone j; and n is the number of species recorded under a use-category in the respective study zone.

It should be noted that since CUV is based on density measurements, CUV of the entire area (EA) is never equal to the sum of the CUVs of CZ and SZ ($CUV_{EA} < CUV_{CZ} + CUV_{SZ}$, always).

While the primary impacts are direct and obvious, we are concerned here with the consequences of the project on the remaining resources in the CZ. On the face of it, CUV_{CZ} expresses the values in the post-project case. However, after the submergence, use-values lost will tend to be compensated from the biomass resources of the CZ. Therefore, the post-project use-value availability to the local population is the difference between the availability in CZ (CUV_{CZ}) and SZ (CUV_{SZ}), which is defined as the Net Use Value (NUV). NUV is an index of the 'net availability' of ethnobotanical resources in the post-project scenario and is expressed as:

$$NUV = CUV_{CZ} - CUV_{SZ},$$

where the subscript CZ and SZ indicate the contiguous forest zone and the submergence zone, respectively.

It may be noted that in the pre-project case there is no SZ and CUV_{SZ} is zero. In other words, in the pre-project case $NUV = +CUV_{EA}$, (i.e. no loss). Hypothetically, if the entire area is submerged there will be no CZ or SZ will be equal to the entire area. In this case, $NUV = -CUV_{EA}$ (i.e. complete loss). In effect, NUV (with the + or – sign) provides a meaningful measure of impact on different use-categories.

The differences in density and utility values of plants will result in a wide range of NUV values making comparison between utility classes somewhat difficult. In particular, comparable values of NUV for two use-categories need not imply similar levels of impact. The comparison becomes more meaningful when these values are 'scaled' by the pre-project values (i.e. CUV_{EA}). The scaled NUV is called Vulnerability Index (VI) and is defined as the ratio of the NUV to CUV_{EA}:

$$\begin{aligned} VI &= NUV/CUV_{EA} \\ &= (\text{Ratio of } CUV_{CZ} \text{ to } CUV_{EA}) \\ &\quad - (\text{Ratio of } CUV_{SZ} \text{ to } CUV_{EA}). \end{aligned}$$

In the absence of the project, there is no SZ and VI will be unity (+1). In the post-project case, values close to +1 signify near absence of impacts, while negative values indicate severe adverse impacts. Positive values around zero also indicate vulnerability and can become negative with slight disturbance. The strength of VI as an index in EIA studies emanates from the fact that its behaviour can be considerably different from NUV. Due to the relative magnitudes of NUV and CUV_{EA}, high (or low) NUV need not necessarily result in large (or small) values of VI or vice versa.

Results and discussion

Use-values

From the study area, local communities were found to use 175 plant species for different purposes[22]. Out of these, 87 were woody species. The use of these species was restricted to the local people who collect these plants as and when required. Commercial exploitation of any species is not known to occur in the study area. The State Forest Department, Government of Madhya Pradesh, exploits only *T. grandis* and *D. melanoxylon* commercially through different forestry operations.

Of the woody species used by local communities, 69 species of 32 angiosperm families were recorded in the sample plots from the entire study area. Nineteen species (27.5%) were recorded with single use, 24 species (34.8%) with two uses and 26 species (37.7%) with three to five uses (Table 2). The use-values of different species varied between 0.5 and 4. The use-value of 52 species is less than 2.5, while only 17 species have a use-value of 2.5 and more. *T. grandis*, *D. melanoxylon*, *Z. xylopyra*, *A. marmelos*, *H. isora* and *N. arbor-tristis* were some of the species showing high use-values as well as relatively higher densities. It was also evident that in both the zones, plants of higher use-values were recorded more in number than those of lower use-values, indicating the overall use-potential of the area (Figure 3). However, in terms of overall plant density under different use-values, we recorded some variations between the two study zones. While relatively more plants of lower use-values are present in SZ, the CZ recorded more plants with higher use-values (Figure 3).

The local people of the area use maximum number of woody species for medicinal purposes, followed by the species used for construction work, food and fodder (Table 3). The 'medicinal' value includes cures for many common human diseases and other health problems. Under this use-category, local people used 44 woody species (63.8%). Further, 75.6% of the total useful plants of the area support the medicinal requirements of the native communities. Common woody species used for different medicinal purposes are *Vitex negundo* for rheumatism; *Terminalia belarica* and *Pterocarpus marsupium* for asthma; *Ougenia dalbergioides* and *Butea monosperma* for body pains; *Ventilago maderaspatana* and *Schleichera oleosa* for sexual disorders; *Adina cordifolia*, *Aegle marmelos* and *Bridelia retusa* for stomach disorders; *Stereospermum suaveolens* and *Lannea coromandelica* for snakebites;

Table 2. Use-value of woody species in different study zones

Family	Species	Use	Use-value	Plants/ha		
				SZ	CZ	Entire area
Anacardiaceae	*Buchanania lanzan*	C, h	1.5	5	4	4
	Lannea coromandelica	E	1.0	9	14	12
Annonaceae	*Anona squamosa*	C, e	1.5	1	–	1
Apocynaceae	*Holarrhena antidysenterica*	D, e	1.5	286	106	199
Bignoniaceae	*Dolichandrone falcata*	e	0.5	1	1	1
	Stereospermum suaveolens	e	0.5	1	–	1
Bombacaceae	*Bombax malabaricum*	c,e,g	1.5	1	1	1
Boraginaceae	*Cordia macleodii*	a	0.5	–	1	1
	Cordia myxa	c,e	1.0	1	1	1
Burseraceae	*Boswellia serrata*	E	1.0	2	6	4
Caesalpiniaceae	*Bauhinia racemosa*	B,d,e,G	3.0	3	26	14
	Cassia fistula	c,d,E,f	2.5	67	41	55
	Hardwickia binata	A,B,G	3.0	7	28	17
Celastraceae	*Gymnosporia montana*	G	1.0	45	18	32
Combretaceae	*Anogeissus latifolia*	B,E,h	2.5	57	156	105
	Anogeissus pendula	c,e	1.0	1	–	1
	Terminalia arjuna	a,e,g	1.5	4	1	2
	Terminalia belarica	c,E	1.5	1	1	1
	Terminalia tomentosa	a,b,c	1.5	14	57	34
Ebenaceae	*Diospyros melanoxylon*	A,C,H	3.0	228	133	182
Euphorbiaceae	*Bridelia retusa*	e	0.5	1	1	1
	Emblica officinalis	c,E,h	2.0	1	3	2
Fabaceae	*Butea monosperma*	d,E,G	2.5	75	7	43
	Dalbergia paniculata	e	0.5	2	3	3
	Dalbergia sissoo	A,B	2.0	1	–	1
	Erythrina suberosa	a	0.5	1	–	1
	Ougenia dalbergioides	a,e	1.0	1	1	1
	Pterocarpus marsupium	a,B,e	2.0	1	3	2
Flacoutiaceae	*Flacourtia ramontchi*	b,c,D	2.0	18	17	18
Lecythidaceae	*Careya arborea*	a,E,g	2.0	1	1	1
Lythraceae	*Lagerstroemia parviflora*	A	1.0	196	135	167
Meliaceae	*Azadirachta indica*	c,E	1.5	1	–	1
	Soymida febrifuga	A	1.0	1	–	1
Mimosaceae	*Acacia catechu*	A,B,C,	4.0	4	28	16
	Acacia leucophloea	E	2.0	13	6	12
	Acacia nelotica	A,B	1.5	1	3	2
	Albizia amara	a,c,e	3.0	–	1	1
	Albizia lebbek	A,B,E	0.5	1	–	1
	Albizia procera	a	2.0	1	–	1
	Dichrostachys cinerea	A,E	0.5	1	7	4
	Mimosa hamata	e	1.5	1	8	4
	Tamarindus indica	b,e,g,C,E	2.0	1	–	1
Moraceae	*Ficus religiosa*	a,b,C,e,F	3.5	–	1	1
	Ficus sp.	e	0.5	–	8	4
Myrtaceae	*Syzygium cumuni*	A,C	2.0	2	1	1
Oleaceae	*Balanites aegyptica*	e	0.5	2	–	1
	Schrebera swietenioides	a	0.5	1	1	1
Poaceae	*Dendrocalamus strictus*	C,G	2.0	14	26	20
Rhamnaceae	*Ventilago maderaspatana*	E,g	1.5	–	1	1
	Zizyphus mauritiana	B,C,d,g	3.0	5	4	4
	Zizyphus nummularia	b	0.5	2	2	2
	Zizyphus xylopyra	B,D,G	3.0	53	190	118
Rubiaceae	*Adina cordifolia*	A,E	2.0	3	1	2
	Gardenia latifolia	B,D	2.0	2	3	3
	Mitragyna parviflora	A,b	1.5	5	4	4
	Morinda tinctoria	b	0.5	1	1	1
Rutaceae	*Aegle marmelos*	C,E,F	3.0	45	40	43
	Chloroxylon swietenia	A,e	1.5	70	11	42
Sapindaceae	*Schleichera oleosa*	A,e	1.5	1	1	1
Sapotaceae	*Madhuca indica*	C,e,H	2.5	2	2	2
Solanaceae	*Solanum xanthocarpum*	e	0.5	1	1	1
Sterculiaceae	*Helicteres isora*	B,c,E,G	3.5	485	772	625
	Sterculia urens	c,d,E,G	3.0	1	1	1
Tiliaceae	*Grewia tiliaefolia*	a,c	1.0	2	18	10
Ulmaceae	*Holoptelia integrifolia*	b,e	1.0	1	1	1
Verbenaceae	*Lantana camara*	c,g	1.0	55	3	30
	Nyctanthes arbor-tristis	D,e,f,H	3.0	16	190	100
	Tectona grandis	A,E,G	3.0	849	590	725
	Vitex negundo	e,g	1.0	57	2	31

A or a, Construction (house and agriculture implements); B or b, Fodder; C or c, Food; D or d, Fuel; E or e, Medicinal; F or f, Religious; G or g, Miscellaneous (fibre, thatching, fencing, poison); H or h, Commercial (sold in local market). Uppercase indicates major use, lowercase indicates minor use.

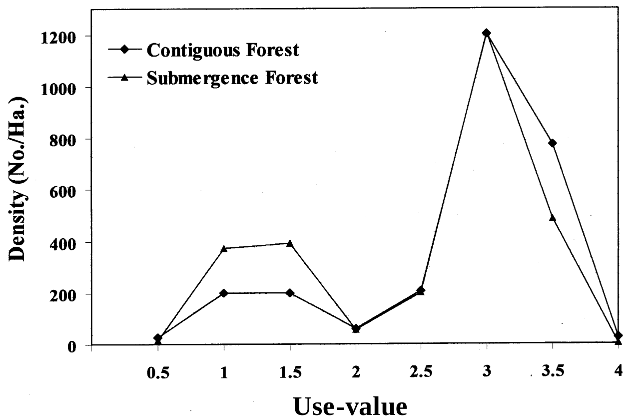

Figure 3. Plant density *vis-à-vis* use-values in the two study zones.

Annona squamosa for boils and *Cassia fistula* for bronchitis[22]. Many of the species are also used for various diseases of domesticated animals, e.g. *Balenites aegyptica*, *Albizia amara*, *Aegle marmelos*, *Careya arborea* and *Dalbergia paniculata.*

Under the 'construction' category, 27 timber-producing species (39%) are used in house construction and for making agriculture implements. 45% of the total useful plants were supporting the construction needs of the people. The village communities in the area showed clear preferences of species and girth classes for different purposes[21]. Teakwood (*T. grandis*) is mostly used in construction due to its durability as well as frequent availability in the area. Other major timber-yielding species of the area are *Acacia leucophloea*, *H. binata*, *L. parviflora*, *Chloroxylon sweitenia* and *Acacia catechu*.

The 'food' category includes all edible species: fruits (*Buchanania lanzan*, *A. squamosa*, *D. melanoxylon*, *Emblica officinalis*, *Zizyphus mauritiana*, *A. marmelos*, *Madhuca indica*); gum (*A. catechu*, *A. latifolia*, *B. monosperma*); bark (*Bombax malabaricum*); tender shoots (*Dendrocalamus strictus*) and flowers (*C. fistula*, *Cordia myxa*, *Helicteres isora*). Different food items were extracted from 25 species (36%) and 39% of the total useful plants.

Twenty species (29%) and 36% of the total plants produce fodder. *H. binata* and *H. isora* provide the majority of fodder collected by local communities. According to one estimate, around 55% of the total households in forest villages collect fodder from these two species only[16]. *Bauhinia racemosa*, *A. latifolia*, *A. catechu*, *Z. xylopyra* and *Mitragyna parviflora* are the other important fodder species of the area.

The 'miscellaneous' category includes the use of species for fibre extraction (*Bauhinia racemosa*, *B. malabaricum*, *B. monosperma*, *H. binata*), roof thatching (*H. isora*, *D. strictus*, *Sterculia urens*, *T. grandis*), fencing the agriculture fields and houses (*Gymnosporia montana*, *Mimosa hamata*) and fish poisoning (*Careya arborea*). Miscellaneous items are extracted from 17 species (24.6%) and about 61% of the total useful plants.

All species for which a local market exists are grouped under a separate 'commercial' category. Six species (8.7%) and 14.5% of the total individual plants fall into this category. Leaves of tendu (*D. melanoxylon*) are used for making 'bidi' (locally made cigarette). Every year, in the pre-monsoon months of May and June, the State Forest Department collects these leaves on a massive scale. It is estimated that from this area on an average, every family of the forest villages collects about 23,500 leaves per day[16]. This generates substantial income to the local communities. The State Forest Department auctions the collected leaves to bidi factories earning good revenue. According to an estimate, from the SZ alone the State Forest Department generates an annual revenue of about rupees 1.06 million[23]. Thus, both local as well as regional markets exist for this species. The fruits of mahua (*M. indica*), used for making liquor are sold at local markets and are always in heavy demand. Local communities use stems of *N. arbor-tristis* in basket weaving. These baskets are then sold in the local markets. Fruits of *E. officinalis* and *B. lanzan* and gum of *A. latifolia* also have a small commercial value in the local markets. It is estimated that every tribal family earns about 5% of its total annual income from the different non-timber forest produce extracted from the SZ (ref. 16). Four species (5.8%) and 7.3% of the useful plants are used for religious purpose. *Ficus religiosa* and *A. marmelos* are the two important species used for this purpose.

Impacts of the dam

It is acknowledged that with the submergence of nearly 400 km^2 of forests, there would certainly be severe impacts on various floral values and wildlife values and vegetation communities[16,19]. As a consequence, there would also be serious shortages of useful plants in the area. Moreover, as discussed earlier, there are two situations to note in the context of impact analysis:

(a) In the pre-project scenario, the SZ meets the resource requirements of the people living within and outside it. However, in the post-project scenario, due to complete loss of resources in the SZ, people living in the CZ are forced to extract more resources from this zone.

(b) In the absence of a proper resettlement plan[3], the CZ will also provide refuge to a large number of project-affected people and their livestock. As a result, the per capita availability of useful plants in the CZ will be reduced, resulting in over-exploitation.

Table 3. Number of useful species and plants under different use-categories in the study area

Use	Number of species			Number of plants/ha		
	Entire area	SZ	CZ	Entire area	SZ	CZ
Total	69	64	58	2727	2732	2694
Construction	27 (39.1)	24 (37.5)	22 (37.9)	1230 (45.1)	1313 (48.1)	1026 (38.1)
Fodder	20 (29.0)	18 (28.1)	19 (32.8)	983 (36.0)	673 (24.6)	1308 (48.6)
Food	25 (36.2)	24 (37.5)	21 (36.2)	1057 (38.8)	956 (35.0)	1157 (42.9)
Fuel	10 (14.5)	10 (15.6)	10 (16.9)	512 (18.8)	526 (19.3)	585 (21.7)
Medicinal	44 (63.8)	41 (64.1)	38 (65.5)	2062 (75.6)	2060 (75.4)	2042 (75.8)
Religious	4 (5.8)	3 (4.6)	4 (6.9)	199 (7.3)	128 (4.7)	272 (10.1)
Miscellaneous	17 (24.6)	16 (25.0)	17 (29.3)	1669 (61.2)	1656 (60.6)	1679 (62.3)
Commercial	6 (8.7)	6 (9.4)	6 (10.3)	395 (14.5)	309 (11.3)	488 (18.1)

Values in parentheses indicate the percentage of total.

In the context of NSP, both the SZ and CZ recorded nearly equal density of useful plants (2732 plants/ha and 2694 plant/ha, respectively) and the number of species under different use categories (Table 3). This gives the impression that submergence will have little impact on use-values because 'to-be-lost' values are commensurately represented in the CZ. However, variations in the density of plants with different use-values (Figure 3) indicate unequal value representation in the two zones. This is likely to cause availability decline in the post-dam scenario, especially due to secondary impacts in the CZ.

Further, when the logic of 'value-representation' is applied to separate use-categories, the 'construction' category with 1313 plants/ha in the SZ as against 1026 plants/ha in the CZ, is likely to be impacted as a result of primary (submergence) and subsequent secondary impacts. The number of plants in the 'fodder' category is significantly high in the CFZ (1308 plants/ha) than in SZ (673 plants/ha) and thus is likely to be unaffected in the post-project case (Table 3). However, the rest of the use-categories were represented marginally more in one or the other zones and may become vulnerable.

Use of indices

It is observed that NUVs range widely, indicating varying degree of impacts to different use-categories. The 'construction' category, with the NUV of – 412 indicates high degree of impact due to NSP, whereas the 'fodder' category with the NUV of + 511.5 is considered to be relatively unaffected (Table 4). Other use-categories with high positive NUVs are also considered to be relatively unaffected. The large positive (or negative) NUVs clearly testify to low (or high) impact (in an absolute sense) on different use-categories.

Relatively low magnitudes of NUVs (both + and –) pose some difficulty while assessing the vulnerability of different use-categories to impacts. In this context, we effectively used the VI, i.e. the scaled NUV to grade impacts. As discussed earlier, the VI provides a better measure for assessing relative impacts and is able to better discriminate between relative impacts.

VI values are high for the use-categories of construction (– 0.34), fodder (+ 0.54) and commercial (+ 0.33). Use of both NUV and VI leads to the same conclusions in these cases without ambiguity. Similarly, lower VI values for the medicinal (0.01), food (0.10) and fuel (0.19) categories indicate their high vulnerability to the project-induced impacts (Table 4).

The following two cases clearly illustrate the usefulness of VI in differentiating the impacts:

(a) The religious category records the highest VI (+ 0.58) showing its relatively unaffected post-dam position unlike the vulnerability shown by NUV. The miscellaneous use category with nearly the same NUV value, however, has low VI far removed from + 1 (0.05), indicating significant impact.

(b) In terms of NUV, the fodder category recorded the highest NUV (+ 511.5) while the religious category recorded a low value (+70), indicating large disparity in the degree of impact. However, the use of VI shows that contrary to the inference from NUV, both are subject to the same level of impact (0.54 and 0.58).

At the species level also, some of the useful species will be impacted, at first, due to creation of the reservoir (primary impact), and subsequently due to increased human activities in the CZ (secondary impacts). By comparing the density of plants in the two study zones, 12 species were considered likely to be impacted due to the dam construction (Table 5). These species have recorded in a low density in the CZ as compared to the SZ. However, in the post-project scenario, species which are the products of forest degradation, such as *Gymnosporia montana* and exotic *Lantana camara* could flourish in the CZ due to increased biotic pressure in this zone. Similarly, in the low-lying waterlogged areas of the CZ the two riverine species, *Terminalia*

Table 4. Measure of impacts for different use-categories in Narmada Sagar Project area

Use	CUV			NUV	VI
	SZ	CZ	Total area		
Construction	1394.5	982.5	1201.5	–412.0	–0.34
Fodder	652.0	1163.5	950.5	+511.5	+0.54
Food	631.5	698.0	666.0	+66.5	+0.10
Fuel	450.5	545.5	496.5	+95.0	+0.19
Medicinal	1831.5	1852.5	1851.0	+21.0	+0.01
Religious	86.5	156.5	121.5	+70.0	+0.58
Miscellaneous	1594.0	1668.5	1632.0	+74.5	+0.05
Commercial	277.5	406.5	389.5	+129.0	+0.33

Table 5. Species likely to be impacted by the Narmada Sagar Project

Species	Use	Use-value	Plants/ha		Degree of impact
			SZ	CZ	
Gymnosporia montana	G	1.0	45	18	Low
Lagerstroemia parviflora	A	1.0	196	135	Low
Vitex negundo	e,g	1.0	57	3	Low
Lantana camara	c,g	1.0	55	3	Low
Terminalia arjuna	a,e,g	1.5	4	1	Medium
Acacia leucophloea	A,B	2.0	13	6	Medium
Chloroxylon swietenia	A,e	1.5	70	11	High
Holarrhena antidysenterica	D,e	1.5	286	106	High
Cassia fistula	c,d,E,f	2.5	67	41	High
Tectona grandis	A,E,G	3.0	849	590	High
Butea monosperma	d,E,G	2.5	75	7	High
Diospyros melanoxylon	A,C,H	3.0	228	133	High

A–H, a–h have the same meaning as in Table 2.

arjuna and *Vitex negundo*, could also flourish due to increased surface and groundwater availability after inundation of the area. Considering all these possibilities, six species can be identified that face higher degrees of impact (Table 5). Of these six species, four have high use-value (2.5 or 3) and are thus more likely to be over-exploited in the post-dam scenario.

Conclusions

In this work we have examined the impacts of a major hydroelectric project on the ethnobotanical resource base in a Central Indian forest tract. The impacts have been assessed using an objective approach by developing certain indices marking a departure from traditional EIA studies. The indices presented here constitute an attempt to integrate heterogeneity in plant distribution and variation in their uses into the criteria for impact assessment. These indices are applicable in any similar situation where the same kind of resources remain to an extent outside the project in a 'refuge' zone. However, information on the mere presence or absence of the same species in the project area and refuge zone is inadequate to develop a better perception of the project-related impacts.

Species of little use and those with high values are not differentiated in the traditional approaches based on presence/absence or density differences. To overcome such limitations, we have incorporated the ethnobotanical values and the relative abundance of plants into two measures – (a) NUV and (b) VI. NUV is an index of the 'net availability' of ethnobotanical resources in the post-project scenario, incorporating, in some sense, the transfer of pressures on resource use from the area lost to project to the outside area, i.e. the 'refuge' zone. It signifies reduced post-project resource availability and is central to the approach proposed and measures impacts more or less in an absolute sense. VI – an improvement on NUV – is a better measure to discriminate between relative impacts since it scales NUV by the pre-project values.

The behaviour of VI can be considerably different from NUV. High (or low) values of one do not necessarily imply similar values for the other since the values will depend on the heterogeneity of the two zones in terms of relative abundance of different ethnobotanical species and their use-scores based on ordinal measures.

The indices developed here may be used to advantage in similar EIA studies where the ethnobotanical values can be quantified and converted into ordinal measures. If the use-score can be improved using a larger ordinal scale rather than simplified scores of 0.5 and 1.0 used here, the utility of these indices will be greatly enhanced. This is possible, if detailed resource extraction data are collected in the course of EIA studies.

When large projects such as the NVDP are implemented in a forested tract with very high ethnobotanical values, it is necessary to quantify impacts on various use-values of plants going beyond descriptive documentation. Numerical indices employed in this study have been used to highlight the expected impacts of NSP on forest-dwelling communities. The approach presented in this study is quite pertinent in situations where the impacts are neglected when ethnobotanical resources lost appear to be well-represented outside the project area. It clearly emerges from this study that even when species representation is almost equal within and outside the project area, varying degrees of impact can be expected to occur on the ethnobotanical resources.

1. Report, Centre for Science and Environment, New Delhi, 1982.
2. Report, Centre for Science and Environment, New Delhi, 1985.
3. Paranjapaye, V., *High Dams on Narmada*, INTACH, New Delhi, 1989.
4. Gadgil, M., *Nat. Resour.*, 1991, **27**, 12–20.
5. Goldsmith, E. and Hildyard, N., *Social and Environmental Effects of Large Dams*, Ecosystems Ltd, Camelford, UK, 1984, vol. 1.
6. Mohanty, R. P. and Mathew, T., *J. Environ. Manage*., 1987, **24**, 315–336.
7. Johnsingh, A. J. T., Prasad, S. N. and Goyal, S. P., *Biol. Conserv*., 1990, **51**, 125–138.
8. Panwar, H. S., Rajvanshi, A., Gautam, P., Murlidharan, V. V. and Rastogi, A., Report, Wildlife Institute of India, Dehra Dun, India, 1990.
9. Jain, S. K., in *Glimpses of Indian Ethnobotany* (ed. Jain, S. K.), Oxford and IBH Publishing, New Delhi, 1981, pp. 191–198.
10. Oommachan, M., Masih, S. K. and Shrivastava, J. L., *J. Trop. For*., 1989, **5**, 182–196.
11. Prasad, R. and Pandey, R. K., *J. Trop. For*., 1987, **3**, 287–297.
12. Prasad, R., Pandey, R. K. and Singh, S. P., *J. Trop. For*., 1988, **4**, 236–241.
13. Prance, G., Balee, W., Boom, B. and Carneiro, R., *Conserv. Biol*., 1987, **1**, 296–310.
14. Brown, K., *Biodiver. Conserv*., 1994, **3**, 734–750.
15. Westman, W. E., *Ecology, Impact Assessment, and Environmental Planning*, John Wiley, New York, 1985.
16. Anon, Report, Wildlife Institute of India, Dehra Dun, 1994.
17. Jain, S. K. and Sastry, A. R. K., *Materials for a Catalogue of Threatened Plants of India*, Botanical Survey of India, Howrah, 1983.
18. Champion, H. G. and Seth, S. K., *A Revised Survey of the Forest Types of India*, Govt. of India Press, New Delhi, 1968.
19. Dixit, A. M., *Trop. Ecol*., 1997, **38**, 87–99.
20. Varma, S. C., *Human Resettlement in Lower Narmada Basin*, Narmada Valley Development Authority, Bhopal, 1985.
21. Dixit, A. M. and Rajvanshi, A., *Trop. Ecol*., 1998, **39**, 151–154.
22. Rajpurohit, K. S., in *Environmental & Adaptive Biology of Plants – Prof. D. N. Sen Commemorative Volume* (ed. Chawan, D. D.), Scientific Publishers, Jodhpur, 1995, pp. 67–83.
23. Doria, R., *Environmental Impact of Narmada Sagar Project*, APH, New Delhi, 1990.

ACKNOWLEDGEMENTS. We are grateful to H. S. Panwar, the then Director, Wildlife Institute of India, for providing an opportunity to undertake this study. We wish to thank the anonymous referee for suggesting several improvements. We also thank Dr K. S. Rajpurohit for the data.

Received 13 January 2000; revised accepted 3 June 2000