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Toward SDGs: Forest, Market and Human Wellbeing Nexus in Indian Western Himalayas

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The wellbeing of mountain communities is determined by the availability and accessibility of ecosystem goods and services. We assessed the relationship between forest quality and wellbeing of local communities of Nanda Devi Biosphere Reserve (NDBR) in the Upper Ganga River Basin, Western Himalayas, India. We used 14 relevant Sustainable Development Goals of the United Nations as indicators to assess wellbeing. Data on these indicators were collected in 22 villages that were selected based on secondary demographic information, remoteness, and the state of the forest resources, which we classified into degraded and less-degraded. Semi-structured questionnaire-based interviews were conducted in randomly selected households ($n = 764$). The households located close to forests scored higher on wellbeing indicators than the households located further away from forests as they have better accessibility to forest resources and freshwater, which provides alternatives to market and agricultural products. Households with access to less-degraded resources also had access to wild fruits, vegetables, and medicinal plants adding to their food and health security. Our study found that the combination of climate change, declining forest resources, and the expansion of the market-based economy is leading to shifts in traditional cropping patterns and hence the nutritional status and forest use patterns of local people, making them vulnerable to diseases and hunger. Accessibility to an intact forest patch near a village contributes to the wellbeing of people and increases their resilience in the face of climate change and the changes dictated by the market forces.

Keywords: livelihood, ecosystem services, resilience, forest resources, market forces toward SDGs, Ganga River Basin

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INTRODUCTION

The current rate of degradation of natural resources makes sustainable development the only choice available to policymakers (Mensah, 2019). The concept of sustainable development focuses on ecological sustenance, economic development, and human wellbeing (WCED, 1987; Paul, 2008). Human wellbeing is a combination of the physical, mental, social, and financial aspects of one's life (Zemtsov and Osipova, 2016). Overall, human wellbeing is an outcome of the experience of individuals, which is often a result of interaction between various socio-political and ecological variables (Kaplan et al., 1976; Danna and Griffin, 1999; Stutzer and Frey, 2010; Conway et al., 2021). Human wellbeing has been a focus of social discourse and policymaking since the advent of civilizations. Scholars from the pre- and post-industrialization eras have discussed the measure of wellbeing at length. However, the notion has, to date, been largely confined to rich societies

and countries. The Human Development School of thought of the United Nations Development Programme only broadened this theory to low-income countries, where quality of life depends on natural resources (Gough and McGregor, 2007), during the 1990s. The links between the wellbeing of forest-dependent communities and their livelihoods have been the center of social studies (Gibson, 1944; Kaufman and Kaufman, 1946; Frey and Stutzer, 2010), which concludes that rapid economic growth might decrease social wellbeing (Frankena, 1980; Freudenburg, 1984; Beckley, 1995) as this growth is usually at the cost of forests and other natural resources (Goldschmidt, 1947; Laurance et al., 2014; Sloan and Sayer, 2015). Goldschmidt (1947) presented that increased concentration of the farm sector led to a decline in rural economic and social wellbeing. He noted that in contrast to a community surrounded by large farms, a community surrounded by small farms had a higher percentage of self-employed and white-collar workers; a lower percentage of farm wage laborers; more business and retail trade; more schools, parks, civic and social organizations, newspapers, and churches; and a better-developed infrastructure and a more defined local decision-making structure (Kusel, 1996).

The wellbeing of the majority of rural human societies depends on the availability and accessibility of the services and goods in the surrounding environment such as the production of food, fuel and shelter, water supply, and control of natural hazards (Costanza and Daly, 1992; Daily, 1997; Díaz et al., 2006; Joshua and Daly, 2006; Dhakal and Kattel, 2019). Forest and other natural resources contribute significantly to the development of a nation, alleviating poverty and securing the ecological, social, and economic sustainability of human society by providing crucial ecosystem services (Jhariya et al., 2021). This contribution has been recognized by various international programs such as the Committee on World Food Security Sessions, the UN's Millennium Assembly, Sustainable Development Goals, and Global Sustainable Development Conference (Faham et al., 2008; Schwerhoff and Mouhamadou, 2017). This contribution is more prominent in the remotely located rural communities of developing countries where people's everyday needs and livelihoods are linked to natural resources (Ramakrishnan, 2007). However, the abilities of people to use these services are often determined by the condition and type of natural resources (Sangha et al., 2018). Economically marginalized rural communities are dependent on products of natural ecosystems for their basic needs; hence the level of their wellbeing varies with the change in the condition of natural resources, especially in developing countries, such as India (Kluvánková et al., 2018; Dandabathula et al., 2021; Halder et al., 2021; Lakshmi, 2021). The restricted availability of natural resources and their reduced ability to provide services has resulted in frequent and intensified ecological and economic shocks to the dependent communities leading to a reduced sense of security, especially among most marginalized communities and women (Adger, 2010; Pecl et al., 2017). The security and wellbeing of marginalized communities are increasingly under stress due to climate change, as climate change in combination with uninformed decision-making has altered the floral and faunal composition and ultimately their ability to provide essential ecosystem services (Summers et al., 2012; Staudt et al., 2013; Malhi et al., 2020; Weiskopf et al., 2020). It is challenging to achieve a balance between economic security and biodiversity conservation (Bawa et al., 2021). In the Indian scenario, social hierarchy and cultural norms control the access to natural resources that ultimately determine the economic mobility of communities and households (Joseph and Selvaraj, 2010). The distribution of ecosystem services is determined by social factors such as resource-specific needs, different cultural identities, differentiated social status and bargaining power, exclusionary and inclusionary social practices, and ecological factors such as differential access and quality of natural resources (Lakerveld et al., 2015). The level of access to ecosystem services also influences peoples' support for natural resource management and conservation (Badola et al., 2012; Kauppi et al., 2018).

The Indian Himalayan region is an important natural capital and provides essential ecosystem services in the area and beyond, supporting livelihoods and other daily needs (Malik et al., 2014). The large population in the area still depends primarily on natural resources. Although the region has been admired and studied for its contribution to humankind, it is one of the most vulnerable ecosystems in the world (Wester et al., 2019). Recognizing the links between the wellbeing of people and the sustainability of such critical ecosystems, and understanding the complexity of the connections between human wellbeing and the quality of services provided by natural systems and biodiversity is essential for effective conservation planning, informed decision making, and sustainable development (Leisher et al., 2013; Sandhu and Sandhu, 2014; Sandifer et al., 2015). The present study thus aimed to assess the contribution of ecosystem services to the wellbeing of forest-dependent local communities of the Nanda Devi Biosphere Reserve (NDBR) and the impact of market development on this community.

STUDY AREA

The Nanda Devi Biosphere Reserve lies in the Upper Ganga Basin in the State of Uttarakhand, India. It covers an area of 6,020.4 km^2 at an altitude of 1,800–7,817 m in the Western Himalayas. The Reserve comprises Nanda Devi National Park and Valley of Flowers National Park interspersed with villages and cultivated lands (**Figure 1**), which is termed "the buffer zone" of the National Parks. The buffer zone is surrounded by a multipurpose transition zone. Both the parks have been identified as Natural World Heritage Sites (Bosak, 2008). Being in the inner Himalayan region it has a microclimatic condition. Vast altitudinal variation (1,800–7,817 m asl) has given rise to a variety of climates ranging from temperate to sub-alpine to alpine. The climate is temperate and monsoonal and can be divided into long winter, short summer, and rainy seasons. Conditions are generally dry with low annual precipitation, but there is heavy rainfall from late June to August. Geologically, the area falls within the Greater Himalayas or Himadri System. A small part of Niti valley has characteristics of trans-Himalayas. Natural forested areas, alpine and temperate grasslands, water bodies (rivers, small streams, and high-altitude glacial lakes), snow and glacier areas, natural landslides, and rocky and barren areas are

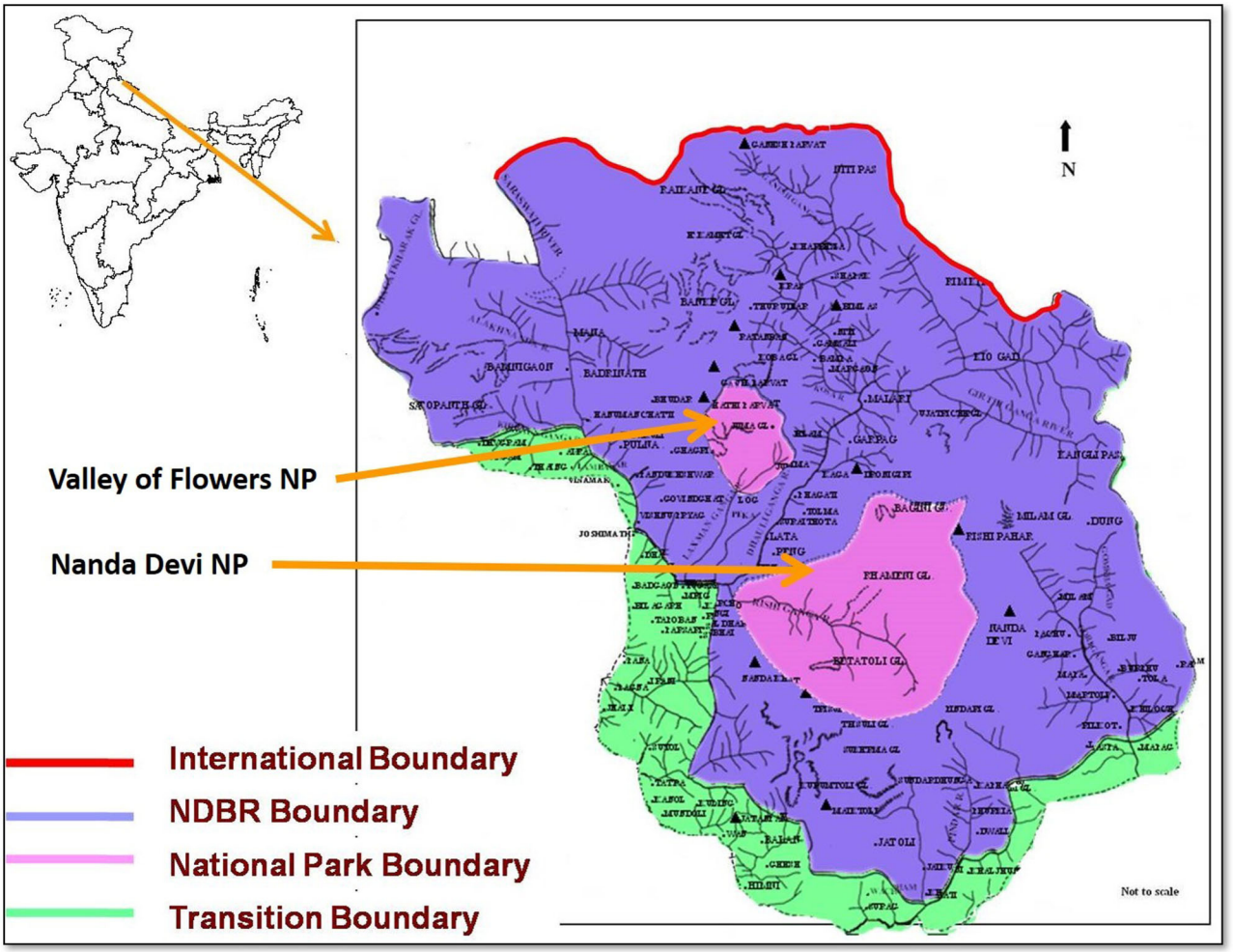

FIGURE 1 | Location map and administration zones of the Nanda Devi Biosphere Reserve.

the LULCs found in NDBR. Settlements (small townships and villages), agricultural land (terrace farms), orchards, plantations, and developmental areas are modified landscapes. Most of the flora and fauna in the NDBR are native and endemic. Forest types of NDBR can be divided into six categories: Subtropical pine, Himalayan moist temperate, Subalpine, Moist alpine scrub, and Dry alpine scrub (Champion and Seth, 1968).

No human habitations are present inside the core zones but there are 47 villages in the buffer zone and 33 villages in the transition zone with six villages in the immediate buffer of the core zones. Forest resource-dependent, Bhotia (Indo-Mongoloid) and Garhwali (Indo-Aryan) are the prominent communities in the area. Bhotias are mainly dependent on handicrafts and tourism, whereas agriculture and cattle and goat rearing are the primary occupations for Garhwalis. Communities of NDBR are culturally and economically dependent on natural resources. The area hosts many religious and recreational tourists per year, which provide alternative livelihoods to the people at the cost of the quality of the natural ecosystem (Dobriyal, 2015).

Remoteness, ecological fragility, limited access to natural and modern resources, clubbed with impacts of climate change make the communities vulnerable to environmental and economic shocks.

METHODOLOGY

The data for social variables of human wellbeing were collected in three stages (Badola and Hussain, 2003; Ofoegbu et al., 2017) (**Figure 2**). The first stage involved a rapid assessment of the study area to obtain an overall perspective of the villages. Secondary data regarding access to basic facilities along with location and distribution of villages with respect to forest, type of forest, distance from forest, and their dependency pattern on forests for resources, such as fuelwood, fodder, and NTFPs, were collected. Forest condition was determined by laying line transects of 2–4 km in the forest patches that were used by local people. Along the transects, circular plots were laid at every

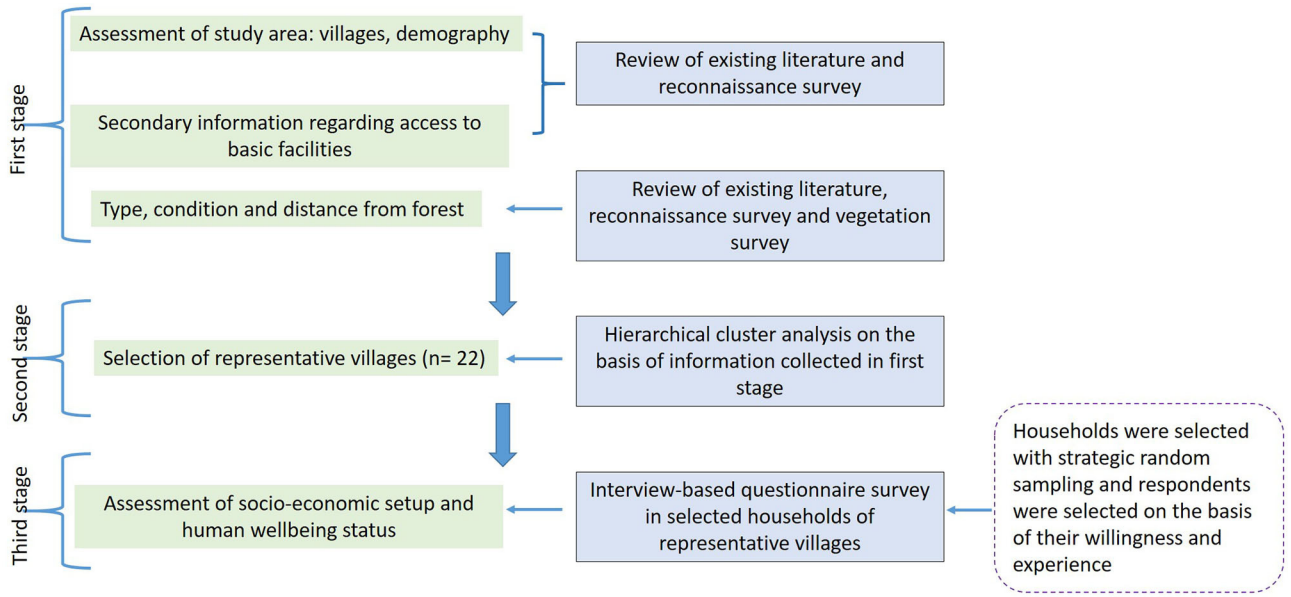

FIGURE 2 | Process followed to assess the human wellbeing status of forest-dependent communities in the NDBR.

200 m. In each plot, information on plant species, canopy cover, invasive species, plot density, sign of human presence such as number of trails, percentage of lopping, grass and fodder cutting, livestock presence, and signs of grazing were recorded. The plot data were further used to categorize the forests into degraded and less-degraded categories. Since most of the forest patches were being used to some extent, a non-degraded category was avoided (Jhala et al., 2009). Households located at a distance of 500 m−2.5 km from the forest were categorized as households located close to the forest while households located at a larger distance than this were categorized as households located away from the forest.

In the second stage, data collected during rapid assessment was used to run a hierarchical cluster analysis (Badola et al., 2012; Dutta et al., 2020). A total of 11 clusters were formed and representative villages ($n = 22$) were identified from each cluster for intensive study. Out of the 22 villages sampled, 10 were in the buffer zone while 12 were located in the transition zone of NDBR.

In the third stage, extensive data on quality of forest resources and human wellbeing were collected in selected villages. Households were selected with a strategic random approach. Head of the house or in absence of the head, any elderly person (irrespective of gender) was interviewed (Nyanga et al., 2016; Thammanu et al., 2021). A semi-structured interview-based questionnaire was developed to collect the data on socio-economic aspects and the status of human wellbeing. It was hypothesized that households located close to the forest will have higher wellbeing. To assess various components of overall wellbeing, namely, social wellbeing, health wellbeing, political wellbeing, workplace wellbeing, and environmental wellbeing, indicators were developed based on Sustainable Development Goals (SDGs) of the United Nations and literature review (Sandhu and Sandhu, 2014; UN-SDG, (United Nations-Sustainable Development Goals), 2015; Friedman and Gostin, 2016; Hossain et al., 2016; Smale and Hilbrecht, 2016; Breslow et al., 2017; Daher-Nashif and Bawadi, 2020; Loveridge et al., 2020; Millennium Ecosystem Assessment, xbib2005) (**Table 1**). Other than SDGs 11, 14, and 17, all the goals were considered to develop the hypotheses (http://www.undp.org). Targets under these goals were used to form questions. A subjective index was developed to calculate the level of different types of wellbeing in every household.

The impact of variables such as the presence of roads, developmental activities such as hydroelectric projects, market forces, and outsiders have been also assessed, as their presence may affect the accessibility and condition of the forest resources. The information collected on the impact of outsiders on the local community and their access to natural resources was validated through interactions with workers of hydroelectric projects and road development agency as well as the tourists visiting the area.

Responses were recorded to access to basic amenities, including clean drinking water, health facilities, sanitation, electricity, LPG, telephone, motorable roads, and markets. Questions related to the shift in cropping pattern; economy, livelihoods, and causes leading to the reported shifts were also recorded to understand the dynamics of the local economy and their impact on natural resources as well as their ability to provide ecosystem services. To avoid personal biases and to maintain the validity and reliability of the answers, interviews were conducted by the same personnel (Bolarinwa, 2015; Story and Tait, 2019). The authors could speak the local language and interacted with respondents in the local language.

TABLE 1 | Indicators used to develop wellbeing index for forest dependent communities from Nanda Devi Biosphere Reserve.

Type of wellbeing	Indicators	Related sustainable development goals	Associated ecosystem services	Linkages with different ecosystem services
Education	1) Literacy rate 2) Level of education 3) Access to educational facilities 4) Distance from educational facilities	• SDG 4: Quality Education	Fodder Fuel wood Leaf litter Clean fresh water	• Accessibility (distance and quality) to natural resources such as fodder, fuel wood, water affects people's ability to have formal schooling, as more time needs to be devoted to collect the resources in both the conditions. • Women engaged in resource collection have less time for their own and children's education.
Health	5) Access to health facilities, clean water and sanitation facilities 6) Knowledge of traditional medicinal plant use 7) Frequency of health conditions due to over exertion. 8) Frequency of water borne diseases due to inaccessibility of clean water	• SDG 3: Good Health and Wellbeing • SDG 6: Clean water and sanitation • SDG 15: Life on Land	Clean fresh water Fodder Fuel wood Leaf litter	• More time and labor devoted to collect the resources results in health problems such as body ache, back ache, headache.
Economy	9) Employment status 10) Stability of the employment 11) Alternative opportunities available 12) Access to market 13) Access to roads 14) Access to electricity 15) Access to telephone 16) Access to LPG 17) Difference in the prices of agriculture and livestock produce (due to distance from road)	• SDG 1: No Poverty • SDG 7: Affordable and Clean Energy • SDG 8: Decent Work and Economic Growth • SDG 9: Industry, Innovation and Infrastructure	Clean fresh water Fodder Fuel wood Leaf litter Agricultural production Livestock production	• Access to forest resources provide an easy and low cost alternative to market products and facilities such as LPG, and livelihoods
Food security	18) Agriculture land 19) Agriculture productivity 20) Access to wild food such as leafy vegetables and fruits 21) Access to market for food	• SDG 2: Zero Hunger	Wild food Agricultural production Leaf litter to be used in agriculture field	• Wild food (fruits and vegetables) has been providing nutritive alternative to the people
Social	22) Experience of social discrimination based on caste or gender 23) Denial the access to community facilities such as water sources, temple based on caste or gender 24) Case of physical and mental harassment against women 25) Adequate representation in self-help groups 26) Sense of security in people 27) Satisfaction with upbringing of children 28) No of legal cases	• SDG 1: No Poverty • SDG 5: Gender Equality • SDG 10: Reduced Inequalities	Clean fresh water Cultural values	• Access to select services such as sites dedicated to or associated with any cultural belief and deity is affected by caste and gender • Less availability of resources leads to competition among people resulting in strained social relations
Political	29) Right to vote 30) Right to choose the representative 31) Right to participate in political activities such as Gram Panchayat election 32) Right to express 33) Active eco-development committee, women development committee, youth development committee	• SDG 10: Reduced Inequalities • SDG 16: Peace, Justice and Strong Institutions	Clean fresh water Fodder Fuel wood Leaf litter Cultural value	• Access and use of all ecosystem services is affected by the political structure of the village as political beliefs determine the control and management of resources • Competition for limited resources sometimes leads to conflict between/within villages.

(Continued)

TABLE 1 | Continued

Type of wellbeing	Indicators	Related sustainable development goals	Associated ecosystem services	Linkages with different ecosystem services
Workplace	34) Wages for work 35) Satisfaction with current job 36) Change in occupation in recent past 37) Cases of discrimination based on sex, caste, religion at workplace	• SDG 5: Gender Equality • SDG 8: Decent Work and Economic Growth • SDG 16: Peace, Justice and Strong Institutions		• Competition for limited resources leads to conflict between users
Environmental	38) Change in forest conditions in last 1, 5 and 10 39) Change in air quality 40) Increase in noise pollution 41) Change in forest resource accessibility and availability 42) Change in time taken to get forest resources 43) Average distance traveled to avail forest resources 44) Change in forest species composition 45) Change in faunal species 46) Change in no. of wild animals 47) Change in incidences of human wildlife conflict	• SDG 12: Responsible Consumption and Production • SDG 13: Climate Action • SDG 15: Life on land	Fresh air Clean fresh water Fodder Fuel wood Leaf litter	• Change in environmental conditions directly or indirectly affect health, livelihood and social structure of user communities.
Cultural value	48) Change in no. of fair 49) No. of visitors 50) Any deity linked to the forest 51) Any historical epic associated 52) Presence of renowned temple	• SDG 4: Quality Education	Cultural services Traditional practices and belief Tourism	• Contributing to economy by providing market for local products and services

Data Analysis

Total household income was calculated using income from different livelihood activities.

$$\begin{aligned} \textit{Annual household income} = {} & \textit{Income from (forest products} \\ & + \textit{livestock} + \textit{agriculture} \\ & + \textit{salaries/wages} \\ & + \textit{government schemes} + \textit{labor)} \end{aligned}$$

$$\text{Average annual household income (I)} = \frac{(i1 + i2 + i3 + \ldots. + in)}{\text{N}}$$

Where i is income from various livelihood sources, and N is the number of total households surveyed.

A subjective wellbeing index was developed using the indicators of heath, political, social, workplace, and environmental wellbeing. One point was assigned to a particular indicator (both positive and negative) if the household scored for the indicator. The total score of the household was divided by the total number of indicators defined for a wellbeing class, and an index was developed. The indices developed for each wellbeing class were further used to calculate overall wellbeing of a household.

$$\text{SWB} = \frac{(\text{P1} + \text{P2} + \text{P3} + \cdots. + \text{Pn}) - (\text{N1} + \text{N2} + \text{N3} + \cdots\ldots. + \text{Nn})}{\text{SWB\_TI}}$$

$$\text{HWB} = \frac{(\text{P1} + \text{P2} + \text{P3} + \cdots. + \text{Pn}) - (\text{N1} + \text{N2} + \text{N3} + \cdots\ldots. + \text{Nn})}{\text{HWB\_TI}}$$

$$\text{PWB} = \frac{(\text{P1} + \text{P2} + \text{P3} + \cdots. + \text{Pn}) - (\text{N1} + \text{N2} + \text{N3} + \cdots\ldots. + \text{Nn})}{\text{PWB\_TI}}$$

$$\text{WWB} = \frac{(\text{P1} + \text{P2} + \text{P3} + \cdots. + \text{Pn}) - (\text{N1} + \text{N2} + \text{N3} + \cdots\ldots. + \text{Nn})}{\text{WWB\_TI}}$$

$$\text{ENVWB} = \frac{(\text{P1} + \text{P2} + \text{P3} + \cdots. + \text{Pn}) - (\text{N1} + \text{N2} + \text{N3} + \cdots\ldots. + \text{Nn})}{\text{ENVWB\_TI}}$$

$$\textit{Overall wellbeing} = \frac{(\textit{SWB score} + \textit{HWB score} + \textit{PWB score} + \textit{WWB score} + \textit{ENVWB score})}{5}$$

Where, *OWB* is the overall wellbeing of a household. *SWB* is social wellbeing. *HWB* is health wellbeing. *PWB* is political wellbeing. *WWB* is workplace wellbeing; *ENVWB* is environmental wellbeing; *P* is a positive indicator; *N* is a negative indicator; *n* is the number of households sampled; and *TI* is total number of indicators.

Social wellbeing represents the satisfaction of respondents with the current social structure in their villages, whether they face any kind of discrimination based on caste and gender and type of relationship among villagers. Political wellbeing represents the respondent's satisfaction with working of the current village-level government and its elected representatives. Workplace wellbeing is the level of satisfaction in a workplace

in terms of payments, working conditions, the dignity of labor, and the presence/absence of any discrimination based on caste and gender at workplace. Environmental wellbeing represents the satisfaction of respondents towards the condition and quality of their source forest for natural resources and the action taken to protect them.

Positive indicators were variables that contributed to any of the above-mentioned categories of wellbeing of the respondent households, while negative indicators were variables that hampered the wellbeing of the respondent.

Mann–Whitney *U*-test was used to compare the difference between the wellbeing of households situated close and away from the forest, and the wellbeing of households dependent on degraded and less-degraded forests. SPSS 16.0 was used to run the test (Hinton et al., 2014).

RESULTS

Profile of Respondents

A total of 764 households were surveyed and representatives were interviewed, out of which 44.6% were women. In total, 66.1% of the households belonged to *Garhwali* settled community and 34% belonged to the semi-nomad transhumant *Bhotia* community. The average family size was 5.51 ± 0.09 people per family. A poor education level has been observed in the area as only ∼10% of the sampled population reported that they had a bachelor's degree or higher education. Approximately 42% of respondents had only received primary education while 20.21% could complete secondary school education. Lack of school facilities in the past (26.5%); insufficient monetary income (22%), and engagement in agricultural, livestock rearing, and household activities (15%) were the major reasons for poor educational status. In total, 12.74% of women reported that they were deprived of education and were engaged in other household works such as agriculture, livestock rearing, and taking care of younger siblings. Sampled households were using oak, mixed conifer, moist deciduous, and deodar forests. Oak, mixed conifer, and moist deciduous forests were used in less-degraded areas close to households, degraded locations close to households, and degraded places away from households categories, while deodar was being used only when it was located close to households (**Table 2**).

TABLE 2 | Profile of households surveyed to assess status of human wellbeing in Nanda Devi Biosphere Reserve.

No. of households surveyed		764
Social communities (%)	Garhwali	66.1
	Bhotia	34
Respondents ($n = 764$) (%)	Male	55.4
	Female	44.6
Average no. of people per household		5.51 ± 0.09
Education (%)	≥Graduation	10.85
	Senior secondary	8.29
	Secondary	20.21
	Middle	19.02
	Primary	24.31
	Illiterate	17.31
Reason for not completing schooling	No school facilities in the nearby areas	26.48
	Poverty	21.85
	Engaged in other works such as agriculture, household, taking care of younger siblings	14.79
	Lack of interest	14.74
	Taboo related to girls getting educated	12.74
	Unaware of the importance of education	9.40
Income (US$ household^{-1}year^{-1})	Average annual household income	1328.42 ± 46.28
	Contribution of forest products	212.70 ± 6.88
	Contribution of agriculture	287.53 ± 8.57
Contribution of different forest type under different categories to average household income (US$ household^{-1}year^{-1})	Oak less degraded (500 m−2.5 km)	245.52 ± 11.65
	Oak less degraded (2.5 km <)	386.85 ± 12.30
	Oak degraded (500 m−2.5 km)	130.86 ± 6.12
	Mixed conifer less degraded (500 m−2.5 km)	236.07 ± 10.45
	Mixed conifer less degraded (2.5 km<)	241.47 ± 11.40
	Mixed conifer degraded (500 m−2.5 km)	128.81 ± 7.77
	Moist temperate deciduous less degraded (500 m−2.5 km)	206.73 ± 9.75
	Moist temperate deciduous less degraded (2.5 km<)	212.11 ± 12.49
	Moist temperate deciduous degraded (500 m−2.5 km)	178.20 ± 10.74
	Deodar less degraded (500 m−2.5 km)	82.53 ± 9.04
	Deodar degraded (500 m−2.5 km)	241.47 ± 11.40

Economic Status and Contribution of Forest Resources

The main occupation in the region is agriculture followed by tourism-based small scale businesses, daily labor, government jobs, and jobs in the private sector. Most of the people employed in the private sector were working in the cities while a few were employed with hydroelectric projects in the area. The average annual household income was calculated as US$ 1328.42 ± 46.28 including income from agriculture, dairy, and other livestock, jobs in the government and private sector and business, floriculture, horticulture, bee-keeping, and forest resources. Forest resources contributed 16.01% to the income of households located close to the forest while they contributed ∼10% of the income of the households located away from the forest. Agriculture as a primary source of income contributed 21.64% to the average annual household income. The contribution of forests varied with the forest type. A degraded oak forest that was located closer to the households was being used the most hence economic contribution was higher for this category (US$ 386.85 ± 12.3 per household per annum) than the rest of the categories that were being used (**Table 2**).

Category of household sampled	Average distance from forest (km)	No. of households surveyed	Wellbeing indices					
			Environment wellbeing	Health wellbeing	Social wellbeing	Workplace wellbeing	Political wellbeing	Overall wellbeing
Close to less degraded forest	1.7	544	0.394	0.759	0.740	0.633	0.537	0.613
Close to degraded forest	2.1	118	0.005	0.730	0.721	0.571	0.614	0.528
Away from degraded forest	8.2	102	0	0.450	0.680	0.538	0.550	0.444

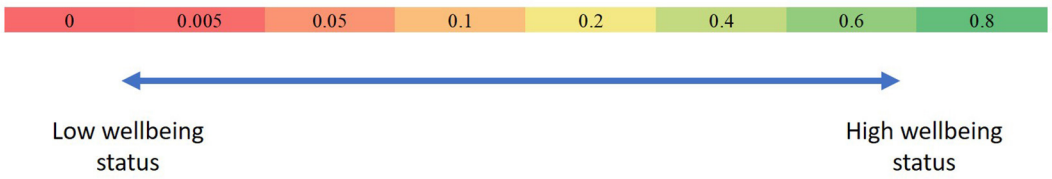

FIGURE 3 | Links between the flow of ecosystem services and human wellbeing under different forest condition scenarios.

Access to Basic Amenities

Access to the basic amenities in the study area was determined by the distance from the road and market. Households with lower income that were located away from roads and markets were not able to access basic amenities frequently or regularly due to high transportation costs. Approximately 47% of LPG users reported that the refill bottle cost them double its original cost as they had to hire a taxi and mule for transporting the cylinder to the refilling station and back. Access to clean water throughout the year was reported to be better for the households located close to forested areas while households located away from forests suffered from water shortages during peak summer months.

Human Wellbeing and Linkages With Forest Resource Accessibility

Human Wellbeing Index and Access to Forest Resources

Overall the wellbeing index was higher for the households located closer to the forest than the households located away from the forest, the difference was statistically significant (U = 5.258E4, $Z = -2.589$, $p < 0.05$). The indices for all the wellbeing types assessed were higher for households located close to less-degraded forests than households located away from less-degraded or close to degraded forests. The wellbeing indices were lowest for the households living away from the forest and those using degraded forest resources (**Figure 3**). The difference was found significant for the environmental wellbeing ($U = 4.084$E4, $Z = -9.402$, $p < 0.000$), social wellbeing (U = 5.134E4, $Z = -3.399$, $p < 0.005$), and health wellbeing (U = 5.105E4, $Z = -3.428$, $p < 0.005$), which were higher for the households close to forest. No difference was observed in political and workplace wellbeing. Overall wellbeing was found to vary with the condition of the forest as it affected the availability of resources and overall ecological and economic security. Environmental ($U = 4.319$E4, $Z = -13.434$, $p < 0.000$), workplace (U = 4. 6.772E4, $Z = -2.058$, $p < 0.05$), health (U = 6.483E4, $Z = -2.916$, $p < 0.005$), and overall wellbeing (U = 64120.500, $Z = -2.909$, $p < 0.005$) were higher for the households dependent on less-degraded forest.

As the people from both categories were not skilled or trained for a technical job, they were not being paid well, which affects their workplace and political wellbeing. As the people did not have access to good educational facilities and institutes which provide professional degrees, they do not qualify for the adequately paid jobs offered by different developmental programs in the area. Workplace and political wellbeing were higher for the households situated close to marketplaces as they have better access to alternative livelihoods and information facilities such as newspapers and television.

Forest Degradation and Impact on Health

The health wellbeing was assessed based on the frequency of health problems among the residents that occurred due to air pollution, noise pollution, impure drinking water, malnutrition, and the physical labor required to collect forest resources. The dominant health problems were acidity, wounds due to accidents in forests, asthma, backache, body ache, cough, depression, ear infection, fever, eye infection, indigestion, stomachache, nerves, kidney and gallbladder stones, typhoid, cold, appendicitis, infection, and pneumonia. It was found that ∼10% (about 75 households) of the members of surveyed households had suffered from at least one of the above-mentioned health problems. Approximately 36% of the respondents said ($n = 743$) that they get less fodder and fuel wood due to the degradation of forest resources. Approximately 47% said that they have to travel long distances to get resources, while the remaining 16% said that they travel long distances and still do not get enough fodder and fuel wood. Of these, 31.4% of the people were living close to the forest while the rest were living away from the forest (68.6%).

There was a significant difference between the frequency of health problems among the households situated close to the forest and away from the forest ($U = 5.105E4$, $Z = -3.428$, $p < 0.005$). A higher frequency of health issues per 1,000 individuals was observed for the households living away from the forest for body ache, backache, stomachache, and accidents in the forest that can be mainly attributed to exertion due to the long distance traveled with a heavy load to get natural resources, especially fuelwood, fodder, and leaf litter. Water-borne diseases were also found to be more frequent in the villagers living away from the forest and close to populated areas and developmental project sites while people living close to the forest did not report any waterborne disease. Members of households located away from the forest also reported that they have to spend more time on resource collection, which makes them more prone to attack by wild animals.

Change in Natural Resource Availability and Reported Causes

More than 90% of respondents reported changes in forest resources in the past decade. The increased population was cited by 74% as the main cause of forest degradation. An influx of people has also resulted in an increase in forest resource usage in these areas. These outsiders are either working in the unorganized tourism sector or developmental organizations such as hydroelectric power plants and road development authorities. Respondents also reported that when non-natives use the resources, they do not consider the regulations set by traditional village-level institutions, which leads to overexploitation of the resources. This not only reduces the availability of the resources for the local people but also affects the ability of the natural system to revive itself. Altogether, 10% of the respondents attributed the change in natural resources to blasting and cutting for hydroelectric power plants, while 16% reported that climate change has resulted in a change in species composition and seasonality in the area, leading to the reduced availability of resources.

Access to Forest Resources and Economic Security

Local communities of NDBR are economically marginalized and despite practicing multiple livelihood activities depend primarily on marginal agriculture production and forest resources (**Table 2**). Crop failure was reported to cause tremendous economic pressure on the household. In case of crop failure, most people opted for daily labor (54.19%), cattle rearing (37.43%), and jobs in the private sector (28.66%) followed by medicinal plant collection (15.31%), firewood (6.68%), NTFP collection (22.38%), business (9.69%), and handicraft (7.59%). Few of the respondents (0.92%) also said that they will migrate to some other place in case of crop or livelihood failure. However, in comparison, 32.84% of the people living close to less-degraded forests, 49% of people living away from forests opted for cattle rearing, as they live in villages located near riverine areas and have access to the riverine grasses, that is the source of fodder during harsh winters and can be stored for a longer time, hence even covetable by the people living close to the forest. Among households living close to the forest, 20.73% said that medicinal plants can be collected and sold to earn money while among the households living away from the forest only 1.83% think that medicinal plant collection is an alternative livelihood option. Our results also showed that 29.36% of households living close to the forest and 5% of those living away from the forest considered the collection of NTFPs from forests an option for earning money. Approximately 20% of households located close to the forest said that daily labor is the only alternative available to them. In the case of households located away from the forest, 23.28% of respondents said that daily labor is the only alternative for their current livelihood. People living close to less-degraded forests have more livelihood options available to them than people living away from the forest.

The Contribution of Forest Resources to Agricultural Productivity

Approximately 84.8% of households were reported to collect the leaf litter that they use as bedding for livestock and later in fields as fertilizer. Forest resources were also being collected to be used directly in the agricultural field. Households (∼84%) cultivating kidney beans (*Phaseolus vulgaris*) were collecting branches to support the crop. Biomass extracted once was being used for 2–3 years and was finally used as fuelwood. Approximately 60% of households were using dry and green leaves to cover the crops (mainly cash crops) to save them from frost during harsh winters. Respondents indicated that the cash crops such as potatoes (*Solanum tuberosum*) and kidney beans need more investment and are more resource intensive. Respondents believed that forests located near their agricultural fields contribute to productivity. All the respondents reported that moisture content is higher in the fields located near the forest than in those located away from the forest, hence they save physical and monetary investment on irrigation facilities. In total, 97.1% said that they needed a lower quantity of fertilizers for the fields located near forests as the nutrients get percolated from decaying litter and contribute to the productivity of the fields.

Change in the Cropping Pattern and Main Causes

A shift in the traditional cropping pattern was observed due to the introduction of cash crops, which is less laborious and ensures instant returns. Approximately 80% ($n = 720$) of the households involved in agriculture reported that they have shifted to cash crop-based practices. However, this is affecting the availability of nutrition to people and monocrops lead to a more ecologically vulnerable agricultural system, as more than 60% of the households that were growing cash crops, such as potato, *Amaranthus* spp., and *Fagopyrum* spp., were using inorganic fertilizers. However, ∼74 households reported that they stopped using inorganic fertilizer as after use the field needs more water, otherwise fertilizers have a negative impact in the long run.

Transfer of agricultural land for development activities such as hydroelectric power plants, tourism infrastructure, and roads provides local people easy and instant money but forces them to consume less nutritional food items bought from nearby markets. At Tapovan town, it was observed that agricultural fields have been acquired to be used as dumping sites (**Plates 1**, **2**). During the survey, ∼10 households were found out of money, although they received approximately half a million Indian rupees as

PLATE 1 | Conversion of agricultural land to developmental activities (being used as dumping ground by hydroelectric power plant).

PLATE 2 | Conversion of agricultural land to developmental activities (being used as construction and dam site by hydroelectric power plant).

compensation for their agricultural land. More than 90% of the households that have lost their land due to any reason are more dependent on the market and subsidized supply by the government for ration. Employment in both organized and unorganized sectors is also an important factor leading to change in agricultural practices. Approximately 34% of orchard owners reported that due to changes in precipitation pattern (both rain and snow), frequency, and timing, the output of orchards has reduced. However, 50% of the respondents reported that they have changed agricultural practices due to frequent crop raiding by wild animals. These people have either completely stopped or reduced growing certain crops such as *Fagopyrum* spp. Approximately 22% of the farmers have mentioned that they used to keep bees and produce good quality honey but have completely stopped, as the bee nests were frequented by the Himalayan black bear, which not only caused economic loss but increased the chances of an attack on humans. The frequency and intensity of negative interactions with wildlife especially with large-bodied animals are known to impact the sense of security among the people.

DISCUSSION

The Convention on Biological Diversity and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services support the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits based on the concept of dependence of human wellbeing on biodiversity and its benefits. Sustainable use of biodiversity has momentous associations with the level of human wellbeing and poverty reduction. Measuring a latent concept, such as wellbeing, can be particularly challenging, as subjective assessments of some elements of wellbeing are moving targets. As subjective wellbeing is determined by respondents' self-evaluations, levels of satisfaction may evolve (up or down) over time based on one's dynamic personal conditions (Timothy and Gruen, 2007; Maggino, 2017; Nima et al., 2020). However, assessment and evaluation of the real contribution of an ecosystem to community wellbeing is a difficult task as the wellbeing index uses a combination of objective and subjective indicators, strongly recommended by quality-of-life scholars (Rossouw and Naudé, 2008; Stanojević and Benčina, 2019). Failure to develop and use both accurately may result in misleading conclusions.

In line with previous assessments such as Zorondo-Rodríguez et al. (2016), the results of the present study also show that the natural resources not only contribute to sustaining the daily requirement of local communities of NDBR but also provide economic benefits directly and indirectly. United States Climate Change Program and other studies established that human wellbeing is positively associated with the availability of forest resources [CCSP (Climate Change Science Program), 2008; Alfonso et al., 2017; Loveridge et al., 2021]. The people living close to the forest have more alternative livelihood options than the people living away from forests who must work as daily laborers in case of failure of present livelihood activity. There was a significant difference between the level of overall wellbeing among households living close to and away from forests which is because of the availability of enough resources for sustenance. This leads to good social relationships and less mental and physical stress, which brings a sense of security among people, making them happier and less vulnerable. While talking to one of the respondents from the village Chai near Joshimath town (the power generation unit was built near this village), reported that "blasting and other construction work has ruined their horticultural production and forest resources. Even if they get rehabilitated to other villages, the people will not share the resources, and questions of survival and livelihood will remain unanswered."

Similar to other studies from India (Singh et al., 2020; Balasubramanian, 2021), our results also indicate that households located close to the forests have better access to high nutritional natural food (wild fruits and vegetables), which adds to their food

security and can be developed as a tool to achieve the SDG 2 sustainably (**Table 1**). However, the impacts of climate change will alter the phenology of the forests, and threaten the resource production and survival of dependent human communities and wild populations (Weiskopf et al., 2020). The health status of households located close to less-degraded forests was also found to be better than the status of households located away from forests. The frequency of health conditions such as body aches and backache arising from extreme labor (in resources collection) was found higher for the households located away from the forest (**Table 1**). Because forests are known to contribute to water filtration and purification (Piaggio and Siikamäki, 2021; Rasolofoson et al., 2021), the present study reported a lower frequency of water-borne diseases in households located close to forests, as they were using natural water sources originating from the forests (**Table 1**). Alike the rest of the Himalayan agricultural system in the Upper Ganga River Basin, agricultural practices in the NDBR area are also connected with the forest resources (Saxena et al., 2005). However, due to market introduction and subsidies on seeds and fertilizers, there is a shift from traditional to cash crop–based agricultural practices. Conversion of the already limited agricultural area to other land use types (**Plates 1**, **2**) also affects productivity and forces the communities to opt for other less-sustainable livelihoods. Maikhuri et al. (2001) and Saxena et al. (2005) have reported similar results and highlighted the vulnerabilities of people due to such phenomena, which is not only resulting in nutrition loss but is also threatening agrobiodiversity. The transfer of resources, especially agricultural land for developmental activities has introduced an easy income, without the training or exposure that would enable people to use it to secure livelihoods, which led to several households experiencing dire circumstances when they lost resources and money or both.

The availability of a wide range of natural resources increases people's ability to adapt to stresses, while their loss increases people's vulnerability to disasters. Continued loss of biodiversity limits the availability of water for household use and affects the productivity of the landscapes upon which human livelihoods and economy depend. The actual value of forests and other natural resources and their contribution to levels of human wellbeing cannot be assessed without knowing their role in the development of directly dependent communities (Uitto, 2019). It is imperative to capture the broad spectrum of values that local communities place on a particular service and to assess local views and attitudes as a basis for situation wise forest management intervention, meaning decisions are not made completely in the dark (Papageorgiou et al., 2005; Dorji et al., 2019). Community not only depends on natural resources for economic reasons, but these resources also shape and determine the cultural, social, and institutional framework of their life that blend to provide a level of predictability and stability to achieve a higher level of human wellbeing. These forest-dependent communities are subjected to a variety of exogenous, macro-level processes that cause changes to occur at an almost dizzying pace (Haynes et al., 1996; Dhungana et al., 2020; Merino-Perez and Segura-Warnholtz, 2021).

The vulnerabilities and resilience of local communities to the impact of climate change are intricately linked with the ecological susceptibility of its forest resources (Adger et al., 2009). Pandit et al. (2007) projected that by 2100 only 10% of the Himalayas will have dense forest and a large portion of endemic species will be lost. This will have ecological, economic, and psychological implications affecting the overall wellbeing of the communities. In an agrarian economy where agriculture-forest and livestock are the primary livelihoods, reduced forest productivity will affect the local economy. Moreover, the degradation of forests will lead to changes in primary productivity (Lucht et al., 2002) and changes in species composition (Ranjan, 2018) forcing people to opt for alternatives. The intricate linkages between sensitive ecosystems and vulnerable local communities are susceptible to the impact of climate change as it is not only changing the surrounding ecological factors but also forcing people to change their traditional environmentally sustainable lifestyles (Zander et al., 2013). This is resulting in a loss of traditional knowledge, although several scholars have reported that traditional knowledge can be used to combat and minimize the impact of climate change (Riedlinger and Berkes, 2001; Altieri and Nicholls, 2017; Singh et al., 2021).

Global and regional assessments such as Intergovernmental Panel on Climate Change and Hindu Kush Himalayan Monitoring and Assessment Programme have cautioned that the sensitive ecosystems such as the Himalayas, in the future will have greater than the global average warming that will affect the natural and socio-economic structures of the area profoundly. The communities can only be prepared to face and combat the situation by strengthening adaptability toward any impact of climate change, and by integrating site and community-specific wellbeing measures, taking into account national policies, strategies, and planning. Governments and international institutions are now realizing that human wellbeing, especially subjective wellbeing, due to its intricate relation with environmental factors, can play an important role in assessing the effectiveness of policies and programs (De Neve and Sachs, 2020). Although SDGs can be advantageous indicators for assessing the impact of climate change and environmental degradation, they often fail to provide insights on a smaller scale, especially in developing countries where information is not available for several parameters. The lack of inclusion of aspects of human wellbeing in SDGs and other such indicator-based global goals makes studies like ours crucial, as they provide a comprehensive understanding of an area. The comparison of SDGs and local wellbeing indicators (**Table 1**) can be instrumental in strengthening wellbeing assessments and links with natural resources for effective planning and actions (Sterling et al., 2020).

CONCLUSIONS

Millennium Ecosystem Assessment indicated a substantial net gain in human wellbeing and economic development, but, at the cost of degrading ecosystem services and increased risks of non-linear changes. Our study also showed similar results,

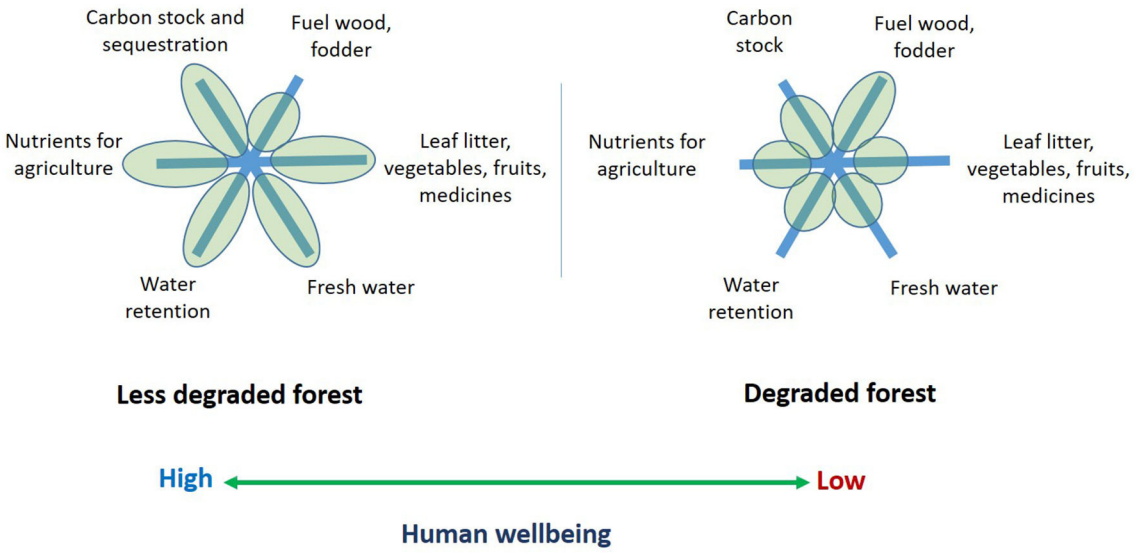

FIGURE 4 | Wellbeing indices for households located close to and away from less degraded and degraded forest.

although these gains have been traded off against the increasing degradation of many ecosystem services. Human wellbeing is determined by access to natural resources, but high resource dependence coupled with other externalities such as climate change and uninformed policies may lead to the failure of ecosystems to provide essential services. Some of the benefits, such as fuel wood, fodder, fruits, and vegetables may contribute more with more extraction; however, the scenario will not be sustainable after a tipping point (**Figure 4**). We conclude that forest resources that are being used the most, contribute more in terms of direct benefits and are being degraded more; and this degradation is higher in forests located closer to user communities, although this varies with resource type. We also conclude that even though developmental activities such as hydroelectric projects and road construction provide alternative livelihood opportunities in the NDBR, they cause a shift from a locally sufficient to a market-based economy, and also contribute to the pressure on agricultural and natural ecosystems. Social and economic vulnerabilities were a result of inefficient education and livelihood policies, and weak institutions that fail to capture the benefits of development programs and ecosystems. The development of benefit-sharing mechanisms and minimizing leakages of benefits will facilitate the people to achieve improved human wellbeing status. Programs such as "International Years of Millets" of the Government of India and the United Nations should be promoted for sustainable traditional agricultural practices that are more suitable for rough conditions marked by climate change.

To measure the impact of environmental degradation on human wellbeing, the right variables need to be chosen, which may include components such as the Human Development Index, GDP per capita, sense of security, and education. Although SDGs are included in these parameters, they do not have an inclusive framework. The time lag between ecosystem degradation and the impact on wellbeing of dependent communities should be considered while planning for natural areas, negligence of this may lead to the failure of conservation or management interventions. The role of various technological interventions and social innovations in decoupling wellbeing from ecosystem degradation should also be considered. Identifying and understanding the site-specific indicators of human wellbeing is necessary and should be considered in policies and initiatives that aim to enable a transition to a nature-sensitive sustainable economy that can help achieve the goals of the UN Decade on Ecosystem Restoration and Agenda 2030. Region-specific programs such as the State Action Plan on Climate Change and the State Biodiversity Action Plan of India in collaboration with traditional approaches or institutions such as Van Panchayat might enable management practitioners and policymakers to develop strategies that conserve natural resources for the uninterrupted flow of ecosystem services that facilitate human wellbeing. A layered and complex institutional arrangement, created with the participation of multiple stakeholders is recommended to channel and maximize the benefits of conservation and developmental activities for local people. Such institutions will enable communities to adapt and respond to the challenges of a globalized economy and changing climatic conditions, by introducing effective and elastic mechanisms to deal with unforeseen challenges.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study was conducted with the permission of the Research Degree Committee (RDC) of the Wildlife Institute of India. For

personal interviews, respondents were made aware of the aims and objectives of the study, and their oral consent was taken before recording any data.

AUTHOR CONTRIBUTIONS

PD, SH, and RB developed concept and designed the methodology. PD collected field data. PD and SB contributed to formal analysis and manuscript writing. SH and RB obtained funding and approved draft manuscript. All authors contributed to the article and approved the submitted version.

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