The well-being of the human society cannot be ensured and sustainable unless the flow of Ecosystem Services (ESs) would be matching with their consistent demand. The consistent flow of ESs required sustainable management of ecological resources of the ecosystem. The management of ecosystem can be ensured with variety of approaches. Integration of indigenous ecological knowledge (IEK) in management prescription with the view that IEK-based extraction of ESs ensures removal of resources from the ecosystem within the limit thereby ensuring the sustainability of ecosystem. The present study is an evaluation to understand the nexus between ESs and IEK for sustainable environmental management. The focus of the study was a tribal dominated socio-ecological patch of Barind Region of Malda district, Eastern India. The assessment of ESs and IEK was based on the data collected from the randomly selected tribal households following the pre-tested questionnaire containing questions on ESs as per millennium ecosystem assessment. The data were analyzed following social preference approach, and statistical tests (Kruskal-Wallis and Mann-Whitney). General linear model (GLM) has also been used to examine the impact of socio-demographic attributes on the perceived valuation of ESs. The results revealed that the provisioning ESs (such as water, fuel wood, medical plants) were most preferred followed by cultural and regulating ESs by tribal. Differential importance of ESs was observed among tribal and accounted by gender, education as well as age of the tribe. A gap between the actual accessibility and evaluation of ESs by the tribal communities was also apparent. The socio-demographic attributes have an immense impact on the valuation of ESs and also governed based on the IEK. Various types of indigenous ecological belief systems were closely linked with conservation of ecosystem and sustainable supply of ESs. The present study can contribute to understand socio-ecological nexus with the lens of IEK in tribal dominated ecological landscapes for improved ecosystem and environmental management besides ensuring sustainability of flow of ESs.

Keywords Cultural services; Customs, Ritual, Socio-ecological system, Taboos, Totems

Highlights
• A nexus exits between Indigenous Ecological Knowledge (IEK) and Ecosystem Services (ESs).
• Tribal livelihood revolves around ESs particularly provisioning ESs.
• IEK are crucial for the ecological management in tribal landscapes.
• Socio-demographic factors govern to perceive value of ESs.

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Introduction

Indigenous ecological knowledge (IEK), an enterprise consisting both the ecological and social systems, is interwoven leading to ensure the sustenance of both the systems. IEK is a sub-set of community specific indigenous knowledge acquired by the indigenous communities through direct contact with the natural environment since generations (Laudari 2010; Obiora and Emeka 2015; Gómez-Baggethun et al. 2010b, 2013) and varies within individual and community based on their native belief systems (Byg and Balslev 2004). IEK is a set of prescriptions harnessed by indigenous communities on daily basis for their livelihoods while ensuring the sustainability of socio-ecological system (Akwetaireho and Getzner 2010; Bhatta et al. 2016; Joos-Vandewalle et al. 2018). IEK is fundamentally vital for livelihood and quality of living (Turner et al. 2000) for tribal; conservation of biodiversity (Gadgil et al. 1993; Berkes et al. 2000) conservation of rare species (Colding 1998); conservation of protected areas (Johannes 1998) and local natural resource management (NRM) for tribal dominated socio-ecological systems.

Global acknowledgements such as millennium assessment recognized that the livelihood and human well-being (HWB) of the indigenous communities are largely dependent on direct and indirect ESs (MEA 2005). HWB, as an outcome measure, capture, and reflect the bundle of ESs for achieving the basic needs and wants of a tribal community for ensuring the quality of life. Therefore, it is necessary to evaluate the importance of ESs and HWB components to sustain the quality of life of tribal community (Smith et al. 2013). Moreover, Intergovernmental Science-Policy Platform on Biodiversity and ESs (IPBES) has recognized the ES approaches as integral part for sustainable development and HWB under the mission ‘to strengthen the science-policy interface for biodiversity and ESs for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development’ (IPBES 2016). In spite of high importance of ES for HWB, the emphasis is more towards the economic valuation of tangible services of ES undermining and discounting the cultural services (Winthrop 2014). Surprisingly, with apparent role of IEK for biodiversity conservation, ecosystem dynamics, community resilience, and sustainable resource use (Berkes et al. 2000; Gadgil et al. 1993; Ruiz-Mallén and Corbera 2013), integration of IEK for ES approaches is lacking across the literature, therefore, poorly accounting social and cultural services of ecosystem (Chan et al. 2012b; Fisher et al. 2009; Lele et al. 2013). The non-inclusion of IEK leads to underrepresentation of cultural services in decision-making framework (Chan et al. 2012a, 2012b) and also against the fourth operating principle of IPBES, which highlights the importance of IEK for the conservation and sustainable use of biodiversity and ecosystems (IPBES 2016).

Well-being of tribal is largely governed by ESs that positively contributes to livelihood (MEA 2005; Pandey 2009; Daw et al. 2011). Various researchers have accounted the social and cultural values of agro-ecological systems using IEK as in India (Das et al. 2012; Harisha et al. 2015; Pandey et al. 2017; Tynsong et al. 2020); and in other countries (Halim et al. 2012; Boafo et al. 2016a, 2016b; Saylor et al. 2017). IEK and related practices for various direct and indirect uses of wild plant resources and for other purposes such as weather forecasting, medicinal use of wild plants by tribes ensure promotion of cohesion between the ecosystem and human well-being (Harisha et al. 2015). Moreover, tribal through IEK make cultural adjustment to bio-physical surroundings for proper resources management (Tynsong et al. 2020) such as Alder Based Agro-forestry System, a IEK-based agricultural practices since time immemorial by indigenous tribes of Nagaland, India (Das et al. 2012), where root nodule of alder trees facilitates soil fertilization and the roots prevents soil erosion in slopes (Rathore et al. 2010; Das et al. 2012). Moreover, indigenous forest management by the local people are based on social justice and equity (Geronimo et al. 2016) and contributes to water availability, livelihood, biodiversity conservation and health care of the people (Halim et al. 2012). Precisely, the practical applications of ES approaches would be more enriched through the inclusion of IEK (Saylor et al. 2017).

The ESs approach is primarily motivated by provisioning ESs and has not well enriched with the cultural and social services of the ecosystem due to the lackluster treatment to the later services (Chan et al. 2012a, 2012b; Boafo et al. 2016a). Moreover, rapid rate of urbanization, industrialization, and economic development resulted into extinction of IEK and also degrading the natural environment (Deng et al. 2016; Deng and Gibson 2018) that causes large scale degradation of ESs (Schäfer et al. 2012; Zeng et al. 2016). The non-inclusion of cultural services in ES approach (Boafo et al. 2016a) and non-accounting of the disturbances leading to flow of ESs (Malik et al. 2016) would have implications for loss of IEK and cohesion between the ecosystem and human well-being along with degradation of socio-ecological systems. In Indian context, IEK is important to manage natures resources among the tribal communities since generations (Cordero et al. 2018; Dkhar and Tiwari 2020; Singh et al. 2018). However, the nexus between IEK and ESs is not accounted rather limited evaluation was made to the ecological significance of IEK to manage ESs from the ecosystems. Therefore, a study was conducted to assess the IEK role and contribution of ES for tribal communities, focusing to tribal dominated villages adjacent to the forest in Briand region, Malda district, Eastern India. The objective of the study was assessment of ESs for tribal welfare and role of IEK for management of ecological resources and HWB for suggesting the
integration of IEK in ES approach, keeping in view the integral nature of tribal livelihood with forests. Exclusively, the present evaluation has a central goal of ecosystem management with regional planning by accounting and integrating IEK into ES approach through emphasizing the relationship among ESs and IEK for ecosystem management.

**Materials and methods**

**About study landscapes**

Malda district, West Bengal, India is characterized by low lying alluvial pains with south slope. North-eastern part of the district contains few elevated tracts which are intersected by deep water channels. On the basis of topography, Malda district is divided into three physiographic divisions namely- Barind, Tal and Diara. Barind region spreads in 1348.3 sq. km. (37.63%) area of the district and is located in the eastern portion of the district extending between 25°01′06″N to 25°12′49″N and 88°12′42″E to 88°21′32″E (Fig. 1). The region is characterized by ancient alluvial humps and old riverine flood plains. Total Schedule Tribe (ST) population of the area is 182411 consisting 58 percent of the total STs of the district. The Schedule Tribes belong to various racial groups such as Santal (dominated over the region), Hansda, and Oraon tribe. Two tribal dominated villages namely Karanja (Habibpur CD block) and Sal-bona village (Gazole CD block) with ethnic origin of Santal and Oraw were selected for study. The villagers were dependent on natural resources for their subsistence livelihood and located around forest area (Tables 1 and 2). Both the villages are characterized by subtropical monsoon climate with an average annual temperature of 30°C and mean annual rainfall is 1250 mm (REFF). The primary profession of villagers was agricultural activities. Majority of the people of the villages were unable to avail basic amenities as well as materials for life such as pure drinking water (particularly in Karanja village) access to education and health facilities. Both the villages are located away from nearest central place (Sal-bona village—about 3 km from Kendupukur, the nearest central place and Karanja village—about 8 km from Alampur, the nearest central place).

**Fig. 1** Location map of the study landscape
Methodology

Conceptual framework to evaluate the relationship between ESs and IEK

The methodological framework for evaluation the nexus between ESs and IEK is reported in Fig. 2. Tribal are primarily dependent on natural resources for their daily requirements. However, with the current climatic and non-climatic factors, the ecosystem is degrading leading to reduction in ESs thereby posing challenges to the livelihood of these tribal. The IEK are significant in maintaining the natural resources and ecosystems in socio-ecological landscapes (Gómez-Baggethun et al. 2010a; Takeuchi 2010; Molnár 2012). This is more pronounced as, the United Nations Convention on Biological Diversity has also highlighted the importance of IEK for the preservation and maintenance of bio-diversity (United Nations, 1992). Moreover, IEK is important for managing and checking the unsustainable utilizations of various ESs (MEA 2005). Therefore, the relationship between ESs and IEK will facilitate pathways for improved community based natural resources management in socio-ecological landscapes under the current challenges.

The ES has been classified into four categories as provisioning ESs (food, water); regulating ESs (flood and disease control); supporting ESs (natural cycling, oxygen production) and cultural ESs (spiritual and cultural benefits) (de Groot et al. 2002). Sixteen ESs distributed in four categories was identified on the basis of ecosystem functions; ecological process and the services in the study area (Table 3). The typology of IEK was categorized on the basis of household survey through questionnaire; direct field observation and interview with the informants. The respondents explained the function of the IEK applied at households and the community level. IEK in the region is governed through their indigenous socio-cultural belief systems for ascertaining the benefits/services from the nearby ecological units, as elaborated by the locals.

Table 1 Geographical settings of study villages

| Block | Village          | Location                        | Elevation (amsl) | Area (in hectare) | Population |
|-------|------------------|--------------------------------|------------------|-------------------|------------|
| Habibpur | Karanja Forest | Long 88°19′13″E Lat 25°5′51″N | 35-50 m          | 48.76             | 880        |
| Gazole | Sal-bona (Forest)| Long 88°12′35″E Lat 25°11′17″N |                 | 125.65            | 1994       |

Source: Census of India, 2011 (area and population)

Table 2 Socio-demographic profile of study villages

| Household Characteristic | Category          | % of respondents |
|-------------------------|-------------------|------------------|
|                         | Karanja (Forest)  | Sal-bona (Forest)|
| Gender                  | Male              | 52               | 36               |
|                         | Female            | 48               | 64               |
| Education               | Primary           | 24               | 40               |
|                         | Secondary         | 4                | 24               |
|                         | Higher secondary  | 0                | 8                |
|                         | Collage           | 4                | 0                |
|                         | Illiterate        | 68               | 28               |
| Profession              | Agricultural labour | 68            | 40               |
|                         | Daily Worker      | 16               | 28               |
|                         | Cultivators       | 0                | 0                |
|                         | Housewife         | 16               | 32               |
|                         | Student           | 0                | 0                |
| Age (in years)          | < 20              | 4                | 4                |
|                         | 21-40             | 44               | 40               |
|                         | 41-60             | 40               | 36               |
|                         | >60               | 12               | 12               |

Source: Primary Field survey (Early 2019)
On the basis of the survey, the IEKs were categorized into four major domains namely (a) local totems and taboos (b) customs and rituals (c) rules and regulations and (d) protected areas (indigenous) or sacred areas, respectively. A questionnaire containing the detail identification of IEK along with their linkages with ES was developed and verified by pilot survey. The list of IEK was developed based on pre-field visit and through a focus group discussion with aged people (Fig. 2).

Application of SPA for ESs and IEK assessment

Qualitative and quantitative research methods were used to assess social value of ESs (Kelemen et al. 2014). The information regarding ESs assessment was collected through rating and ranking of ESs (Santos-Martin et al. 2018). Social Preference Approach (SPA) was applied to assess the value of ESs and linkage of IEK with ESs as well as interpret social value of ESs considering perception, individual knowledge and associated value (Ciftcioglu 2017; Castro et al. 2011; Campbell 2018).

Data collection tools and sample size determination

In Barind region, Gazole CD and Habibpur CD block contains tribal villages with differential tribal population ranging from 10 to 90% tribal population due to the settings of the villages around the ecological landscape. The two tribal dominated villages namely Karanja from Gazole and Salbona from Habibpur contains around 80% ethnic origin of tribes (mainly Santal and Oray) due to unique settings of the villages around the forest and wetland dominated landscape. Moreover, villagers were having high dependencies on the natural resources for their subsistence, and no other avenues of alternate livelihood other than extraction from the ecological units were existing around the villages. These attributes and necessity signify the basis for in depth evaluation of these villages.

Data was collected from the two tribal villages during February and March 2019 through questionnaire containing perception about the ESs, delivered by the local ecosystems and about IEK of the tribal communities. The questionnaire was sub-divided into four sections as: (a) general information of the respondents (such as age, gender, educational level, and occupations) (b) identification of major ecosystems and ESs provided by the local ecosystems (c) major drivers of ESs change and (d) identification of IEK and its linkages with ESs, respectively. The field survey was conducted by researchers along with one local villager. The respondents were asked to provide relative value of ESs and IEK based on five point Likert scale. The respondents of the villages were informed about basic objectives of the study before the start of field survey for obtaining their consent. The two selected villages contain 172 households with around 80% tribal. Therefore, a sample of 75 households following scientific approach was selected at 10% confidence level from the two villages (Asmamaw et al. 2011) i.e. Karanja (33) and Sal-bona (42), consisting of evaluation of around 50% tribal population from the two villages.
| Category       | ESs                               | Description                                                                                                                                                                                                                                                                 |
|----------------|-----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Provisioning** |                                   |                                                                                               |
|                | Main food (rice, wheat)           | Collected from agricultural fields, home gardens and used for domestic purposes and selling to market.                                                                                                                                         |
|                | Medical plants                    | Medical plants from local forests, bushes are used for common health problems (such as cool, pains, fever)                                                                                                                                       |
|                | Water (drinking, bathing, irrigation) | Local ponds are the main sources of water for various household purposes including irrigation for cultivation of crops particularly during pre-monsoon season                                                                 |
|                | Wild edible plants                | The tree leaves collected from local forested areas or bushes are used for domestic animals.                                                                                                                                                        |
|                | Fodder for livestock              | The fodders are collected from agricultural lands mainly for domestic animals.                                                                                           |
|                | Materials for house               | The leaves of the palm trees, dated palm trees are used for roofs of the house, fences.                                                                                                                                                |
|                | Fuel wood                         | The branches of the trees, leaves collected from forest areas are used as fuel for cooking.                                                                                                                                                  |
| **Regulating**  |                                   |                                                                                               |
|                | Maintenance of the clean and fresh air | The local forest areas, water bodies have indirect impact on the maintenance of air                                                                                                                                       |
|                | Water regulation and purification | The natural infiltration of water regulate water cycle and help in natural purification of water                                                                                                                                               |
|                | Seed dispersals                   | The animal species particularly birds species help for seed dispersal from the local forests.                                                                                                                                           |
|                | Soil fertility                    | The soil fertility in agricultural lands are maintained through the crop residual.                                                                                                                                                    |
| **Supporting**  |                                   |                                                                                               |
|                | Erosion prevention                | The presence of vegetation covers prevent soil erosion particularly during rainy season                                                                                                                                                    |
|                | Place for wildlife (Habitat)      | The presence of trees, forest areas provide habitat for various species.                                                                                                                   |
| **Cultural**    |                                   |                                                                                               |
|                | Spiritual and cultural value      | The presence of belief systems that preserves natural environment.                                                                                                   |
|                | Local customs                     | The rituals, norms observed by the tribal communities at households as well as community level                                                                                                                                           |
|                | Aesthetic value                   | Different plant species (flowers) are used to enhance the aesthetic beauty of the house.                                                                                                                                           |
\[ n = \frac{Z^2 \times N \times (1-p)}{e^2 \times (N-1) + x^2 \times p \times (1-p)} \]

\( n \) = Sample size; \( Z^2 \) = table value of Chi-square at 1 degree of freedom of the desired confidence interval (3.841); \( N \) = size of the population; \( p \) = expected proportion of population response (0.05), \( e \) = desired margin error (expressed in %).

**Evaluation of the perceived data**

The importance of the ESs was evaluated on five point Likart scale based on the perception of the households where 5 assigned as very high importance; 4 is assigned as high importance; 3 is assigned as Medium importance; 2 is assigned as low importance; 1 is assigned as very low importance and 0 is assigned as no importance respectively. Responses of no importance provided by households were not recorded (Calvet-Mir et al. 2012; Langemeyer et al. 2016).

**Statistical analysis**

Non-parametric Kruskal-Wallis and Mann-Whitney test was applied to assess the difference in perception of ESs. A generalized linear model (GLM) was applied to examine the impact of socio-demographic attributes on the perceived importance of ESs. Gender, age, educational level and occupational status were taken as the independent (or explanatory variables). All these statistical analyses were performed using SPSS software (Version 22) and Social Science Statistics (SSSs) on line software package.

**Result**

**Valuation of ESs perceived by the tribal communities**

The data analysis results that tribal households attached highest importance to provisioning ESs (3.76) followed by regulating ESs (3.47), cultural ESs (3.31) and support services (3.24), respectively. Among all the provisioning ESs, the highest importance was attached to water for drinking and bathing (4.86) followed by main food (4.71), material for house (4.17); maintenance of soil fertility (4.07), maintenance of air quality (3.83), and water regulation (3.54) amongst regulating services; spiritual value (3.92), local customs and rituals (3.38) and aesthetic value (2.63) for cultural services; habitat for species (4.01) amongst supporting services, respectively (Table 4). The highest importance to the provisioning ESs by tribal communities was due to their requirement and direct benefits for livelihood. Most of the tribal households were having very limited accessibility and availability to the basic services and amenities such as drinking water facility within premises, good housing conditions. The limited accessibility and availability leads to the households on higher dependency on ESs particularly provisioning ESs, tribal reported.

**Table 4** Mean importance of individual ESs based on socio-demographic attributes

| Category | ESs | Gender | Age range | Educational level | Overall importance (Average) | Ranking |
|----------|-----|--------|-----------|-------------------|-----------------------------|---------|
|          |     | M      | 21–40     | 41–60 >60         | Pri. | Sec. | H.S | Clg. |                         |         |
| Provisioning | Main food (rice, wheat) | 4.9 | 5.0 | 4.8 | 4.9 | 4.5 | 4.6 | 4.7 | 4.4 | 4.6 | 4.71 | 1       |
|          | Medical plants | 3.6 | 4.7 | 3.8 | 3.9 | 4.1 | 4.3 | 3.4 | 2.9 | 2.6 | 3.70 |         |
|          | Water (drinking, bathing) | 5.0 | 5.2 | 4.6 | 5.2 | 4.9 | 4.8 | 4.8 | 4.7 | 4.9 | 4.86 |         |
|          | Wild edible plants | 3.6 | 4.4 | 3.4 | 4.6 | 3.5 | 2.4 | 3.5 | 2.9 | 2.5 | 3.42 |         |
|          | Fodder for livestock | 3.8 | 3.8 | 2.9 | 3.8 | 3.6 | 2.8 | 4.1 | 3.6 | 2.6 | 3.43 |         |
|          | Materials for house | 4.7 | 4.5 | 4.4 | 4.3 | 4.5 | 3.7 | 3.9 | 3.8 | 3.7 | 4.17 |         |
|          | Fuel wood | 4.6 | 5.0 | 4.4 | 4.5 | 4.8 | 4.5 | 3.7 | 4.4 | 4.1 | 4.44 |         |
|          | Average importance of PESs | 4.30 | 4.84 | 3.94 | 4.2 | 3.96 | 2.96 | 3.69 | 3.59 | 3.14 | 3.76 |         |
| Regulating | Maintenance of the clean and fresh air | 4.1 | 4.2 | 3.4 | 3.3 | 3.9 | 3.3 | 4.1 | 4.4 | 4.2 | 3.83 | 2       |
|          | Water regulation and purification | 3.8 | 3.6 | 3.5 | 3.3 | 3.4 | 3.6 | 3.2 | 3.7 | 3.8 | 3.54 |         |
|          | Seed dispersals | 2.9 | 2.8 | 2.2 | 2.4 | 2.3 | 2.1 | 2.2 | 2.5 | 2.8 | 2.47 |         |
|          | Soil fertility | 4.4 | 4.2 | 4.1 | 4.3 | 4.1 | 3.1 | 3.9 | 4.2 | 4.3 | 4.07 |         |
|          | Average importance RESs | 3.80 | 3.70 | 3.3 | 3.32 | 3.42 | 3.02 | 3.35 | 3.60 | 3.77 | 3.47 |         |
| Supporting | Erosion prevention | 3.2 | 2.5 | 2.2 | 2.1 | 2.0 | 1.9 | 2.2 | 2.4 | 2.6 | 2.34 | 4       |
|          | Place for wildlife (Habitat) | 4.1 | 4.5 | 3.8 | 3.9 | 4.1 | 4.2 | 4.1 | 3.9 | 3.8 | 4.14 |         |
|          | Average importance of SESs | 3.65 | 3.50 | 3.0 | 3.0 | 3.05 | 3.05 | 3.15 | 3.15 | 3.2 | 3.24 |         |
| Cultural | Spiritual and cultural value | 4.3 | 4.5 | 4.0 | 4.1 | 4.4 | 3.5 | 3.9 | 3.4 | 3.2 | 3.92 | 3       |
|          | Local customs | 3.5 | 3.8 | 3.2 | 3.5 | 3.7 | 3.2 | 3.5 | 3.1 | 3.3 | 3.38 |         |
|          | Aesthetic value | 2.8 | 3.1 | 2.3 | 2.1 | 2.7 | 2.6 | 2.5 | 2.7 | 2.9 | 2.63 |         |
|          | Average importance of CESs | 3.53 | 3.80 | 3.16 | 3.23 | 3.6 | 3.1 | 3.3 | 3.06 | 3.03 | 3.31 |         |
| Overall importance of ESs | 3.78 | 3.86 | 3.32 | 3.41 | 3.5 | 3.03 | 3.37 | 3.35 | 3.28 | 3.44 |         |

Codes: M male; F Female; Pri primary (I to IV); Sec secondary (V to X); H.S higher secondary (XI to XII); Clg. graduation
Provisioning ESs was given highest importance (ranked 1) followed by regulating ESs (ranked 2), cultural ESs (ranked 3) and supporting ESs (ranked 4), respectively (Table 3). The perceived importance of ESs varies on the basis of gender, age and educational level of the tribal households. For example, in case of gender, female perceived more importance (4.54) to provisioning ESs as compared to male (4.30). The females are directly dependent on various services provided by local ecosystems (Fig. 3 a, f, and h). On the other hands, in case of regulating ESs, male perceived more importance (3.80) than female (3.70) due relatively better understanding the role of ESs in regulating environment. The livelihood pattern the tribal households largely depends on the direct benefits obtained from local ecosystems (Fig. 3). Basic needs of the tribal households were significantly influenced by the services of the local ecosystems, tribal’s reported.

Fuel wood was given highest priority (98%) by the tribal households followed by water (drinking and bathing), main food, material for house and wild edible plants, respectively (Fig. 4). Provisioning ESs, crucial for the livelihood of the tribal households was also vulnerable due to socio-economic transformation and climate change. For example, water bodies were most vulnerable due to irregularities of rainfall and most of the water bodies get dried up during summer season. The tribal households use polluted water for their daily purposes. Most of the tribal households were directly and indirectly dependent on agricultural activities and these agricultural lands were the basic sources of food (such as rice, vegetables). However, in recent past, most of the agricultural lands were kept as fallow due to lack of proper infrastructures and economic support (for example high price of fertilizers). Thus, the sources having provisions of ESs became vulnerable in tribal-dominated ecological landscapes.

Impact of socio-demographic attributes on ESs valuation

The importance along with dependency of people on ESs was largely influenced by socio-demographic attributes of the households such as age, gender, educational level, occupation. Kruskal-Wallis test was significant for provisioning ESs for gender, education and occupation (p <0.05). Female (4.74) opted high importance to provisioning ESs as compared to male (4.10). Higher SD in case of male showed that there was higher variability of importance of provisioning ESs as compared to female. From the field survey, it was observed that women were primarily responsible for household management and therefore attached more importance to provision ESs (Fig. 3 a, c, f, and h).

Educational level was important for determining the significant differences for the importance of provisioning ESs. The importance of ESs decreased with increasing educational level, i.e., 3.00 (at collage level) to 4.62 (illiterate). The illiterate in general were having fewer opportunities for income generation than literate. Moreover, illiterate had less voice in public and also having low social acceptance beside their sacredness to be public. The overall behavior and opportunities to illiterate leads to low entitlement and deprivation for livelihood and thus has high importance for provisioning service. No significant differences of provisioning ESs were observed for age classes due to the critical role of provision services for overall welfare of household. Therefore, irrespective of the differential age groups, the households were attaching more or less equal importance to provisioning ESs. Significant differences of importance perceived by the respondents were recorded for occupational status. Result showed that most of the respondents were engaged with primary economic activities (particularly agricultural activities). Agricultural labor, cultivators, daily workers, housewife valued more to provisioning ESs due to their direct dependency on the ecological landscapes. Only results of the provisioning ESs were discussed due to (i) higher dependency of households on ESs and (ii) no significant differences were found in case of perceived importance of other ESs. Therefore, the importance of provisioning ESs was varied with inter-educational, inter-occupational and inter-gender difference, respectively. The significance of provisioning ESs supports that overall the socio-demographic attributes had a crucial role to perceive the importance of ESs (Table 5). As per the result of GLM, it was found that socio-demographic attributes were the dominant determinants towards the perceived valuation of ESs.

The average perceived importance of ESs was highest for provisioning ESs (4.42) followed by regulation ESs (3.00) and cultural ESs (2.24), respectively (Table 4). Female valued more to provisioning ESs as compared to male. Average perceived importance of provisioning ESs was 3.92 and highest importance was given by illiterate (4.62) followed by primary, secondary, higher secondary and collage respectively. In case of age and occupational status also, the perceived importance of provisioning ESs was highest in comparison to other ESs. Therefore, it is clear that the perceived importance of ESs was largely influenced by socio-demographic attributes of the tribal community (Table 4).

Linkage between ESs and IEK in tribal ecological landscapes

It was observed during the interactions with the informants that IEK were in practice at households and
community level to manage ESs though their socio-cultural mechanism. The IEK practices were manifested in their routine livelihoods such as framings, extractions from forests; use of plants, and climate prediction.

Fig. 3  Glimpses of the study area (a) woman collecting fuel from the forest (b) agricultural land (c) woman cooking with forest leaves (d) Sal leaf plates for income earning (e) local material for housing (f) local ponds for washing utensils and clothes (g) wild edible plants (h) pond for bathing (i) irrigation from ponds

Fig. 4  Perceived importance and vulnerability of ESs in the study areas
These IEK practices were performing a significant role for livelihood sustainability of the tribal people, and sustainable conservation and management of natural resources. The tribal people collect fuels from the local forest, build houses with thatches (collected from palm trees, date palm), collected fodders, the water bodies are used for bathing, washing as well as for irrigational purposes (Fig. 5). This clearly denotes the fact that daily livelihood of the tribal people was largely influenced by the services from the local ecosystems. No killing of animal, no destruction of plant species, conservation of trees, sacred groves have significant ecological value and followed by tribal through IEK practices. Therefore, IEK has the potential to improve the well-being by ensuring the flow of ESs from ecosystems besides promoting social resilience and fostering social cohesion, tribal reported. The IEK practices implied with indefinite and intimate relationship with the belief system by tribal for biodiversity conservation and maintenance of ecosystems were grounded in a series of customs, rituals, and rules and regulations (Table 6).

**IEK practices in the form of taboos and totems**

During survey, it was observed that taboos and totems applied at households and community level for the conservation of resources, i.e., managing the overharvesting of provisioning ESs leading to future use. Moreover, the villagers reported that the IEK promotes and supports for thriving of species (biodiversity) through restorations of animal and plant species. Many taboos such as prohibiting the killing of various animals and cutting of plants species with attaching the local deities, were under practice. For example, (i) among Hansda community, ducks (Anatidae) was considered as god and no harm was being made to ducks. (ii) Among “Soren” community, pigeon (Columbidae) was considered as gods (iii) among “Pauriya” community, shoal fishes (Channa striata) were treated as deity. Apart from animal species, plant species were also prioritized within taboos and totems for example, Betel nut (Areca catechu), Palash tree (Butea monosperma) and Banyan trees (Ficus benghalensis) were worshiped as god. This clearly denotes that taboos and totems in terms of the respect and belief systems were inherently linked with the conservation of biological diversity and management of...
ecosystems. Indigenous conservation of these plant species not only help to conserve biodiversity rather act as “safety net” and “resources ground” to the tribal communities.

**IEK practices in the form of customs and rituals**

Customs or rituals were the particular social norms, practices as well as ceremonies maintained by households or communities for sustainability of the ecological resources, tribal reported. The IEK practices in the form of customs and rituals were performed either to enhance accessibility to ESs or to raise productivity of land through symbolically appreciating the importance of ecosystems. For example, celebration of a ceremony during harvesting new crops (popularly known as “noban” performed at the households’ level) and worshiping of gods at community level during drought for rains or good crop productions were in practice. Such ceremonies at household or community level ensure an equitable and flexible distribution of resources, and also ensure harmony among the people. During ceremony for rain, frogs were married at community level with pray to god for rain and high agricultural productivity. Medical plants such as Tulshi (*Ocimum tenuiflorum*), Dhutura (*Datura stramonium*) were used for various common diseases such as cough, cold, headache, ear pain etc for their health well-being and has strict restriction for their uprooting along with attaching a holy significance to these species. An elderly tribe remarked, “we rarely visit hospitals or doctors as we use local medical plants for our health problems such as fever, cold, pains.” The eco-spiritual tradition among tribal communities has immense ecological significance. The conservation of provisioning, regulating, and cultural ESs were closely linked with the different IEK practices implemented at tribal households as well as community level. Therefore, a strong nexus between IEK and socio-ecological system in tribal dominated ecological landscapes were observed (Table 6).

**IEK practices in the form of rules and regulations**

Various rules and regulations were enacted by the villagers to protect ESs (though it was not categorically recognized by the tribal households). Strict rules were imposed on households and punishments were levied for violating such rules and regulations. In the study villages, it was observed that killing of pregnant animals were strictly prohibited and punishable. Such rules and regulations were not only significant for biodiversity conservation rather crucial for environmental sustainability. Particularly, animals like ducks, pigeons were not hunted rather preserved from spiritual perspectives. The ducks were reared and eggs were sold to local markets.

### Table 5 Perceived importance of ESs based on socio-economic profile of the respondents

| Factors          | Sub-indicator | PEs Mean | SD  | REs Mean | SD  | SEs Mean | SD  | CEs Mean | SD  |
|------------------|---------------|----------|-----|----------|-----|----------|-----|----------|-----|
| Gender           | Male          | 4.04     | 0.69| 2.64     | 1.62| 1.2      | 1.73| 1.42     | 0.87|
|                  | Female        | 4.42     | 0.46| -        | -   | -        | -   | 1.98     | 1.20|
|                  | >60           | 4.27     | 0.55| 2.66     | 1.63| 1.7      | 2.35| 2.40     | 1.86|
| Educational level| Primary       | 4.15     | 0.52| 2.44     | 1.42| 1.28     | 1.80| 1.90     | 1.67|
|                  | Secondary     | 4.01     | 0.55| 2.70     | 1.63| 1.32     | 1.80| 2.02     | 1.82|
|                  | Higher secondary | 3.81  | 0.72| 2.90     | 1.69| 1.32     | 1.75| 1.88     | 1.64|
|                  | College       | 3.00     | 0.40| 3.24     | 1.90| 1.34     | 1.75| 1.86     | 1.61|
|                  | Illiterate    | 4.62     | 0.49| 3.18     | 1.74| 1.56     | 2.03| 2.64     | 2.34|
| Age range        | 20–40         | 4.04     | 0.69| 2.64     | 1.62| 1.2      | 1.73| 1.42     | 0.87|
|                  | 41–60         | 4.42     | 0.46| -        | -   | -        | -   | 1.98     | 1.20|
|                  | >60           | 4.27     | 0.55| 2.66     | 1.63| 1.7      | 2.35| 2.40     | 1.86|
| Occupation       | Agriculture labor | 4.54 | 0.31| 3.36     | 1.88| 1.56     | 2.00| 2.40     | 2.15|
|                  | Wage labor    | 4.17     | 0.67| 3.04     | 1.67| 1.12     | 1.40| 2.44     | 2.19|
|                  | Cultivator    | 4.28     | 0.36| 2.98     | 1.82| 1.3      | 1.66| 2.38     | 2.19|
|                  | House wife    | 4.28     | 0.56| 2.66     | 1.51| 1.1      | 1.37| 2.70     | 2.40|
|                  | Student       | 3.37     | 0.56| 2.94     | 1.67| 1.38     | 1.77| 1.80     | 1.55|

N number of respondents; SD standard deviation; Bold color indicates significant at 0.05 levels.
Apart from restriction for animal species, strict restrictions on the use of community resources such as water bodies, patches of trees were also existent and without permission from the chief of the village, these resources cannot be used. For example, the leaves and branches of the trees were not used from the restricted areas such as sacred sites, community forest resources. Capturing fishes from the community ponds or water bodies without permission was punishable. Violation of rules and regulations, i.e., use of resources from the restricted areas may cause fines. Thus, IEK practices in the form of rules and regulations have twin benefits on tribal communities, i.e., environmental sustainability and economic well-being, respectively.

IEK practices in the form of Indigenous protected areas

IEK practices in the form of indigenous protected areas were applied to protect specific local ecological landscapes such as water bodies, sacred groves, trees, bushes etc. There were few tress particularly Banyan tress \( (\text{Ficus benghalensis}) \), Sal trees \( (\text{Shorea robusta}) \) which were religiously protected by worshipping on daily basis. These ecological landscapes were protected, however most of the time, tribal communities were unaware about the role of such protection to their environment well-being. In the study villages, there were strict restrictions on entrance and use of these sacred places so that the places should be protected and conserved, tribal reported. Permissions were needed from the villagers or chief of the village to enter into the sacred places. Thus, protection of scared groves was a unique example of community based conservation of nature as well as ESs without any moral supports. Many times, plots of ecological landscapes were treated as sacred places and known as “Jaherthan” and “Majhithan” to the local people. Most of indigenous sacred places were preserved around forested areas, bushes, water sites and even inaccessible forested areas. These sacred indigenous ecological landscapes were classified and barricaded by barriers (made of bamboo, bricks) (Table 7). These sacred places were considered to be the abode of different deity who not only protect the villages from the natural calamities, diseases and famine but also provides mental well-being to the tribal.

Assessment IEK awareness and compliance of the tribal communities

The field survey resulted higher discrepancies between IEK awareness and compliance among the respondents (Fig. 6). Higher responses in case of awareness were reported from all four types of IEK in comparison to compliance. The IEK in respect of indigenous protected areas was having high awareness (87%) however low compliance (60%). The IEK for taboos and totems was known by about 80% of the total...
respondents; however, only 57% respondents had practiced the taboos and totems in their routine. Seventy-one percent respondents were aware for IEK of customs and rituals with only 45% respondents comply the IEK related to the customs and rituals however, similar trend was observed for awareness and compliance for IEK for rules and regulations within the communities (Fig. 6). The villages’ wise analysis of the four IEK practices showed similar responses for compliance and awareness for practicing the IEK within the communities of the two villages. For example, in case of traditional protected areas, 85% of the total respondents were aware in Salbona village whereas it was 87% for Karanja village, respectively. The similar patterns for the use of IEK for various practices reflect the importance of IEK within the overall household welfare of these peasants and importance of ecological landscapes. The result reveals that the IEK was relevant in the remote villages and villagers use various practices to protect the ecological landscapes so that they can maintain the ecological integrity of the landscape leading to support for their day to day requirements. However, the low compliance in comparison to the awareness may be attributed to the heterogeneities in the various characteristics of the individual households such as demographic, economic, skills respectively.

Discussion

The tribal households were largely dependent on provisioning ESs for their daily livelihood. The socio-demographic attributes were important and significant for utilizing the ESs for household livelihood. IEK is closely linked with ESs (Fig. 5) and directly and indirectly influenced the use and protection of flow of ESs as per the local socio-cultural norms of the tribal (Berkes et al. 2000; Colding and Folke 2001). Many indigenous communities in different parts of the world use indigenous knowledge to regulate and management of flow of ESs (Boafo et al. 2016a; Saylor et al. 2017; Cebrían-Piqueras et al. 2020). The result recorded reflected the strong socio-ecological synergy within the tribal IEK practices. The tribal community protects and conserves specific ecological landscapes such as sacred groves, water sites and fallow land due to its unique linkages with socio-ecology by imposing various rules and regulation with strict restrictions to avoid deterioration of indigenous protected areas. Moreover, protections of ecological landscapes are crucial for socio-economic, cultural as well as environmental well-being of the communities (Boafo et al. 2016a). Strong associations between IEK practice and ESs or conservation of environment are reported in many evaluations as per the indigenous belief system of tribal (Boafo et al. 2014); protection and conservation of sacred groves, fallow land, bushes (Miller et al. 2004).

Management of ESs through IEK practices was linked with human well-being such as security, basic materials for life, health, good social relation and freedom of choice. The linkages had varied intensity (as weak, medium, and high) for achieving the household welfare depending upon the requirement and availability and accessibility of resources and therefore contribute for provision of households. The trees or water sites or patches of tress were worshipped for generation to generation though IEK practices therefore conserving the resources and also enriching the culture for environmental sustainability. Previous evaluations reported that socio-cultural norms have significant role for community based management of natural resources (Turner and Clifton 2009) and decisions for community based management of natural resources are largely governed by the social institutions, IEK and ecological factors (Díaz et al. 2011; Elmqvist et al. 2004). In Indian context, community-based management of natural resources is under-rated in policy framework (Ramakrishna 2002; Ramakrishnan 2007) before the implementation of Joint Forest Management (JFM) (Khawas 2003) in spite of the fact that tribal communities has strong nexus between IEK and natural resources management (Cordero et al. 2018; Dkhar and Tiwari 2020; Singh et al. 2018). Therefore, apart from government rules regulation, community-based natural

| Activity                                      | Applicability of activities |
|-----------------------------------------------|----------------------------|
| Deforestation in and around the sacred sites  | -                          | √                          |
| Human disturbances in and around the sacred sites | -                          | √                          |
| Collection of any resources from the sacred sites | -                          | √                          |
| Fence around the sacred sites                 | √                          | -                          |
| Walking people in sacred sites                | -                          | √                          |
| Worshipping the sacred sites                  | √                          | -                          |
| Guards in sacred sites                        | -                          | √                          |
| Taking blessings of newly married couple from the sacred sites | √                          | -                          |
resources management must be promoted in tribal dominated ecological landscapes.

IEK contributes significantly to sustain livelihood of the stakeholders, to restore ESs and bio-diversity and also for resilience of the socio-ecological system (McDade et al. 2008; Reyes-Garcia et al. 2014; Gómez-Baggethun et al. 2012) (Fig. 7). IEK can contribute for managing and ensuring the sustainable utilization of resources and management of ecosystem for flows of ESs under the current unprecedented deterioration and degradation of ESs and biodiversity (Boafo...
et al. 2016a). However, IEKs are degrading rapidly due to variety of reasons as (i) loss of local languages (McCarter and Gavin 2011; Reyes-García et al. 2013); (ii) alteration of land use (Kingsbury 2001; Gray et al. 2013) (iii) integration of marketing system (Godoy et al. 2005; Reyes-García et al. 2005); and (iv) industrialization and rapid urbanization (Turner and Turner 2008; Gómez-Baggethun et al. 2010b) respectively. Therefore, role and use of IEK has emerged as one of the research themes for sustaining socio-ecological resilience due to the global environmental change and deteriorations of ecosystem (MEA 2005). Moreover, IEKs are important (i) a source of inspiration for designing environmental management and (ii) restoration and ecological modeling for sustainability.

The main focus of IEK is ecological knowledge maintained by local cultures and closely linked with local ecosystems transferring from one generation to provide a strong support and knowledge for environmental sustainability and natural resource conservation and management on long term basis (Menzies and Butler 2006). World Commission on Environment and Development (1987) stated in Our Common Future that “larger society could learn a great deal from indigenous skills of indigenous cultures in sustainably managing very complex ecological systems.” IEK of the indigenous people builds an ecologically balanced interaction and sustains sustainability of the environment. Therefore, traditions and practices of IEK are becoming a prominent fields and wisdom regarding design of ecosystems and sustainable use of resources (Menzies and Butler 2006; Armstrong et al. 2007).

Differential extractions of ESs by the households are governed by the heterogeneity of the household characteristics (Pandey 2010). Therefore, sustainable management requires adequate consideration of various services provided by the ecosystems along with the household characteristics, keeping in view of the role for human well-being and social welfare (Colding and Folke 2001; Mascarenhas et al. 2014). Therefore, highlighting the significance of the benefits, valuing of ESs is crucial (Elliott and Whitfield 2011) for overall welfare of the social and ecological systems. Particularly in developing countries, no emphasis is attached on the value of ESs during developmental planning and policies. Therefore, the current research will guide to integrate ESs in environmental management in development framework (Fig. 7).

**Policy implications**

The study demonstrated that IEK has significant impact on the ESs management and has great ecological significance. Moreover, respondents were categorically reported that IEK among tribal communities is depleting fast and vulnerable due to rapid socio-economic transformations as also mentioned by Boafo et al. (2016b). Therefore, effective utilization as well as management of ESs requires effective integration of IEK across tribal landscapes to design and implement practical initiatives and proactive measures. The initiatives are urgent due to lack of effective policies at regional as well as local
level for strengthening IEK and apply for ecosystem management through a participatory approach. For the impactful implication of participatory methodology, active involvement and collaboration of the tribal communities along with all stakeholders are essentially required. The significance of IEK for environmental management can also be mainstreamed in formal education system with strong scientific base as well as through the informal educations. The policy must promote the indigenous conservation of scared plant, birds and animal species along with scared groves by making integral part in policy perspective with some incentive, if possible. Moreover, the medicinal plants being used by tribal should be protected and conserved through suitable mechanism along with promoting the practices leading to facilitate improved management of resources. The animals and plants which can be useful for some services to tribal should not be harmed and this may be ensured by developing policies for sustainable harvesting and promoting the of animals. The overall analysis guided that policy makers must enact policies associated with the management as well as conservation of ESs and build strong nexus between tribal communities and environment.

Conclusion

The present study dealt with the assessment the nexus between IEK and ESs from socio-ecological perspectives in tribal dominated landscapes. The analysis showed that provisioning ESs were the prominent ESs to which tribal households were largely dependent due to direct benefits and higher dependency for their daily livelihood. Moreover, socio-demographic attributes (such as gender, age, educational level, occupations) of the tribal households have immense impact on attribution of ecosystem, services. Various types of IEK practices in the form of taboos and totems; customs and rituals; rules and regulations and indigenous protected areas were integral part of the tribal cultures and had crucial role for the conservation as well as management of ESs for ensuring the overall household welfare. Therefore, socio-ecological nexus between IEK and ESs can guide for significant opportunities to prioritize the IEK practices for better management of ESs by making strategic planning for ecosystem management. The findings of the study also provide feedbacks to the government policies and supports for implementing various rules and regulations by the government through integration of IEK practices for ecosystem management. The scientifically integration of the IEK in decision making framework may support for sustainable management of ESs as well as to enhance well-being of the people.

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Author contribution  MD, SS and AD conceptualize and designed the study; MD collected and analyzed the data with the support of RP and written the paper; MD, AD, SS and RP interpreted the analysis. MD, AD, SS and RP read and modified the paper. All four have contributed extensively for data interpretation and discussions. All authors consented for the publication.

Data availability  The datasets used during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval  “Not applicable”

Consent to participate  All participants were provided their consent for participating into the interview.

Consent for publication  “Not applicable”

Competing interests  The authors declare no competing interests.

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