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Mapping of the ecosystem services flow from three protected areas in the far-eastern Himalayan Landscape: An impetus to regional cooperation

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ABSTRACT

The ecosystem services (ES) concept is an essential tool to promote interregional conservation and development, especially in landscapes where ecological, economic, and sociocultural resources are connected. Our study capitalizes on the interregional ES flow among the three countries – China, India, and Myanmar – that share the far-eastern Himalayan Landscape. We used participatory GIS mapping to visualize the ES flow from three protected areas (PAs) in the landscape, and participatory scenario analysis to understand the direction PA management could take. The service provisioning hotspots, the service beneficiary areas (SBAs), and the degraded service provisioning hotspots (dSPHs) were mapped for ES that was of high management priority. The trade-offs among the ES were analysed for the three scenarios – Nature-at-Work, Nature-People Harmony, and People-at-Work. The argument for regional cooperation was affirmed with several dSPHs lying along the border, and SBAs reaching beneficiaries beyond the PAs and one country. The performances of ES under different scenarios indicated that future management of PAs must widen conservation constituencies and capitalize on multiple benefits from PAs, essentially to maximize livelihoods benefits to communities who live in and around PAs. We recommend intra, inter-country, and regional cooperation pathways for the future sustenance of ES from PAs in the landscape.

1. Introduction

Ecosystem services (ES) is defined as nature's contribution to people (Costanza et al., 1997) and relate to the various good and services that people derive from biodiversity to fulfil human needs (Daily, 1997; MEA, 2005). The ES perspective provides a conceptual link between ecological functions and processes, a variety of intermediary and direct benefits, and human well-being (TEEB, 2010; Haines-Young and Potschin, 2010; Scholes et al., 2013). It recognizes the integration of ecological, socio-cultural, and economic value systems and trade-offs (De Groot et al., 2010; Martín-López et al., 2014; Hicks et al., 2015), and brings conservation and development discourses together (Hummel et al., 2019; Burkhard et al., 2010) to reinforce sustainable development. In the context of protected areas (PAs), the usefulness of ES for effective conservation planning is well acknowledged (Chan et al., 2006). The ES concept has furthered their scope and values to the sustenance of wider objectives such as livelihood development, climate change adaptation and mitigation, health provisioning, water and food security, natural disaster reduction, tourism and economy promotion, research and education, and the promotion of cultural values (Braat and de Groot, 2012; Watson et al., 2014; Smit et al., 2017).

The "Programme of Work on Protected Areas" of the Convention on Biological Diversity stresses on enhancing ecological, economic, cultural, and social benefits from PAs, including the processes of participatory decision making, co-management, and regional cooperation in their management (Coad et al., 2012). However, operationalizing the ES perspective for effective management of the PAs is challenging (Schirpke et al., 2017) mainly because the benefits that arise from ES accrue at multiple scales (Palomo et al., 2014), and ES are often explored within narrow biophysical boundaries and so its interregional dimensions are

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overlooked (Koellner et al., 2019). Often, areas providing the services and the areas benefitting are scattered (Syrbe and Grunewald, 2017), and it is difficult to measure an ecosystem's capacity to produce services, the pressures that hamper an ecosystem's ability to provide such services, and the societal demand for these services (Villamagna et al., 2013). In the context of landscapes where the geophysical, ecological, and sociocultural resources are connected, understanding the interregional dimensions of ES (Schröter et al., 2018) is crucial, as they provide strong evidence of the flow of ES from the origin to the beneficiaries (Bagstad et al., 2013), and thus facilitate effective biodiversity and ES governance (Kissinger et al., 2011). Importantly, effective PA management, and policies must consider engagement of all potential beneficiaries (Schirpke et al., 2014).

The far-eastern Himalayan Landscape is a biodiversity hotspot that has been accorded high priority in terms of conservation; here, the three countries concerned – China, India, and Myanmar –have established different types of PAs (ICIMOD, 2018). These three countries, while discussing the aspect of regional cooperation within the Landscape Initiative for far-eastern Himalayan Landscape (HI-LIFE) have expressed the need to understand the following issues: what are the kinds of ES coming forth from particular PAs; what's the scale of the beneficiaries; and, how are the services being influenced or changed over time? This paper attempts to explore the spatial relationship between where the services originate and are used; what factors deteriorate the services; and how the services could possibly change under certain scenarios. The primary aim is to develop a shared understanding among decision makers, PA managers, and other stakeholders in the landscape; this involves understanding the wider values of PAs, comparing the services of the PAs in different countries, and more importantly, helping the countries explore joint interventions for the protection and improvement of ES. The literature on ES states that comprehending the spatial extent of supply and demand for services, and the extent of overlaps between service provisions and service beneficiary areas (Serna-Chavez et al., 2014; López-Hoffman et al., 2010) is vital for developing effective management strategies for the PAs and the biodiversity outside them (Guerry et al., 2015). The understanding of the direct and indirect contributions of the ecosystems (TEEB, 2010), the trade-offs and synergies between services (Turkelboom et al., 2018), and the power realionships between stakeholdes to foster equal access to ES (Felipe-Lucia et al., 2015) help strike a balance between the objectives of conservation and the goals of sustainable development (Schröter et al., 2018). We attempt to build such knowledge for the landscape and then aim to explore the context of interregional flow of services to trigger regional cooperation between the three countries for the long-term sustenance of biodiversity and ES in the landscape. Regional cooperation to translate regional conservation and development challenges into opportunities for sustainable mountain development has been clearly outlined in the comprehensive Hindu Kush Himalayan Assessment report (Wester et al., 2019).

2. Study areas

The study was carried out in three PAs: Gaoligongshan National Nature Reserve (GNNR) in Yunnan, China; Namdapha National Park and Tiger Reserve (NNP-TR) in north-east India; and Hkakaborazi National Park (HKNP) in north Kachin, Myanmar. A comparative account of three PAs (Table 1) provides the current environmental and socio-cultural context in three PAs.

These three PAs, along with the Hponkanrazi Wildlife Sanctuary (HPWS) in Kachin, Myanmar, form a contiguous ecological landscape in the north-western part of the far-eastern Himalayan Landscape (Fig. 1). This transboundary landscape has been jointly identified by the International Centre for Integrated Mountain Development (ICIMOD) and its partners in the three countries as a site to promote regional cooperation in the area of integrated conservation and development (ICIMOD, 2018)

The far-eastern Himalayan Landscape covers approximately 71,000 km^2 of area, comprising the Gaoligongshan range in north-western Yunnan of China in the east, the Namdapha National Park and Tiger Reserve and the adjoining areas of north-east India in the west, and in between, seven townships in the Kachin state of northern Myanmar. The

Table 1
General features of the Gaoligongshan National Nature Reserve (GNNR), the Namdapha National Park and Tiger Reserve (NNP-TR), and the Hkakaborazi National Park (HKNP) (Source: Chaplin, 2005; Lodhi and Samal, 2013; Rao et al., 2011).

Features	GNNR (China)	NNP-TR (India)	HKNP (Myanmar)
1. Establishment year (Total area)	1986 (4055 km^2)- 1983 as a provincial nature reserve in 1983 and converted into a national nature reserve in 1986	1983 (1985 km^2 with a core zone spanning 1808 km^2 and a buffer zone covering 177 km^2)	1996 (3812 km^2)
2. Country (Location)	China (24°40′N-28°30′N and 97°30′- 97°30′E)	India (27°23′30″ to 27°39′40″N 96°15′2″ to 96°58′33″E)	Myanmar (28° 05′ N to 97° 44′ E)
3. IUCN category	I- Strict Nature Reserve	II- National Park	II- National Park
4. Important Bird Areas	A1, A2, A3	A1, A2	A1, A3, A4i
5. Key protected species	Myanmar snub-nosed monkey, Gaoligong Hoolock gibbon, Marbled Cat Pardofelis marmorata, Assamese macaque, Phayre's leaf monkey; Gongshan's muntjac	Assamese macaque, pig-tailed macaque, Hoolock gibbon, Tiger, leopard, Snow leopard	Leaf deer, Black Musk Deer, Red Panda, Takin, Red Goral
6. Challenges and threats	Agriculture intensification and deforestation in lower elevation; Timber extraction, construction of the dam; unsustainable farming practices	Haphazard extraction of forest products, habitat fragmentation, habitat encroachment, illegal trade, and poaching	Habitat loss due to logging and slash and burn agriculture, commercial wildlife hunting, remote and limited park regulation outreach
7. Transboundary issue	Illegal wildlife trade and unregulated extraction of medicinal plants; asymmetric scientific knowledge	Immigration of people and demographic pressure, illegal cross border trade, lack of transboundary monitoring	Illegal wildlife trade, illegal timber logging and sale, unregulated extraction of medicinal plants; limited scientific exploration
8 Ethnic communities and livelihoods	About 16 different ethnic groups; agriculture, small scale industry, selling of NTFPs	Three well defined groups- natives, migrated and refugees; Agriculture, fishing, hunting and trade and daily wages	Four major ethnic tribes including one almost vanishing tribe called Taron; Agriculture, collection of medicinal plants; hunting and trade
9 Unique feature	Natural corridors for seasonal migratory species; incredible range of bioclimatic conditions and biotic diversity; known as world nature museum and world species gene pool	Has the dual status- NP and Tiger reserve; Only park in the world to have all four big cats; Habitat of several endemic and rare species and medicinal plants	Hosts Hkakaborazi mountain- highest peak in south east Asia; last remaining tract of intact forest of northern Myanmar forest complex; Habitat of leaf deer
10 Enabling conservation mechanism	UNESCO biosphere reserve; Strong support from the provincial government for research and long term monitoring	Wildlife Protection Act 1972; Has Park Management Plan; Monitoring, patrolling and afforestation program run by the forest department	Strong regulatory mechanisms- The Conservation of Biodiversity and Protected Areas Law (2018).

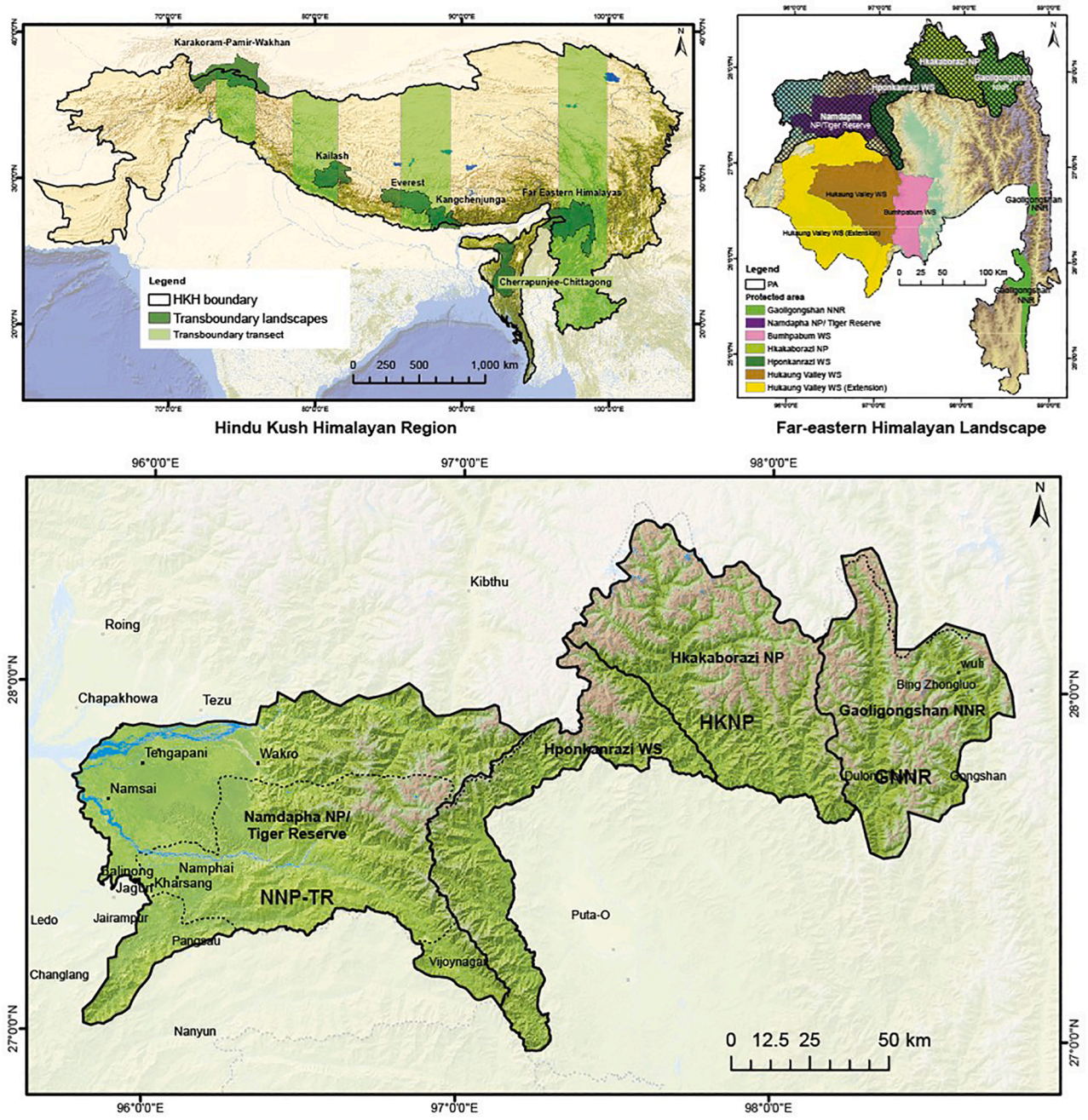

Fig. 1. Study areas in the three countries. The far-eastern Himalayan Landscape (top-right map) is one of the six transboundary landscapes identified in the Hindu Kush Himalayan Region (top-left map) to facilitate integrated conservation and development interventions. It has seven PAs. This study concerned the three major PAs (bottom map): Gaoligongshan National Nature Reserve in China (GNNR); Hkakaborazi National Park in Myanmar (HKNP); and Namdapha National Park and Tiger Reserve in India (NNP-TR).

landscape, as a unit, is one of the most intact and biodiversity-rich transboundary complexes within the Hindu Kush Himalayan Region that hosts biodiversity elements of three global biodiversity hotspots – in the Himalayas, Indo-Burma, and south-West China (ICIMOD, 2018). While the Himalayan and Gaoligongshan ranges possess both natural and cultural assets, including rich mineral and gem deposits (Shen et al., 2010; Chaplin, 2005), the northern Myanmar forest complex at its northern-most part hosts pristine old-growth forests (Renner et al., 2007). Here, the complex topography, combined with diverse climatic conditions, makes the landscape suitable for a wide range of floral and faunal assemblages that show a high degree of endemism (Behera et al., 2002).

3. Methods

We adopted the transdisciplinary knowledge co-production approach (Lang et al., 2012) to sensitize the wider stakeholders on issues of ES, and to capture as much stakeholder value and local dynamics as possible (Young et al., 2013). A three-step harmonized method was followed for the three PAs; this comprised: the participatory identification of ES of high management priority; the participatory mapping of ES flow; and a participatory scenario-based assessment of the prioritized

ES. The facet of knowledge co-production was facilitated through three stakeholder workshops in China, India, and Myanmar where a total of 122 participants contributed, with a respective representation share of 29%, 34%, and 37% among these countries. For each step, to capture and accommodate diverse views, the preliminary discussion was done in three groups- government, academia, and communities facilitated by local development partners. The points from each group were aggregated in the final participatory plenary, and consensus on data and information was derived among the participants. Preliminary results through GIS maps and excel charts were shared and discussed with the participants on the last day of the 3-days workshop.

With the understanding that the method of social learning is more effective with mixed group of participants (García-Nieto et al., 2019), we ensured that the participants in all the three workshops were a mixed group of representatives from government agencies (PA management, ministries, and line departments), research and academic institutions, and private-sector bodies; there were also development practitioners from international and non-governmental organizations, as well as community members present at these workshops. To avoid ad hoc selection, participants were invited through focal agencies for HI-LIFE such as the Forest Department in Myanmar, G. B. Pant Institute of Himalayan Environment in India, and Kunming Institute of Botany in China. The focal agencies adopted purposive sampling ensuring participation of key conservation and development institutions engaged in the area, the experts with thematic and field experiences in these areas, and community or village heads representing major ethnic groups living in and around the PAs. GIS maps, PCA (principal component analysis) biplots, and Excel charts were used to visualize the results. The details of each step are given below.

3.1. Step 1: Participatory identification of ES of a high management priority

The workshop participants were asked to list the range of ES from the chosen PAs in their respective countries. The services were grouped under categories such as provisioning, regulating, cultural, and supporting –in line with MEA (2005). A participatory ranking exercise was carried out to identify the ES of the highest management priority – i.e. the ES that needed the most immediate management attention. A harmonized indicator-oriented scoring pattern was executed to assess both the vulnerability and usefulness of the prioritized ES. The indicators of vulnerability included: the status of the current conditions; future supply and demand; the extent of drivers and factors influencing the services; and the availability of enabling policy and management support. The usefulness indicators outlined the extent of the users, the scale of the beneficiaries, immediate market benefits, and the prospect of intrinsic value.

3.2. Step 2: Participatory mapping of the flow of services

Participatory mapping uses geospatial technology to visualize the community perception of landscape features, services, and benefits, and is a powerful tool to integrate the complex ES information into landscape conservation planning and management (González-García et al., 2020). Participatory GIS mapping is said to bring explicit multidisciplinary perspective and participation (Brown and Fagerholm, 2015), and helps engage both societal experts (community members living in and around the PAs) who are often excluded in conservation and PA management dialogues, as well as disciplinary experts (academia/government decision makers and thematic experts) who develop management strategies and facilitate the implementation of PA programmes (Hummel et al., 2017). The ES identified in step 1 were used for participatory GIS mapping following Palomo et al. (2013). A0-sized printed maps showing PA boundaries and the adjoining areas were used for the mapping exercise. The participants were asked to use coloured pins and locate the service provisioning hotspots (SPHs), service beneficiary areas (SBAs), and degraded service provisioning hotspots (dSPHs) in the map as per their knowledge, expertise, and experience. Blue pins were used for SPHs, yellow ones for SBAs, and red pins for dSPHs. The discussion points were added as qualifier information. Each point represented a key area of significance in terms of either source or sink, and the areas where ES was under threat. Vertical digital photographs of the maps with pins were taken for each of the prioritized ES. The digital image was geo-referenced based on the points of the map graticules, and superimposed on other spatial layers. The shapefile layer of the SPHs, SBAs, and dSPHs was digitized using ArcGIS. The Euclidean distance was analysed to determine the spatial distribution and intensity of each service. The results were visualized in the form of three GIS layers that depicted the extent of origin, the extent of beneficiaries, and the areas of degradation.

3.3. Step 3: Participatory scenario planning and assessment of priority services

Participatory scenario planning is a useful tool to create a common vision, improve decision-making, and foster cooperation (Biggs et al., 2007). Scenarios are increasingly being used in PA management (Palomo et al., 2011; Brown et al., 2001) and regional planning (Peterson et al., 2003). They have been regarded useful in creating plausible descriptions of how the future might unfold, based on a coherent set of assumptions about the key elements and drivers of change (Carpenter et al., 2006). We approached the participatory scenario planning for the PAs following Palomo et al. (2011), but with a slight improvisation of their six-step process. The first three steps on prioritization of stakeholders, prioritization of aspects of the system that were important to stakeholders, and characterization of past and current conditions were built into participatory exercises in steps 1 and 2. The next three steps on defining a set of scenarios; characterization of each scenario, and defining management strategies were included in this step. The improvisation was in terms of the harmonization of three plausible scenarios: Nature-at-Work (protection oriented); Nature–People Harmony (adaptation oriented); and People-at-Work (extraction oriented). The harmonization was necessary in order to make the result comparable across the three countries. However, the characteristics of the three scenarios were defined in terms of each country, based on their respective national PA and the conservation policy directives. Lastly, the performance of the prioritized ES under each scenario was assessed using a 0–10 scoring frame, with 0–4 indicating complete degradation of services or limited provision, 5–7 indicating satisfactory provision, and 8–10 reflecting adequate provision.

4. Results

4.1. Ecosystem services of high management priority in the three PAs

All four types of ES were listed from the three PAs – 25 from GNNR, 21 from NNP-TR, and 20 from HKNP. All the regulating services were found to be prominent: water regulation (by way of conservation, purification, water quality, recharge, and flow maintenance); air/climate regulation (carbon sink); protection from natural disasters (landslide regulations, hazard regulations); soil stabilization and conservation (nitrogen sedimentation, waste decomposition); the habitat maintenance of globally important species (endangered, endemic, rare); pest and disease regulation; pollination (maintenance of wild pollinators); carbon sequestration; and local climate regulations-. Likewise, a wealth of cultural services was listed, based on: historical/heritage significance (Sino-Japan war history-hump airway, silk route, relic sites); cultural significance (tea culture; traditions and cultures of ethnic communities); brand value (ethnic identity); aesthetic value (religious, pristine, and picturesque landscape); educational value (scientific/traditional knowledge); cognitive development (inspiration for art and culture); and recreation. The provisioning services indicated a wide range of

biodiversity resources (in terms of flora, fauna, agrobiodiversity, and wild edibles) that provide tangible provisioning services relating to food and materials for household use; and equally importantly, there are medicinal plants, fodder, timber, and other genetic resources. The ability of pristine landscapes with diverse topographic regimes that create the right ambience for species productivity, evolution, and diversification was placed as supportive services.

The ranking exercise involving this extensive list of services revealed four ES of high management priority (Table 2). These included: provisioning services (mainly relating to medicinal plants and genetic resources); cultural services (mainly relating to tourism and recreation, education and knowledge, and aesthetic and heritage significance); habitat regulation (relating to the provision and maintenance of habitat for important biodiversity and ecological functions); and water regulation (relating to both the provision of water and the maintenance of its quality and flow).

In terms of the cumulative vulnerability and usefulness of the four prioritized services (Fig. 2), it was evident that all the services had a higher vulnerability score range of 69–94% and a usefulness score range of 77–96%. The observation was that all these services catered to multiple users, with beneficiaries at local–national (within the country), regional (across landscape), and global scales (beyond the three countries). For example, the water provisioning and regulating services were conceived to be regionally significant as they catered to a network of springs, rivulets, and river systems across the landscape – including wider downstream areas in the three countries.

All the four services were regarded to have a non-monetary intrinsic value that contributes to higher usefulness. Concerning vulnerability, the participants reflected that while the demand for all the four services will increase in the future, the supply could decline given the influence of both localized and global drivers of change. As for a comparative study between the three countries in terms of vulnerability, the average vulnerability of GNNR (about 78%) was found to be less compared to the other two PAs in the landscape. For HKNP, the average scores for both vulnerability and usefulness were the highest among the three PAs.

4.2. SPHs, SBAs, and dSPHs of the four services

4.2.1. Provisioning services

Altogether, 89 SPH points (Fig. 3a) were evident both inside and outside the PAs, with 93% of representation of SPHs within the three PAs. The SPHs reflected a range of vegetation, ecosystems, and biodiversity-rich areas. About 39 SBAs (Fig. 3b), with 72% representation, reflected the settlements in or at the vicinity of the PAs. In terms of acquisition of provisioning services, the communities living in and near the PAs were found to be the major beneficiaries, by way of daily household use, farming, and income-generation activities. About 28% of the SBAs were found to be located away from the PAs – these reflected the beneficiaries located at distant urban centres or across borders where biodiversity resources are used. The dSPHs (Fig. 3c) mostly consisted of areas of human settlement both inside (90%) and at the outskirts (10%) of the PAs where high-value medicinal plants were more intensely collected for commercial purposes. The dSPHs also represented border areas of the three countries where resources are unsustainably and haphazardly extracted for trade. Areas of timber felling and deforestation for agricultural expansion were also explicitly found in the dSPHs, especially in the cases of the HKNP and the NNP-TR.

Table 2
The top four ecosystem services of the highest management priority in the Gaoligongshan National Nature Reserve (GNNR), the Namdapha National Park and Tiger Reserve (NNP-TR), and the Hkakaborazi National Park (HKNP). The percentage in brackets is the ranking score.

Ecosystem services	GNNR (China)	NNP-TR (India)	HKNP (Myanmar)
1. Provisioning of medicinal plants/genetic resources	Medicinal plants (63%)	Genetic resources and medicinal plants (50%)	Medicinal plants (35%)
2. Cultural services of recreation, education, and heritage	Education and knowledge (50%); Recreation (47%)	Tourism and recreation (37%)	Heritage value and knowledge (27%)
3. Habitat regulation	Habitat provisions (41%)	Habitat for important biodiversity (53%)	Habitat for ecological and evolutionary functions (32%)
4. Water provision and regulation	Provision of water (23%)	Water flow and cycle maintenance (31%)	Freshwater provision (62%); Water regulation (58%)

4.2.2. Cultural services

About 78% of the SPHs of cultural services (Fig. 4a) were found to be inside the PAs. These reflected areas with pristine habitats and unexplored biodiversity, and home to indigenous and ethnic communities: Han, Yi, Bai, Lisu, Nu, and Dulong in the GNNR; Rawang, Lisu, Kachin, and Tarong in the HKNP; and Jingpaw, Lisu, and Chakmas in the NNP-TR. The SPHs also indicated spaces of natural, cultural, and historical significance within the PAs that held spiritual values, and provided cognitive and educational benefits – such as the sacred forests in the NNP-TR, the areas used by the almost vanishing Taron tribe in the HKNP, and the ethnic Dulong community in the GNNR. About 28% of the SBAs (Fig. 4b) appeared beyond the PAs and these involved cultural services of global scientific value, especially for academicians interested in knowing about the rich biodiversity in the three PAs. Other SBAs included recreation and tourism sites and natural scenic spots catering to both domestic and international tourists and travellers. The dSPHs (Fig. 4c), accounting for 83% of the representation within the PAs, included areas of sociocultural conflicts and areas where the traditional systems of the local communities are deteriorating; the dSPHs outside the PAs were mainly areas with unplanned development infrastructure.

4.2.3. Habitat services

The SPHs of habitat services (Fig. 5a) reflected habitats that host the landscape's major flagship species such as the tiger (*Panthera tigris*), elephant (*Elephas maximus*), and other globally endangered fauna such as takin (*Budorcas taxicolor*), leaf deer (*Muntiacus putaoensis*), black muntjac (*Muntiacus crinifrons*), red panda (*Ailurus fulgens*), Asiatic black bear (*Ursus thibetanus*), stump-tailed macaque (*Macaca arctoides*), hoolock gibbon (*Hylobates hoolock),* and temminck's tragopan (*Tragopan temminckii*). About 15% of the SPH points were located outside the PAs; these are key biodiversity areas, with several of them located in the Hponkanrazi Wildlife Sanctuary that connects the NNP-TR and the HKNP. The SPHs in the NNP-TR are home to the globally threatened and migratory black-necked crane (*Grus nigricollis*), blyth's tragopan (*Tragopan blythii*), black-faced warbler (*Abroscopus schisticeps*), and rare species like the root parasitic plant, *Sapria himalayana* (Adhikari et al., 2003; Srinivasan et al., 2010). The SPHs of the GNNR are pristine and host some of the most diverse vertical mountain vegetation in the form of endemic species (Lan and Dunbar, 2000). Likewise, in the case of the HKNP, the SPHs include areas hosting ecologically and aesthetically important mammals – for example, the Nam Tarnai River that serves as a natural barrier for the distribution of the hoolock gibbon (*Hoolock hoolock*) which are mainly found on the west side of the river; then there's the black barking deer (*Muntiacus crinifrons*) which is restricted to the east side (Tun, 2001). The participants found the SBAs (Fig. 5b) to be well-preserved forest areas with undisturbed vegetation, and with endemic and rare species; these areas serve as hotspots for key flora and fauna such as rhododendron (*Rhododendron giganteum*, the largest rhododendron in the world, found in the GNNR), orchids (*Paphiopedilum wardii*, the black orchid), and migratory birds. These SBAs indicated areas of species protection and distribution; yet, 41% of the SBAs were located outside the PAs. With regard to the dSPHs (Fig. 5c), they were

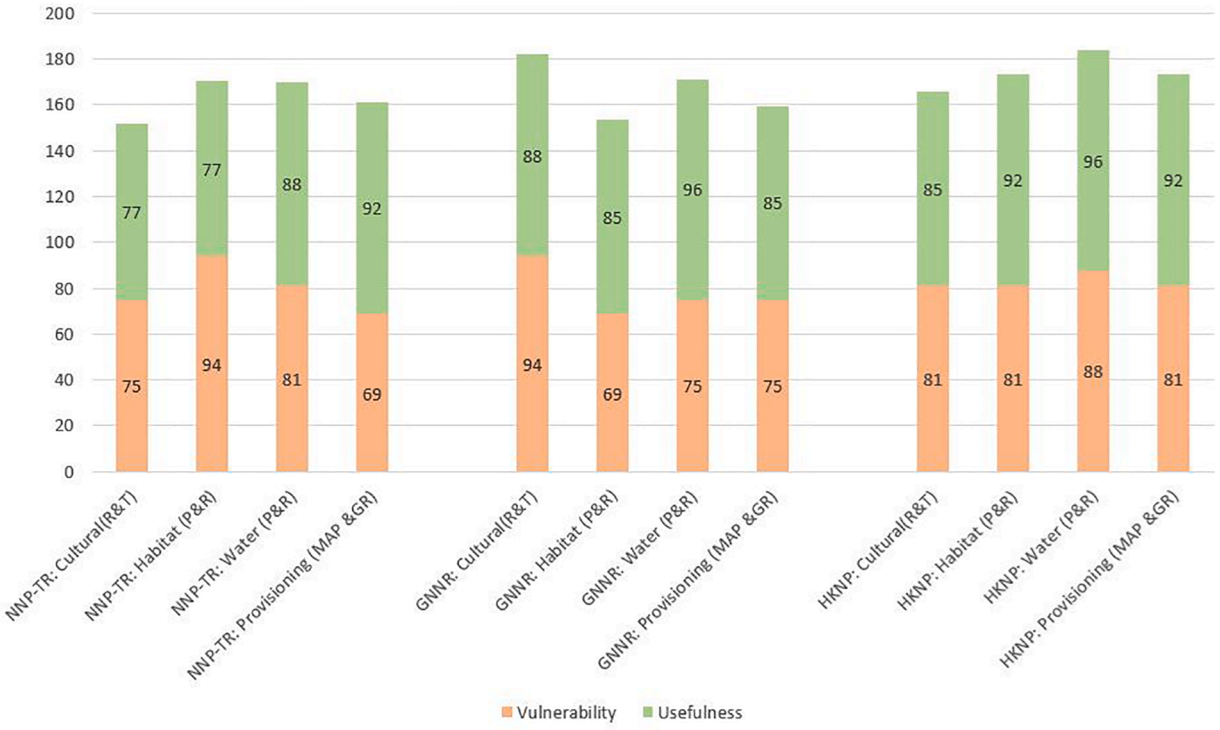

Fig. 2. Cumulative vulnerability and usefulness score of the four prioritized services in the three PAs.

less prominent in the GNNR and the HKNP, as here the primary vegetation were intact, whereas in the case of the NNP-TR, 71% of the dSPHs featured areas of unmonitored vegetation clearing, and land encroachment for settlements; and about 29% of the dSPHs were located outside the PAs.

4.2.4. *Water services*

Forested watersheds, several wetland ecosystems, including snow-covered mountain peaks, glaciers, and alpine lakes were marked as the SPHs for water provisioning/regulatory services (Fig. 6a), with 72% of the SPH representation inside the PAs. The HKNP, adjoining the GNNR, presented a more complete vertical bioclimatic belt, serving as a water tower for entire Myanmar. The PAs in the landscape also feed water to three major rivers –Brahmaputra in India, Ayeyawady in Myanmar, and Salween in China. The SBAs of water (Fig. 6b) represented both local settlement areas along the valleys where water is used for daily household and farm work, and the population (52% representation) residing outside the PAs where water regulatory services are vital to sustain rivulets and river systems which nourish the downstream areas and their population. The dSPHs (Fig. 6c), with 80% of representation inside the PAs, include areas where land erosion, forest degradation, and deforestation, including haphazard timber extractions, are occurring, In the case of Myanmar, the dSPHs are also sites of dam construction.

4.3. *Participatory scenario planning and assessment of four ecosystem services*

Existing policy and management directions were used to define the logic of the scenarios (Table 3). The GNNR is currently managed as a Strict Nature Reserve, and the policy direction is towards zonation and the creation of a national park along the lower elevation to aid both biodiversity protection and economic development. The HKNP is a national park, and the policy direction is towards strengthening community-based conservation mechanisms to meet the dual objectives of conservation and sustainable development. The NNP-TR is currently both a national park and tiger reserve, with the policy direction towards the expansion of buffer areas in order to mitigate conflict over land resources and their use by the ethnic communities.

The scores of the four services in the three scenarios (Fig. 7) show that in the case of all the three PAs, the most favourable scenario is Nature–People-Harmony where all the services are maintained in moderation and trade-offs between the services are minimal. The other two scenarios, at the two extremes of the conservation–economy spectrum, show certain trade-offs among the services – for example, for the GNNR, the Nature-at-Work scenario seems to enhance habitat and water services but compromises on the provisioning of essential commodities for the communities; thereby, compromising also on the cultural services related to the communities' traditional knowledge and practices around conservation and use of natural resources. Likewise, the People-at-Work scenario, with a higher economic orientation, the provisioning and cultural services are better but at the cost of habitat and water services.

5. Discussion

The operationalization of the ES perspective with regard to PA management requires stakeholders to take into account the spatial aspect of service supply and demand (Dirk et al., 2015), and understand the trade-offs among the services (Turkelboom et al., 2018). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) highlighted the importance of environmental interactions and their economics over distances for sustainable development (IPBES, 2018). While the participatory mapping outlined the extent of ES from the PAs in the landscape, it also helped the participants to realize the importance of interregional flow of services (Schröter et al., 2019) – and thereby the prospect of regional cooperation to sustain the delivery of these services. Here, we discuss the regional implications of ES in terms of transboundary landscape management by analysing: i) the usefulness of SPHs, SBAs, and dSPHs in effective regional-scale PA planning; and ii) types of cooperation pathways for long-term sustenance of ES in this landscape.

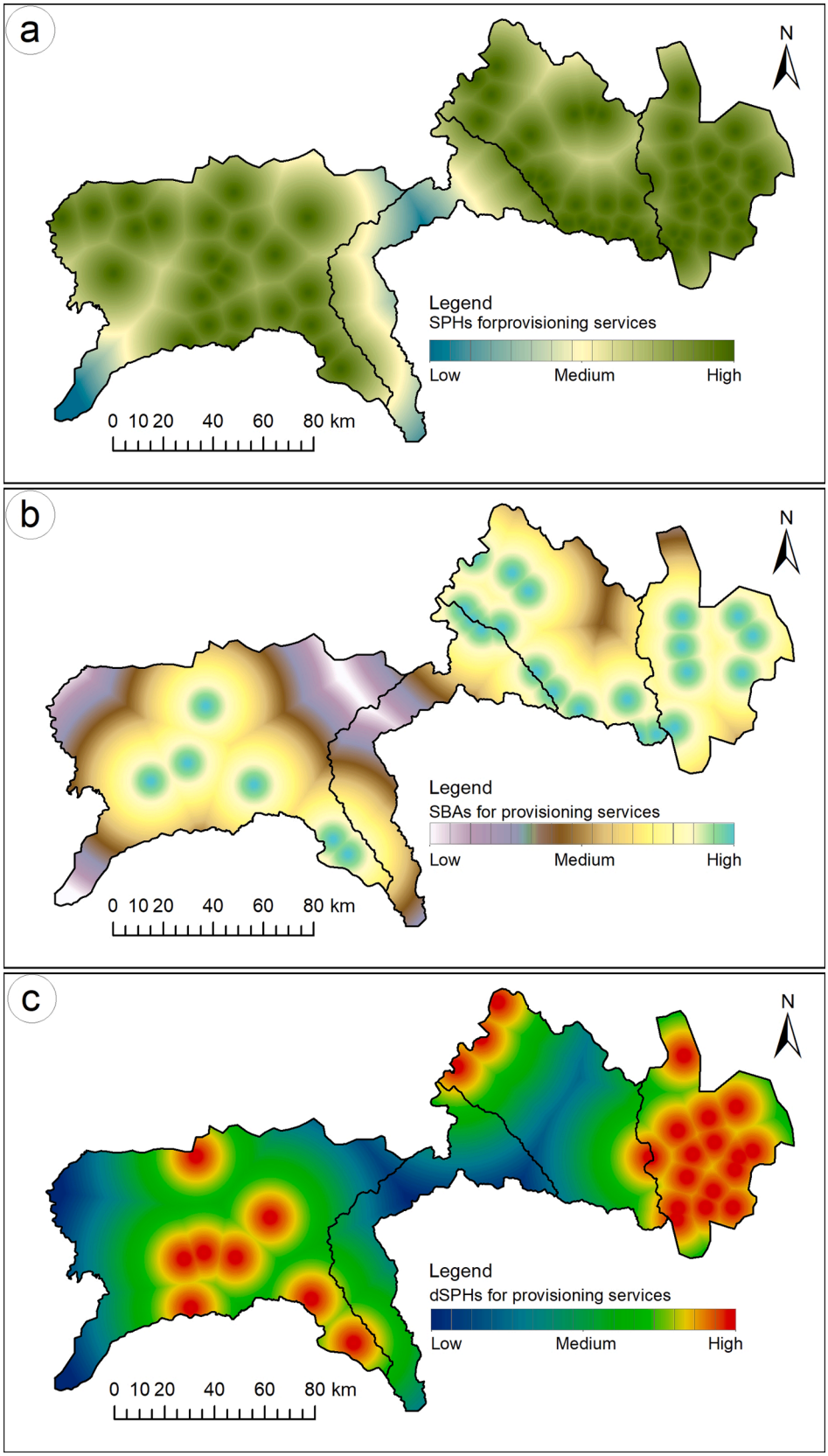

Fig. 3. The SPHs (a), SBAs (b), and dSPHs (c) of provisioning services in the three PAs.

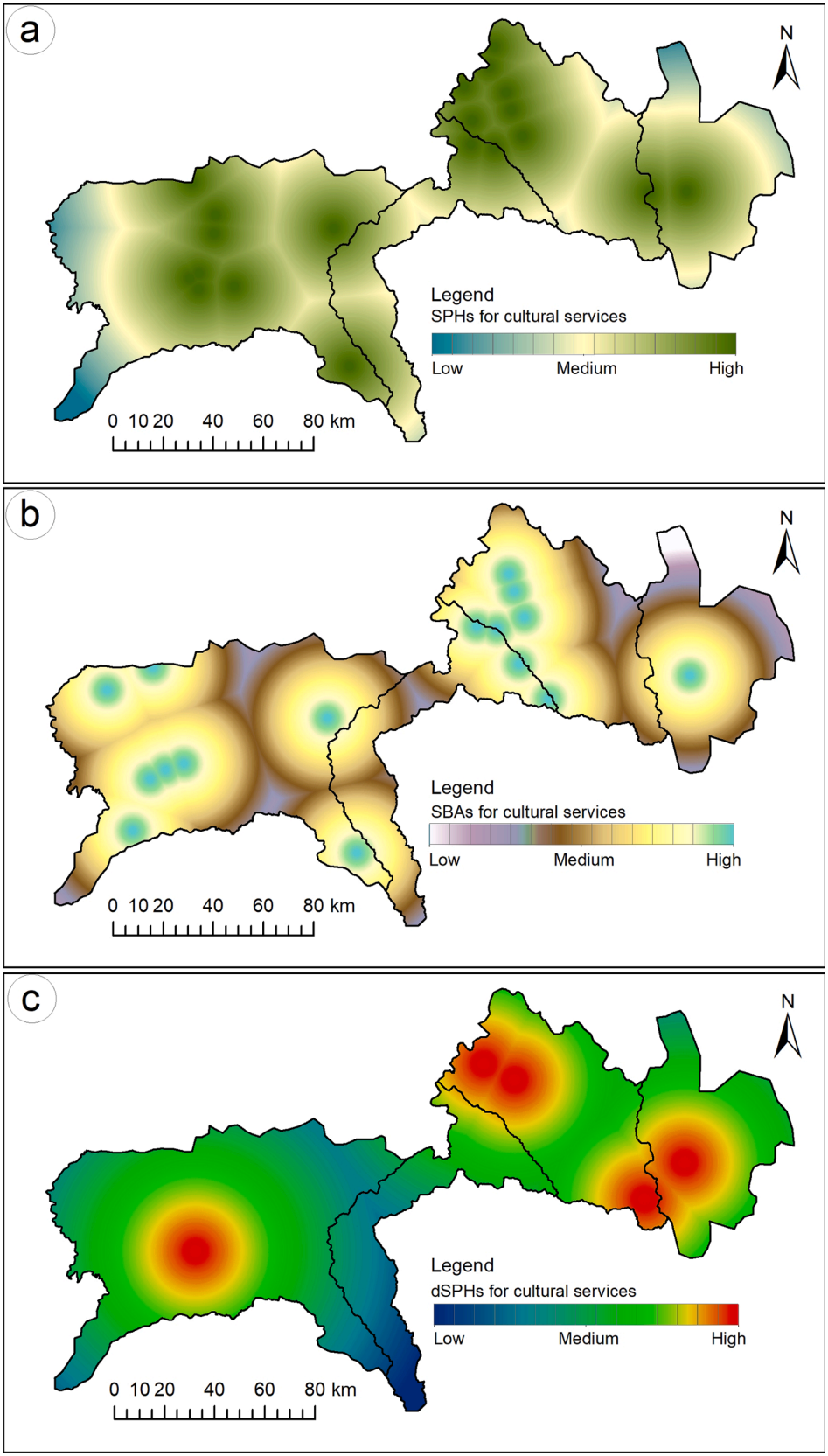

Fig. 4. The SPHs (a), SBAs (b), and dSPHs (c) of cultural services in the three PAs.

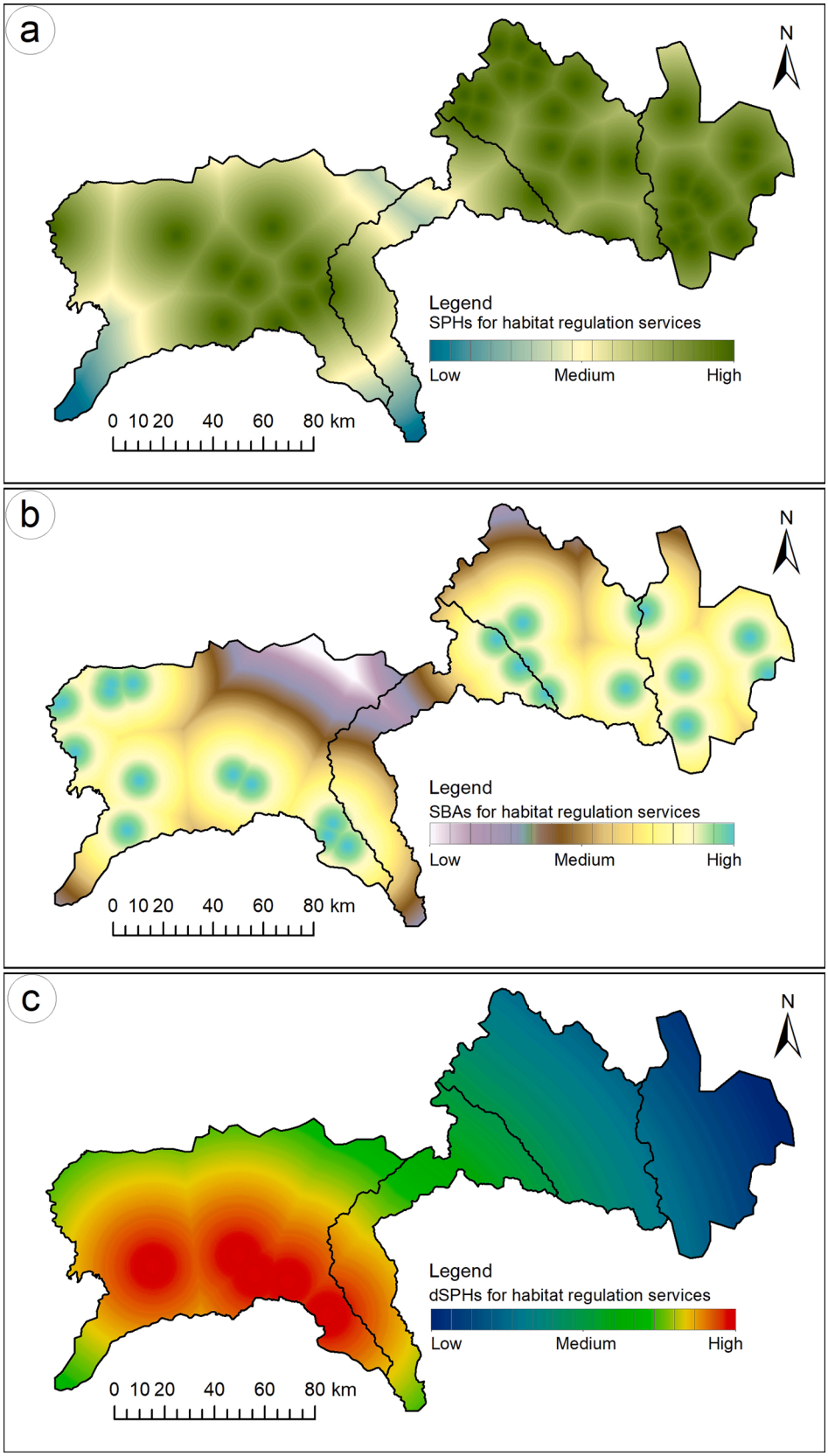

Fig. 5. The SPHs (a), SBAs (b), and dSPHs (c) of habitat services in the three PAs.

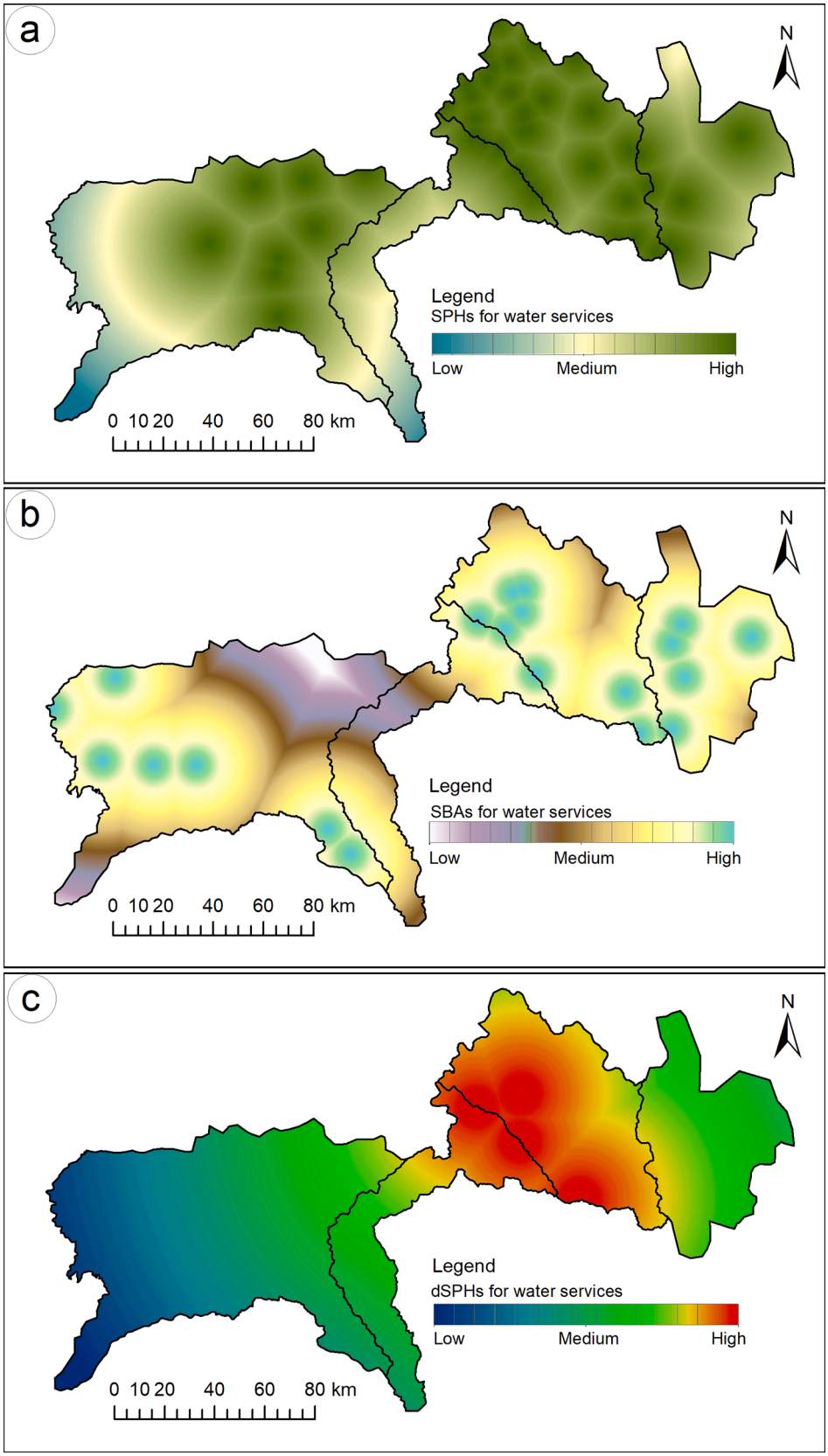

Fig. 6. The SPHs (a), SBAs (b), and dSPHs (c) of water services in the three PAs.

Table 3
The logic of each scenario for the three PAs as outlined by the participants during the workshops.

GNNR	
Nature-at-Work	The GNNR remains a Strict Nature Reserve, with several lower elevation areas also brought under strict management; traditional land management practices prohibited hence restricts socio-cultural influence and agricultural resources development; protection activities are stipulated by government rules and strict regulations; greater investment towards non-nature–based livelihoods
People–Nature Harmony	The GNNR core zone is preserved as a Strict Nature Reserve; the lower stretch is managed as a national park where cultural and conservation-linked economic opportunities are allowed; development infrastructure to be eco-friendly; wise use of technological innovations; zone-specific plans and policies; exploration of income through payment for ecosystem services
People-at-Work	The GNNR core zone is preserved as a Strict Nature Reserve; other areas remain as zones of economic growth; booming tourism and use of commercial products; haphazard development infrastructure
NNP-TR	
Nature-at-Work	The NNP-TR core zone is protected and has no communities living inside it; settlements restricted in the buffer zone, so, conflict aggravates among the ethnic communities over land tenure
People–Nature Harmony	The NNP-TR core zone is well protected with positive engagement from the communities living inside it; the buffer zone expanded and used as a multifunctional landscape; tourism is flourishing, with a focus on local culture and nature-based ecotourism
People-at-Work	The NNP-TR core zone faces further land encroachment and extraction of resources; the settlements in the outskirts of the PA grow; the development infrastructure provides wider opportunities for commercial tourism development and business
HKNP	
Nature-at-Work	The HKNP managed as a national park and run strictly under government plans and policies; the areas around the park to be also converted into PAs with limited access to use of resources; strict control over the use of resources for economic benefits
People–Nature-Harmony	The HKNP landscape and biodiversity are well maintained; the southern part expanded and conservation areas co-managed with the help of the local communities; communities diversify their livelihood options; nature- and culture-based tourism promoted; sustainable land use, energy, and water-related technologies strengthened
People-at-Work	The HKNP remains a national park, but resource extraction and degradation are not monitored adequately; business and development infrastructure promoted for enhancing the livelihoods of the local communities, but more gains for the stakeholders from outside; trade based on natural resources increases

5.1. Extent of SPHs, SBA, and dSPHs, and spatial planning for PAs

Biodiversity is integral to the sociocultural and economic well-being of the people in the far-eastern Himalayan Landscape (Rerkasem et al., 2002; Rao et al., 2011). Although the intention and efforts by the governments in three countries to designate and manage PAs have been scientific given the value of rich biodiversity, the management challenges in terms of resource use restriction and conflict, research and monitoring, financial management, and human resource capacity development have been constrained (Myint, 2007). The important realization this study brings is that the benefits and services from biodiversity in the form of ES relate to beneficiaries ranging from the communities living in and around the PAs to the stakeholders in distant locations within each country or different countries (see Fig. 9). This implies that stakeholder value judgement and power stakes become crucial in maintaining the services (Felipe-Lucia et al., 2015), and that PA management responsibilities must be shared between the government and non-government actors to safeguard the flow of ES to different beneficiaries (Sangha et al., 2019).

The individual PCA biplots (Fig. 8) validate the participants' perceptions on the source and sink areas of the services. The degradation of the SPHs related to habitat services (HdSPHs), and the SBAs for cultural (CSBAs), water (WSBAs), and habitat (HSBAs) services – found to be positive in PC2 and PC1 – imply that they strongly influence the delivery of ES. The dSPHs related to habitat services (HdSPHs) in the NNP-TR substantiate the unsustainable transformation of the PAs (Datta et al., 2008) as a result of multiple factors as identified by the participants; these factors include land-use change, land erosion, population growth, internal conflict, habitat encroachment, agricultural expansion, mining, haphazard extraction of resources, deforestation, extensive logging, and illegal hunting and trade. The SBAs and the SPHs in the case of cultural services (CSBAs, CSPHs) confirm that the management of the PAs in the landscape needs to also consider bio-culturally sensitive areas outside the PAs, as they enhance the aesthetic and knowledge values of these PAs (Ament et al., 2017). In the case of the NNP-TR, although the state policy is sensitive to the traditional rights of the indigenous communities, this has negatively influenced habitat regulation services, with increased encroachment even in the core zones (Arunachalam et al., 2004). The concept of integrated landscape management will be fundamental here in addressing the challenge of ethnic land-use tenure and in minimizing habitat encroachment and deforestation. The degradation of the SPHs in terms of cultural services (CdSPHs) and the SBAs in terms of provisioning services in the HKNP – both found positive in PC1 – justify their importance in enhancing the services of these PAs. For the HKNP, the SPHs and the dSPHs in the case of water services are shown to be positive in PC1, which highlight the importance of the PA being the water tower of the entire country. The watersheds and forests in the PAs have received strong national conservation priority, and despite the remoteness of their location and the low population density of the ethnic communities living in and around the PAs, currently, all services are being maintained well (Tun, 2001) except for cultural services that have been compromised due to the socio-political conflicts in the region (Renner et al., 2007). In the case of the GNNR, habitat services, along with provisioning services related to genetic resources and medicinal and aromatic plants, are on a strong footing (Zhang, 2015) compared to water regulation/provisioning and cultural services – both appear negative in PC1 and PC2.

The extent of provisioning, regulating, cultural, and supporting services identified in the three PAs substantiate that the PAs can safeguard both biodiversity and various environmental, sociocultural, and economic services that benefit the people (Palomo et al., 2014). The above-average score for the current condition of the four prioritized ES (see Fig. 7) reflects a good potential of the PAs to moderate the interaction between nature and humans, while also protecting nature's social assets (Hummel et al., 2019). Adoption of Nature–People Harmony scenario enhances this relationship as it reflects a more holistic, multifunctional landscape services concept (Rodríguez-Loinaz et al., 2015), that minimizes trade-offs among the multiple services driven by management strategies (McShane et al, 2011) or by value dimensions (Martín-López et al., 2014). This scenario, as depicted by the participants, considered the development aspiration of the communities in and around the PAs and also promoted aesthetic, recreational, knowledge and education-related partnerships and interactions (Smit et al., 2017) in the landscape. PAs in the landscape are a recent phenomenon compared to the dwelling of some of the ethnic communities in the landscape and their traditions of resource use and mobilization (Myint, 2007; Renner et al., 2007; Arunachalam et al., 2004). It is well acknowledged that indigenous cultures around the world have protected several areas by rituals and have shaped the relationships between people and nature (Russell et al.,2013; Ormsby and Bhagwat, 2010). Participants indicated that when PA governance is not aligned to the indigenous communities' knowledge and practices around resource management, the amount of dSPHs and the trade-offs among the ES go up. The current situation of

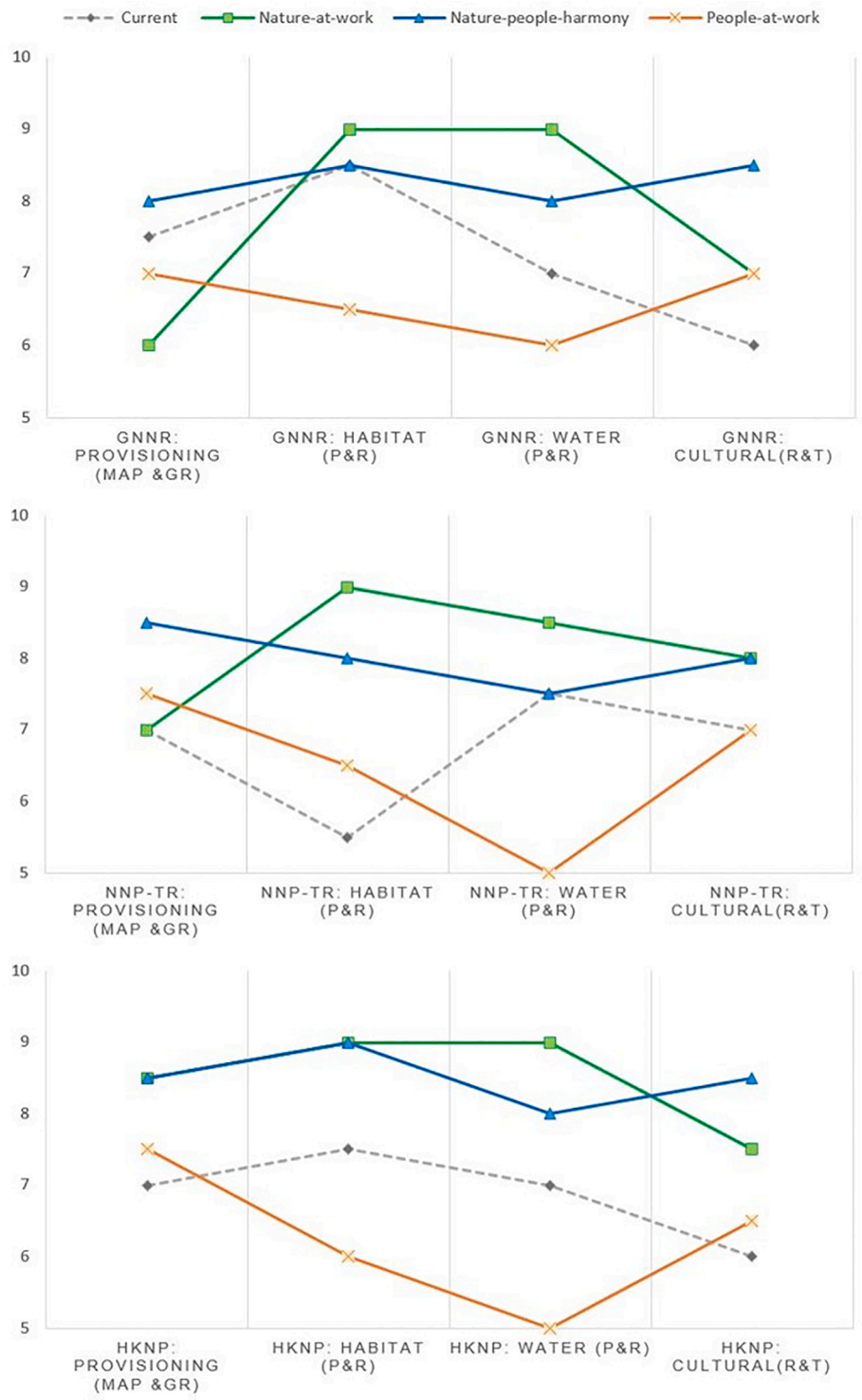

Fig. 7. Comparative performances of the ES under three scenarios.

habitat and water regulatory services in HKNP more or less reflects this adaptive scenario (Fig. 8) where community-led resource management is still fundamental in maintaining the dSPHs that overlap with the SBAs, or the SPHs outside the PAs as these represent areas of rich biodiversity nurtured by the traditions and cultures of the ethnic communities (Allendorf & Yang, 2013). Such socio-ecologically distinct spatial units acknowledging value based dependence of local communities on biodiversity are considered important for ES-based decision-making (Schirpke et al., 2020). The Forest Department of the Ministry of Natural Resources and Environmental Conservation in Myanmar informed that the 2018 Biodiversity Conservation and PA law now endorses such conservation efforts by indigenous community. The other two scenarios relate to situations where conservation and development objectives are not balanced. Participants recognize these scenarios where PA management actions incurs greater trade-offs between ES because in one situation the concerns of local people as custodians and users of ES are overlooked (Chaudhary and Bawa, 2011), and in the other nature's capacities to provide long-term ES is compromised by haphazard and unplanned development interventions.

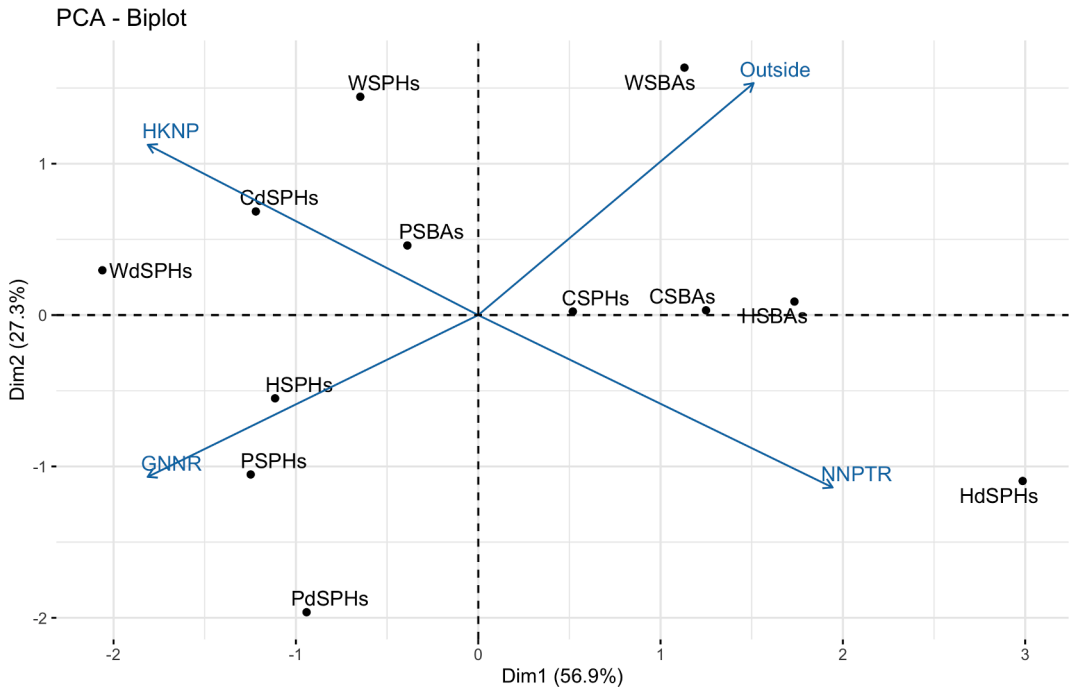

Fig. 8. Individual PCA biplots showing the relationships of SPHs, SBAs, and dSPHs in the three PAs.

5.2. Cooperation pathways to manage multiple services

While participatory mapping and scenario development helped consolidate the stakeholders' diverse perspectives on the prospects of the PAs, they also imparted the knowledge that: i) the PAs have complex spatial relationships between the source and sink areas in terms of ES delivery; ii) currently, the four ES are maintained at above-average conditions, with higher percentage of SPHs compared to SBAs, but SPHs are vulnerable threatened by the common pressures such as land-use change and land encroachment, habitat fragmentation and deforestation, climate change, haphazard extraction and exploitation of resources, and illegal trade and poaching; iii) there are trade-offs in managing multiple ES, and adaptive PA management can help mitigate the longer-term trade-offs resulting from the stakeholders' diverse influence on the ecosystems; and iv) the four ES of high management priority in the landscape show interregional connect, with the SBAs of all the services reaching beneficiaries beyond the PAs and across the landscape. The examples in this regard are the informal and formal trade between China and Myanmar in medicinal plants and wildlife products; the exchange of knowledge, traditions, and culture among the ethnic communities; the shared habitats of globally threatened species; and the shared water services of the Ayeyawady River (Uddin et al., 2019; Rao et al., 2011).

The interregional connections of ES mean that the degradation of one SPH can influence the flow or transfer path of ES to SBAs in distant locations (Schirpke et al., 2019), and that action in one PA in one country has consequences for ES in another country (Howe et al., 2014). For example, when the buyers on China's eastern seaboard ran the timber business along the Yunnan–Myanmar border, the intensity of logging in northern Myanmar increased significantly; this quickly depleted timber resources, thereby affecting both Myanmar's timber products and the livelihoods of the stakeholders in the market chain (Kahrl et al., 2004). The PAs in the three countries, while they are reasonably governed in terms of protecting the flagship species and the globally endangered ones, the management focus needs to shift towards an integrated landscape approach (Sayer et al., 2013) which considers multifunctional landscape planning (Minang et al., 2015), habitat connectivity (Chettri and Shakya, 2010), the resilience of ecosystems and natural capital (Barbier, 2011), local livelihoods through wise use of resources (Willemen et al., 2013), and conservation through application of traditional knowledge (Kakoty, 2018). Such shift is essential to respond to interactions and feedbacks from many factors at multiple scales affecting the nature's ability to provide benefit to people (Dıaz et al., 2015).

We recommend three cooperation pathways - intra-country, inter-country, and regional - for the long-term maintenance of the four priority services. These pathways consider spatial and temporal trade-offs from ES (Rodríguez-Loinaz et al., 2015), and pave way for creating an enabling policy, social, and institutional environment to deliver multiple services from PAs (Bennett et al, 2009), and rationalize the PA network for shared financing and collaborative management (Ervin et al., 2008). For that to happen, the governments in the three countries need to view the PAs as part of a wider landscape that connects the biodiversity and ES of the PAs to the landscape elements outside them (Beresford et al., 2005); and bring together stakeholders with a wider set of social values (Bryan et al., 2010). This will enable the protection of key biodiversity areas or the SPHs located outside the current PA network, and reinforce ecological connectivity (Locke, 2011). Several possible connectivity for ES management can be extrapolated from the SBAs, SPHs and dSPHs (Fig. 9). One example is the spatial connection between the NNP-TR and the Kamlang Wildlife Sanctuary in the north, which increases ecological contiguity between the two PAs protecting the SPHs along their borders. The world heritage site nomination proposed for the HKNP aims to include the southern extension of the landscape (UNESCO 2014) – this is justified as several SPHs and SBAs are located in this extension area. This also includes one of the dSPHs or the threatened rainforests of Naung Mung south and west of the current HKNP boundary which host most of the unique aspects of the region's biodiversity (Rubio et al., 2020; Yang et al., 2019). Between Myanmar and China, since several dSPHs and SBAs lie at the border of these two countries. The spatial extension for conservation in the form of transboundary PAs (Trillo-Santamaría and Paül, 2016) can open up avenues for cross-border biodiversity protection and benefit-sharing of the ES (Yang et al., 2019; Meyer et al., 2017), as well as for shared governance based on mutual interests between countries (Allendorf and Yang, 2013).

The landscape being hotspots for biodiversity has a high national conservation priority, which mean there is a very small economic

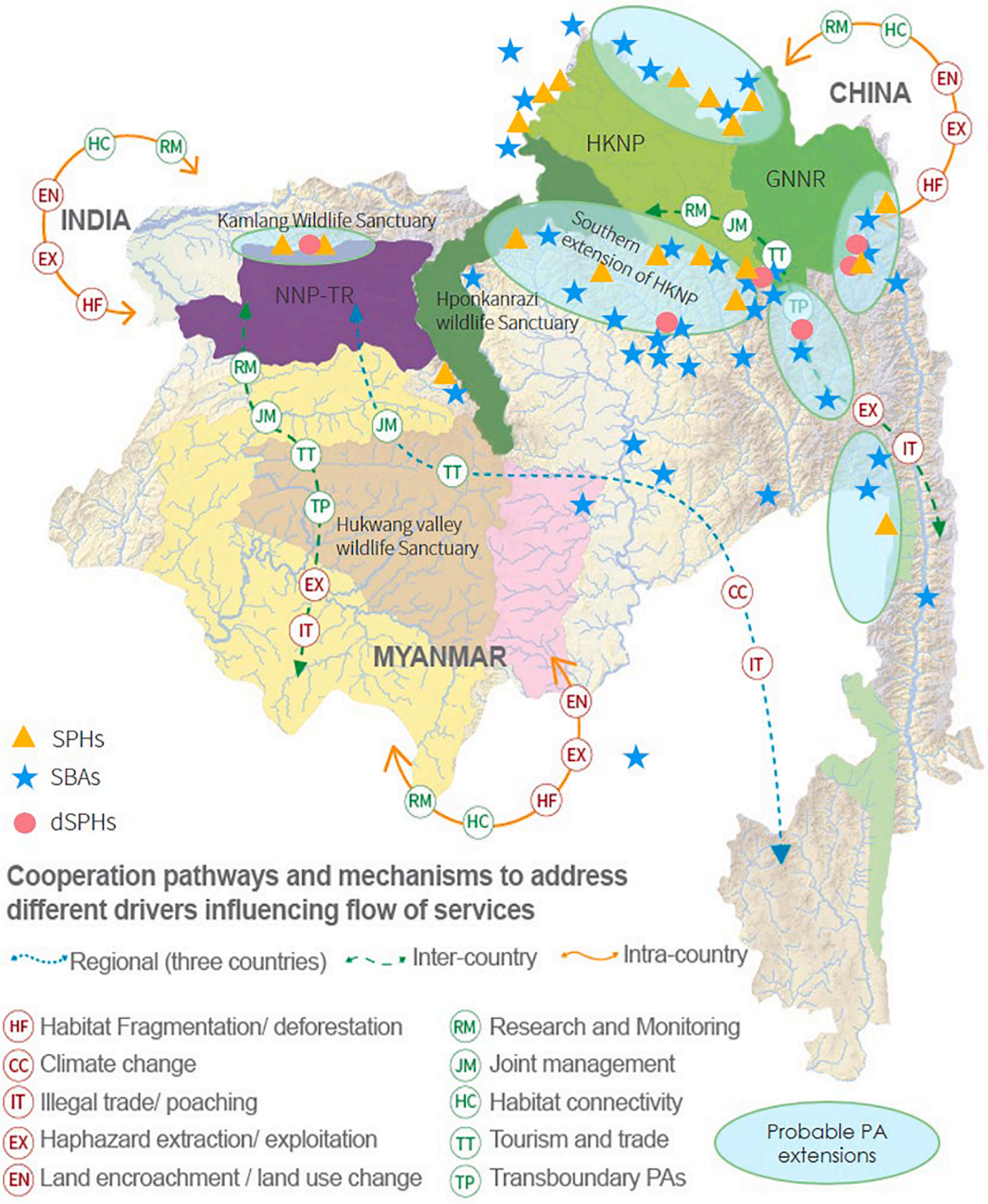

Fig. 9. Regional implications of the flow of services, showing the extent of beneficiaries, the usefulness of the four services in each PA, and the types of cooperation pathways that address the different drivers affecting ES.

opportunities for local communities, and they remain developmentally marginal. In such context of conservation-development trade-offs, the intra-country pathways need to rationalize conservation and include mechanisms such as: buffer zones, community-conserved areas, conservation/habitat corridors, community-based forestry with plantation of timber and fuelwood species, and silvi-horti-agri practices. Such mechanisms create habitat links between the PAs and the priority SPHs outside them, safeguard ES from the currently unprotected SPHs, allow local communities to generate financial and social benefits, and decrease transaction costs for conservation of large landscapes. Likewise, economic valuation of ES (Martín-lópez et al., 2011) to incentivize conservation actions (Xu et al., 2019; Bullock et al., 2011) especially in the SPHs within the PAs with high dSPHs will minimize haphazard resource extraction and unorganized land-use changes, and mitigate pressure on the SPHs of various ES (Villamagna et al., 2013). As for inter-country collaborative pathways, the ES management mechanism must be built on common SPHs, SBAs, and dSPHs between two countries and should aim to address sensitive cross-border challenges such as poaching and illegal trade, as well as transboundary ecosystem fragmentation (Liu et al., 2020); Joint biodiversity research using harmonized protocol and monitoring mechanisms, joint management actions, and the collective engagement of communities across borders in conservation and conservation-linked economic actions would facilitate effective institutional collaborations between the two countries (Sandwith et al., 2001). Participatory partnerships considering the diversity of the stakeholders, the managers and beneficiaries of the services would allow better understanding of trade-offs among the uses of multiple services (López-Hoffman et al., 2010). The regional pathway to enhance cooperation among the three countries entails working across administrative and political boundaries through formalizing regional cooperation (Kotru

et al., 2020). This can be facilitated through transboundary landscape initiatives such as HI-LIFE (ICIMOD, 2018). Landscape initiatives offer the opportunity to discuss effective natural resource governance among the countries which will generate both conservation and livelihood co-benefits in the entire landscape (Gurung et al., 2019; Shakya et al., 2011; Zomer et al., 2011).

Cooperation in this landscape is often directed by competition over the extraction of natural resources for economic gains (Bawa et al., 2010) and illegal cross-border trade remains a sensitive issue (Singh, 2007; Than, 2005). The strengthening of age-old practices of transboundary community cooperation for cross border trade and resource use through pro-poor trade strategies can improve the prospect for sub-regional cooperation for trade and tourism (Dong and He, 2018; Tiwari and Joshi, 2015). Regional cooperation can open up avenues for a trans-regional tourism circuit across India-China-Myanmar that will help the three countries collectively highlight and promote landscape's rich natural, historical, and cultural treasure and heritage (Badola et al., 2018; Yang et al., 2008), building upon the historic and traditional ethnic linkages (Eilenberg and Wadley, 2009). Such positive social marketing around both nature and culture based tourism can help mitigate the regional and global market demand of wildlife products (Burgess et al., 2020). Likewise, the establishment of joint research and monitoring facilities and joint surveys can benefit biodiversity knowledge networking and information exchange between the countries (Eppink et al., 2012). The use of GIS remote sensing in this regard, can be very promising in understanding spatiotemporal change in forests and ecosystems in the landscape (Pastick et al., 2019), and scaling up of local scale data around ecosystem functions and processes from PA to landscape to inform regional ES policy and management (Abelleira Martínez et al., 2016). Additionally, formal institutional arrangements that facilitate intergovernmental dialogues, common policy initiative, and collaborative trans-border practices (Molden et al, 2017) can strengthen cooperation among national government for transboundary environmental conservation and sustainable development.

6. Conclusions

The PAs in the far-eastern Himalayan Landscape provide a diverse range of ES that reaches beneficiaries beyond the park boundary or even beyond the boundary of one nation. The spatial extent of the SPHs, the SBAs, and the dSPHs, and their performance against three plausible future scenarios reiterated that conservation actions in the landscape must prioritize PA networks, facilitate multiple use of diverse ES from them, and engage a wider constituencies to share the cost of management of PAs network and balance conservation and development benefits. Harmonized participatory exercises across the three PAs not only sensitized the stakeholders in each country on the wider benefits and values of the PAs, but also helped set the basis for regional cooperation among the countries. The regional implications were that in all the three countries, the SPHs were located both within and outside the PAs and that future governance of the PAs need to integrate land use outside the PAs as conservation corridors, buffer zones, community forestry areas, and community-conserved areas; and thus promote ownerships and engagement of local communities towards sustainable use and management of natural resources. For all the four prioritized ES, the inter-regional flow indicated that the demand for the services are both regional and global. In the future, a landscape-scale valuation of ES with an analysis of the cost of transfer of services to regional and global beneficiaries, and developing a wider range of user payment mechanisms may allow the three countries to collectively define regional environmental and biodiversity management policies. The interregional ES flow perspective will also enable the countries to explore the prospect of transboundary PAs especially in areas where human-wildlife geographic space overlaps, and to collectively reduce resource conflict in border areas, mitigate challenges such as spread of forest fire, spread of invasive and alien species, and outbreaks of pests and epidemic diseases, and promote ecological contiguity for flagship species such as tigers, takin, hoolock gibbon, and snub-nosed monkey that are distributed across the far-eastern Himalayan Landscape. Safeguarding the landscape's high Outstanding Universal Value in terms of natural, geological, and cultural features through World Heritage Site unfolds yet another domain for regional perspective to maintain the long-term health and resilience of ecosystems, the continual delivery of ES, and the vitality of the societies and stakeholders across the landscape.

7. Disclaimer

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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