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PERSPECTIVE

# Small habitat matrix: How does it work?

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**Abstract** We present herein our perspective of a novel Small Habitats Matrix (SHM) concept showing how small habitats on private lands are untapped but can be valuable for mitigating ecological degradation. Grounded by the realities in Sabah, Malaysian Borneo, we model a discontinuous "stepping stones" linkage that includes both terrestrial and aquatic habitats to illustrate exactly how the SHM can be deployed. Taken together, the SHM is expected to optimize the meta-population vitality in monoculture landscapes for aerial, arboreal, terrestrial and aquatic wildlife communities. We also provide the tangible cost estimates and discuss how such a concept is both economically affordable and plausible to complement global conservation initiatives. By proposing a practical approach to conservation in the rapidly developing tropics, we present a perspective from "ground zero" that reaches out to fellow scientists, funders, activists and pro-environmental land owners who often ask, "What more can we do?"

**Keywords** Biodiversity · Funding · Landscape ecology · Protected area

## INTRODUCTION

A basic tenet of ecology suggests that in most cases animal species diversity increases concurrently with increase in area. Though this species–area relationship (SAR) is also dependent on other factors such as animal size, lifecycle needs and natural dispersal range (Rybicki and Hanski 2013), the central goal of conservation practice over the past 50 years has been to secure as large as possible contiguous blocks of intact landscape so as much biodiversity is preserved as possible (Cantu-Salazar and Gaston 2010). The scientific consensus so far appears to be "larger is better". Additionally, the single large or several small (SLOSS) debate is still on-going since 1970s and the resolution has not emerged (Fahrig 2020).

According to Baillie and Zhang (2018), estimates ranging from 25 to 75% of major ecosystems are required to be retained. A global target of 17% was proposed as an international policy in the CBD Aichi Biodiversity Target 11 (Leadley et al. 2014), although more recently, Dinerstein et al. (2019) proposed 30% as a more plausible threshold. Others have argued that anything below 50% (usually referred to as "half earth" or "nature needs half"; NNH) would not be sufficient (Locke 2013; Wilson 2016; Dinerstein et al. 2017; Pimm et al. 2018). Given the especially high and on-going anthropogenic pressures in fast growing and developing country context, securing large intact landscapes seems now unlikely (Büscher et al. 2016). Thus, under prevailing circumstances, we ask—how can smaller and disturbed landscapes contribute to maintain a reasonable level of biodiversity?

Literature supporting maximizing the coverage of protected areas is abundant (e.g. Baillie and Zhang 2018; Pimm et al. 2018; Dinerstein et al. 2019). Investigating the values of small spaces that are privately owned and outside protected areas, however, is relatively not common to science (Volenec and Dobson 2020). Although some commendable studies had supported the plausibility of residual spaces for biodiversity enrichment, these often stopped short on offering ideas or schematics to illustrate exactly how small spaces can be configured and optimized in a pragmatic manner (e.g. Turner and Corlett 1996; Law and Dickman 1998; Benton et al. 2003; Bennett et al. 2006; Fahrig et al. 2011; Rosa et al. 2015).

Literature also suggests that small isolated habitats do retain some important ecological functionality. For example, species diversity is often triggered by habitat fragmentation that then provides opportunities for adaptive divergence and speciation albeit over an extended period of time (Berger et al. 2010; Ruiz-Sanchez et al. 2012; Moritsch et al. 2014). Moreover, it has been shown that sometimes rapid and non-linear change is also part and parcel of natural system dynamics (Pickett and Thompson 1978; Zhang et al. 2016; Xi et al. 2019). For example, even without anthropogenic disturbances, habitats are naturally modified and fragmented by rivers, floods, fires, typhoons, strong winds, droughts, volcanic eruptions or earthquakes. After the natural disturbances, given time and when the circumstances are conducive, residual populations often gradually adapt and restore themselves to a new equilibrium in damaged habitats (Loucks 1970; Gunderson 2000; Junk and Wantzen 2007). In fact, the domesticated landscape over time is an example of such a new ecological equilibrium. Therefore, we argue that in reference to the classical resilience theory, island biogeography theory and meta-population dynamism theory (MacArthur and Wilson 1963; Levins 1969; Holling 1973), the capacity of wildlife communities to persevere and re-adapt in damaged and fragmented habitats cannot be discounted.

Whilst ideas are scarce and the debate of protected area threshold is on-going, time is a luxury we cannot afford. Pro-environmental land owners, conservationists and activists must make decisions now and many are desperately seeking some plausible solutions at the grass-root level. So far the practice of establishing clusters of small protected areas intentionally for minimalizing biodiversity declines is not evident in our region of work. We believe that the anthropogenic landscape can be configured and re-adapted to support biodiversity enrichment, at least to a certain degree. The emphasis of this paper is on providing a tangible view of how this can be achieved.

## SMALL HABITAT MATRIX

Species communities are widely assumed to require large and contiguous natural landscape although a comprehensive review by Prugh et al. (2008) concludes that patch size and isolation are actually poor determinants of occupancy. There is, in fact, pre-existing literature supporting small isolated habitat patches as “stepping stones” for linking biological populations at the spatial level (e.g. Saura et al. 2013; Gilroy et al. 2014; Newmark et al. 2017; Lynch 2018) and a fair level of small species biodiversity within small isolated habitats has been widely documented (e.g. Sayer 2009; Bernard et al. 2014; Lynch 2018; Wang et al. 2019). Turner and Corlett (1996) report that fragments of < 100 ha can sustain a fair level of biodiversity decades after isolation in the Indo-Malayan tropics. Another review, furthermore, found species diversity exceeding that of monoculture oil palm can be retained in the presence of habitat patches as small as 20 ha (Lucey et al. 2017).

Aerial species, especially, are known to make ontogenetic movement across multiple small habitats to acquire various resources to complete their lifecycle (Law and Dickman 1998; Bowne and Bowers 2004). For example, bats forage in various habitats on a daily basis (Furey and Racey 2016) and migratory birds fly long distances and temporarily inhabit contrasting habitats along the East Asian-Australasian Flyway in accordance with annual seasonal changes (Yong et al. 2018). Bees, wasps, butterflies and damselflies have been reported to frequently traverse between forest fragments through disturbed landscape to some degree (Tscharntke et al. 2002; Krewenka et al. 2011; Lucey and Hill 2012; Khazan 2014; Filgueiras et al. 2015). Amphibians and reptiles make favourable use of biowaste in monoculture landscapes (e.g. fronds) as refuge for resting and predator avoidance (Gallmetzer and Schulze 2015). Reptile diversity and abundance was found to actually be higher in oil palm plantations when compared with other habitats (Paoletti et al. 2018).

Studies show elephants, orang-utans, macaques, palm civets, birds and other terrestrial wildlife are using monoculture landscape to varying degrees for feeding and shelter while moving between larger forest tracts, as long as there is no harassment from humans (Fig. 1) (Meijaard et al. 2010; Nájera and Simonetti 2010; Campbell-Smith et al. 2011; Estes et al. 2012; Nakashima et al. 2013; Ancrenaz et al. 2014a, b; English et al. 2014; Davies et al. 2017; Berliani et al. 2018; Oram 2018; Ruppert et al. 2018; Spehar and Rayadin 2017; Davies et al. 2019; Othman et al. 2019; Evans et al. 2020). Not surprisingly, studies have also shown that sun bears, bearded pigs and other small mammals benefit nutritionally from eating oil palm fruits especially during drought when forest food availability may be insufficient (Wong et al. 2005; Fredriksson et al. 2006; Love et al. 2018).

Many other studies provide confirmatory evidence that a series of isolated small habitat patches can be effective for, (1) providing meta-population connectivity in the landscape, (2) increasing the effective extent of protected areas for biodiversity conservation, by, (a) catering to niche lifecycle and dispersal functions, (b) offering temporary or periodic refuge or even viable habitats for juveniles and animal species of small body size, and (c) securing suitable spatio-temporal heterogeneity for some species (Noss 1991; Bowne and Bowers 2004; Uezu et al. 2008; Cantu-Salazar and Gaston. 2010; Carbó-Ramírez and Zuria 2011; Caryl et al. 2012; Lynch 2018; Ferreira et al. 2019; Tomadon et al. 2019). On these grounds, and supporting

**Fig. 1** Bornean elephants foraging and moving across oil palm plantation landscape. Photo by Enroe Soudi

literature mentioned, we propose the Small Habitat Matrix (SHM) concept (Fig. 2).

Central to the SHM approach is that private land (i.e. specific land areas where some form of state recognition exists of rights to private ownership or use, and where a governmental department does not have sole authority) is eligible to be set aside—either spared or shared—by legal or personal means for biodiversity conservation. In Malaysia where the idea of SHM is conceived, land right of individual or commercial enterprise is governed by the Torrens land title system which was first implemented during British colonial rule (Kelm et al. 2017). The concept of sparing or sharing land for conservation is not new in developed countries although the plots are often larger and typically defined and governed as “privately protected areas” (Mahoney et al. 2015; Mitchell et al. 2018a). In addition, in some places there is increasing interest among landowners and agriculture enterprises to conserve a portion of their lands for purely altruistic reasons and/or by Corporate Social Responsibility (CSR) initiatives (Haufler 2014; Drescher and Brenner 2018). The concept is non-existent, or rudimentary, or not endorsed by government, or very new in many developing nations. Yet, from over numerous conversations over the past 5 years with approximately 100 agricultural smallholders and enterprises in Sabah, they have voiced concerns to us personally over biodiversity loss and some already offered to set aside a portion of their land for conservation purposes.

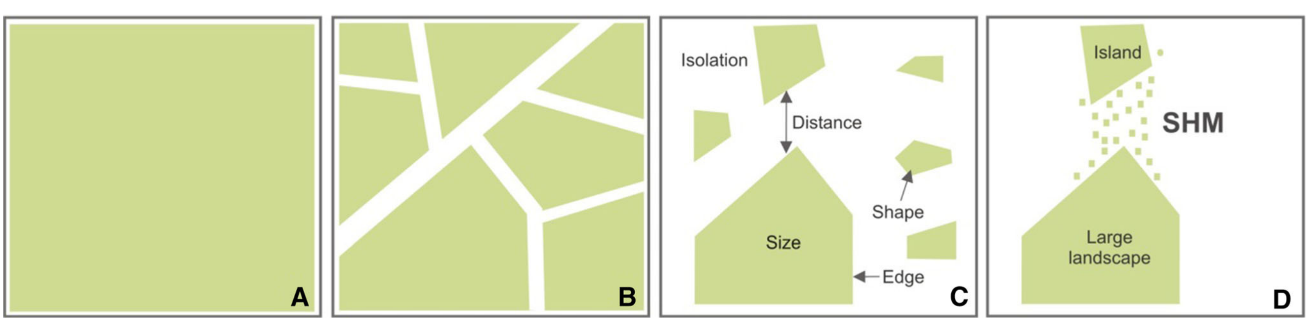


**Fig. 2** The transition from wildland to farmland typically follows the sequence from undisturbed (**a**), fragmentation (**b**), and finally isolation (**c**). The proposed SHM concept is aimed at linking island habitat to large undisturbed landscape (**d**)

In support of privately held set asides, we define the SHM as an integrated network of small terrestrial and aquatic habitats that optimize species meta-population and landscape ecological vitality in an anthropogenic region. To elaborate, the SHM concept calls for the creation of a series of small or "micro" terrestrial and aquatic natural habitats in private lands within an altered landscape. The concept permits permeability so mobile biota can move freely between and within mixed-use landscapes that include natural and anthropogenic features and supports re-colonization by smaller species from adjacent larger habitats. For large and wide ranging species such as elephants and male orangutans, the SHM concept enables the use of the accumulated sum of small habitat patches for shelter or feeding as wildlife travel through heavily disturbed regions between larger protected areas. This way, the overall landscape retains some key ecological functionality despite disturbance. Consequently, the rate of species extinction will likely decrease and some meta-populations could even regain equilibrium (Law and Dickman 1998; Beger et al. 2010; Newmark et al. 2017).

While terrestrial habitats are often deliberated in two-dimensions (2D), the SHM places a heavy emphasis on three-dimensional (3D) ecological functionality (Fig. 3). Vertical stratification of a SHM is conceived as having both an above-ground and below-ground level component. The above-ground component is necessary for terrestrial and arboreal species (Emmons and Gentry 1983). Tropical examples include red giant flying squirrel (*Petaurista petaurista*), paradise flying snake (*Chrysopelea paradise*), bats and many bird species. Chimpanzees (*Pan troglodytesi*) and orangutans (*Pongo pygmaeus morio*) though often prefer trees for resting and nest building also engage in ground-level movement (Ancrenaz et al. 2004, 2014b; McCarthy et al. 2016; Davies et al. 2017, Davies et al. 2019; Spehar and Rayadin 2017).

Currently, landscape ecology research has largely been confined to the terrestrial realm often to the exclusion of other key aspects, most notably global freshwater biota (Dudgeon 1992; Balian et al. 2008; Strayer and Dudgeon 2010; Giam et al. 2015; Reid et al. 2018). This is surprising as freshwater habitats and aquatic species are universally agreed to be key indicators of overall ecosystems health (Allan and Flecker 1993; Chapman et al. 1996; Bunn and Arthington 2002; Beger et al. 2010; Fahrig 2017;

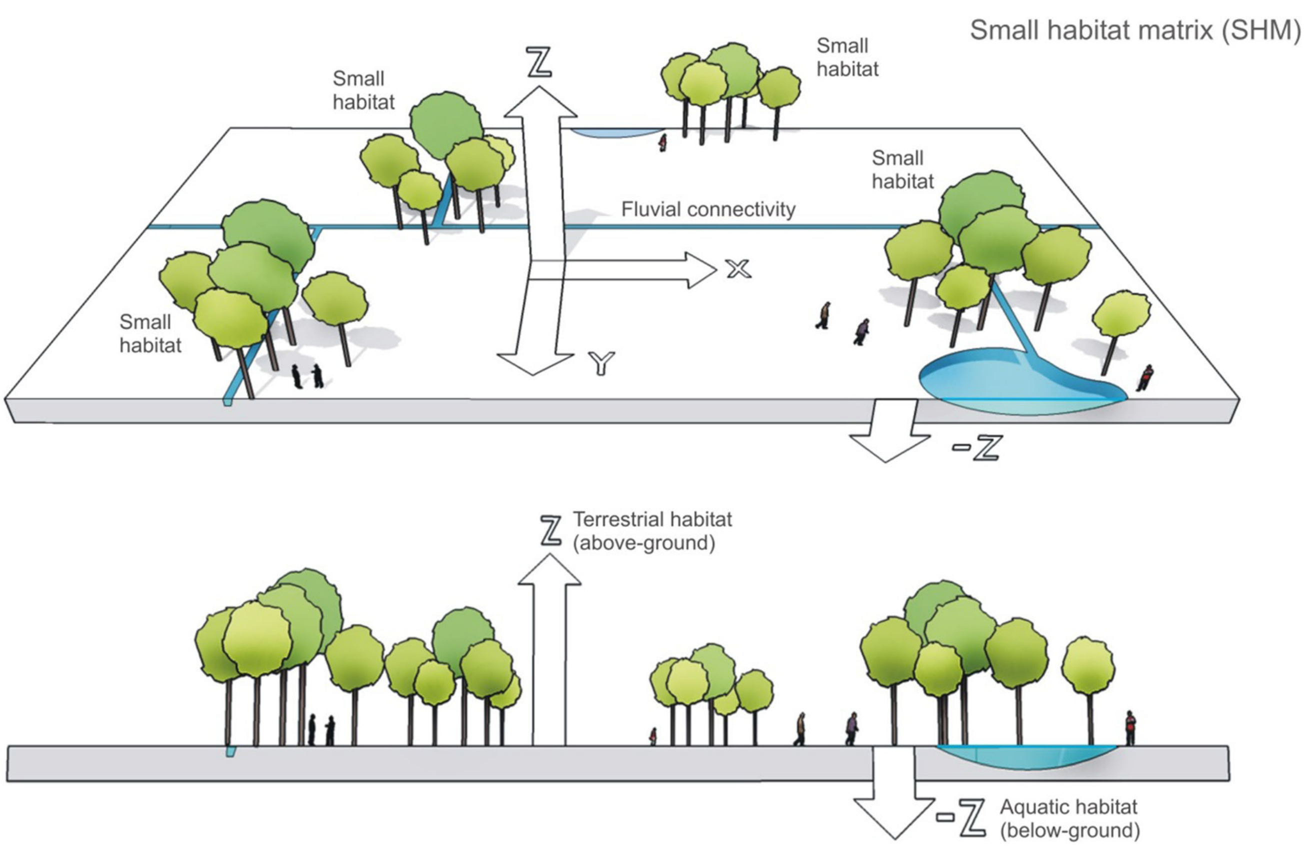


**Fig. 3** An illustration of how the SHM incorporates 3D mosaic complexity for use by a variety of species. Small habitats can also provide ecosystem services in the form of wild food production, raw materials for cultural craft-making and so on, giving additional value to rural people as well

Villaseñor et al. 2017; Koschorreck et al. 2019) thus freshwater habitats are integral to the SHM concept.

In aquatic ecology, species population and food-web vitality is highly dependent on the availability of vertical zonation namely, (1) littoral (shallow-waters receiving sunlight), (2) profundal (deep-waters where sunlight does not penetrate), (3) demersal (waters immediately above benthic), and (4) benthic (pond bottom consisting soil and organic sediments) (Choy et al. 1996; Covich et al. 1999; Reynolds 2006). The SHM concept thereby places a strong emphasis on readapting existing irrigating and drainage channels in the oil palm plantations for providing as full strata of zonation as possible. Some ponds may be artificially constructed to provide deeper and still waters habitat needed by slow moving aquatic species. Additionally, the lentic (still waters habitat; pond) and lotic (flowing waters habitat; irrigation channel) network would be interlinked to mimic a tropical wetland or peat swamp that accommodates increases and decreases in water level during and after heavy rainfall thus supporting typical natural processes in the tropics. The SHM capacity to accommodate water level variance is crucial as research has shown flood pulses have beneficial ecological function to tropical aquatic population diversity and structure (Junk 1999; Agostinho et al. 2001; Amoros and Bornette 2002; Thomaz et al. 2007; Escalera-Vázquez and Zambrano 2010; Ng et al. 2019). With periodic flooding, small lentic habitats are expected to be momentarily reconnected to the waterways thus enabling temporary habitat expansion and biological exchanges between them. Through the SHM capacity building process, the smallholders will be aware that aquatic biodiversity is supposed to be conserved in the channels and ponds. Consequently, they would be more careful with agrochemical applications thus ensuring toxic runoff do not taint waters in the channels and ponds.

To summarize, the multi-strata assembly of small habitats will promote maintenance of various ecological functions and connectivity for aerial, arboreal, terrestrial, amphibious and aquatic biological communities. Therefore, we believe the SHM approach is plausible as, (1) a pre-emptive measure to minimize biodiversity loss in proposed development sites, and (2) a restorative measure to improve biodiversity in a landscape already damaged by anthropogenic change.

## THE EXAMPLE IN SABAH, NORTH BORNEO

The Indo-Malayan region represents a global biodiversity hotspot (Mittermeier et al. 2011). Located in the biogeographically distinct region that straddles the paleogeographic regions of Sundaic and Wallacea, the region hosts the highest proportion of endemic and threatened species globally (Myers et al. 2000; Sodhi et al. 2010). However, globally, nowhere is biodiversity loss more rapid and anthropogenic pressures more severe than in this region (Allan et al. 2019). For example, from 1990 to 2011, approximately 9.5 million ha of land has been converted to oil palm (*Elaeis guineensis*) plantations across Malaysia and Indonesia (Wicke et al. 2011).

The rapid expansion of large oil palm plantations in north Borneo, administratively known as Sabah, Malaysia, over the last few decades has resulted in significant biodiversity declines (Payne 1992; Duckworth et al. 2012; Payne and Davies 2013; Struebig et al. 2015; Abram 2016; Ancrenaz et al. 2016; Goossens et al. 2016; Santika et al. 2017; Morgans et al. 2018). For example, there were about 20,000 orangutans in Sabah in the mid-1980s (Payne 1988). The population, however, was estimated to be about 10,300 orangutans in the latest study (Simon et al. 2019). Besides terrestrial mammals, declines in birds, various insect groups, freshwater aquatic and amphibian species have also been documented (Chung et al. 2000; Brühl and Eltz 2010; Azhar et al. 2011; Gillespie et al. 2012; Faruk et al. 2013; Wilcove et al. 2013; Ng et al. 2017; Scriven et al. 2018). Following decisions by the State government from 1970 up to recent times to liquidate large, old growth forest trees for export income and, crucially, in 1983 to allocate half of Sabah—including all the lowlands—for agricultural expansion, the main drivers of biophysical degradation and habitat fragmentation have been timber extraction followed by land conversion for agro-businesses, mainly oil palm (Koh et al. 2013; Abram 2016; Gaveau et al. 2016; Rosa et al. 2016; Hughes 2017).

Under such severe circumstances, practical innovations to sustain remaining biodiversity are urgently needed in Sabah. Furthermore any mitigation will have important relevance to biodiversity conservation throughout the rapidly developing tropical region globally. Here we propose a specific example of how the SHM approach could be applied in a disturbed landscape dominated by smallholder oil palm plantations in Sabah, located between Tawai and Ulu Sapa Payau (Fig. 4).

In Sabah, a “protected area” is regarded as an area in compliance with IUCN Categories for Protected Areas which is typically forested, legislated or gazetted under State legislation (i.e. Land Ordinance 1930, Forest Enactment 1968, Parks Enactment 1984 or Wildlife Conservation Enactment 1997) for flora and fauna conservation (Payne et al. 2007). Tawai (22 697 ha) and Ulu Sapa Payau (720 ha) Forest Reserves are protected areas located within the 54 million ha Heart of Borneo (HOB) region. The HOB was launched as a cross-national conservation initiative between three countries, Brunei Darussalam, Indonesia and Malaysia, to work together in support of biodiversity conservation island-wide (Van Paddenburg et al. 2012).

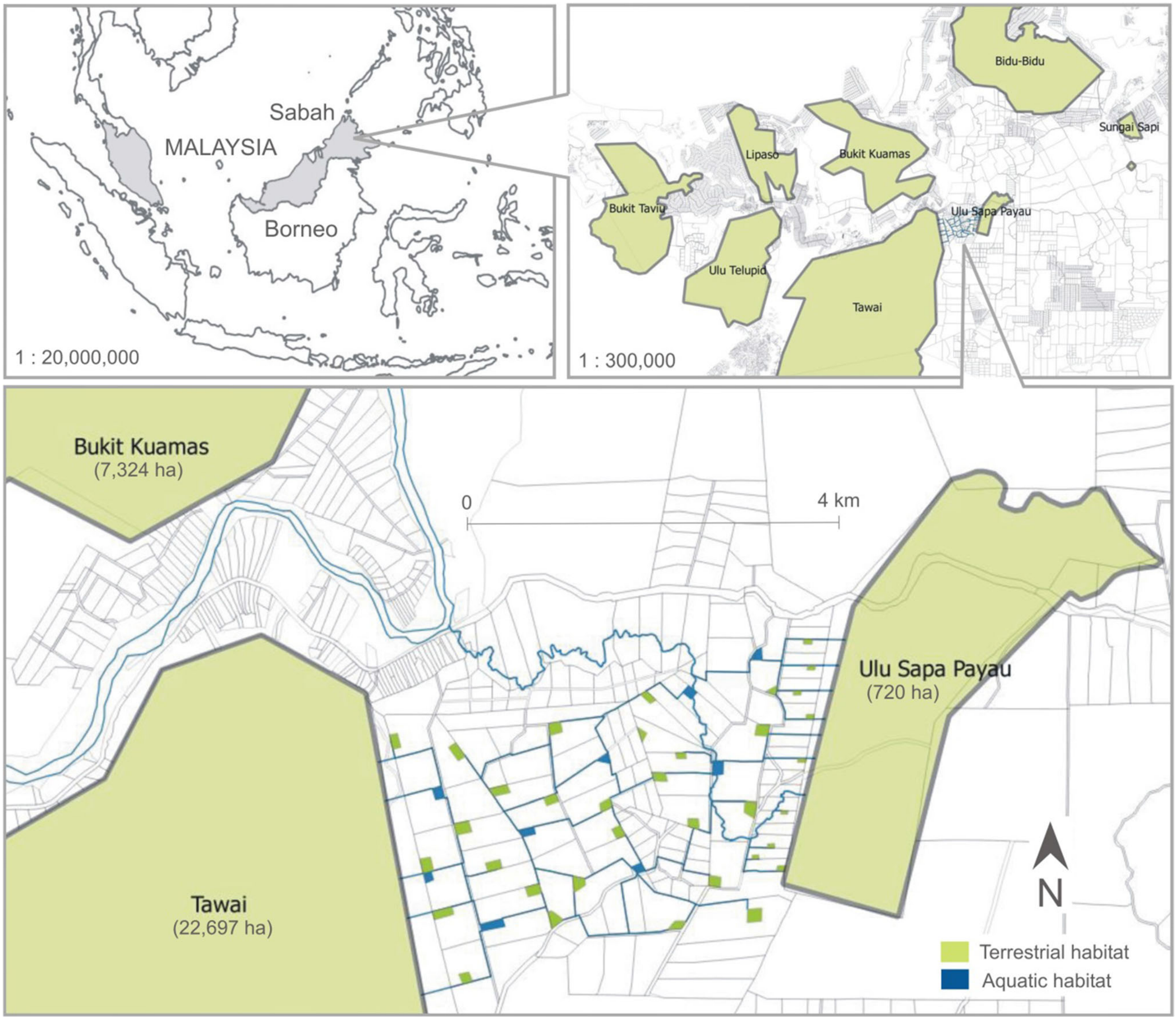


**Fig. 4** An example of a SHM interweaved into private agricultural plots of smallholders between the protected areas of Tawai and Ulu Sapa Payau in Telupid, Sabah. The a priori expectation is that there would be biological exchanges among individuals to support meta-population conservation at the landscape level

The HOB framework is credited with an increase in protected areas from 1 038 890 ha (2014) to 1 386 614 ha (2018) in Sabah (Sabah Forestry Department 2018). Unfortunately, protected areas within the HOB region are highly fragmented. The areas were selected not because of their ability to conserve biodiversity, but because their steep slopes and low fertility soils make them of marginal suitability for agriculture. As in most regions of the world, lowland biodiversity in Sabah has been disproportionately lost to human use.

The small green and blue spaces marked in Fig. 4 are to be restored deliberately with a view to enrich habitat productivity and usefulness for focal species. For example, elephants when not restricted typically move along a pathway of least resistance to reach feeding grounds in a particular season (Alfred et al. 2012; Mills et al. 2018). However, small mammals such as mousedeer (*Tragulus* sp.) that are key prey species may have a more complex route selection to avoid detection by predators that may not necessarily make use of the most obvious routes (Bernard et al. 2019). Since the concept is based on the idea of discontinuous "stepping stones", rather than a continuous corridor, it thereby accentuates the value of small, open and scattered habitats. In so doing, the SHM concept offers not only an enrichment of the overall mosaic complexity, but enhances permeability as well to provide numerous options of benefit to both large and small wildlife and enabling the maintenance of a critical ecological link between Tawai and Ulu Sapa Payau.

Though Da Fonseca and Robinson (1990) defined "small" in the context of biodiversity conservation as an area of less than 80 ha, in the exemplar SHM application in Sabah, "small" will be very much smaller than 80 ha (c. 0.28–2.18 ha as described in the following section). Rather, we follow Rodrigues and Gaston (2001) who suggested the approach of "minimum percentage of area" required to retain biodiversity. From their comprehensive assessment of studies from Europe, North America, Africa and the Neotropics, they found a mean value of 13.6% was needed. As noted earlier, it would be unrealistic to be able to adopt 30% or 50% (Pimm et al. 2018; Dinerstein et al. 2019) as the minimal threshold in a landscape such as our example. Thus, in our proposal outlined in Fig. 4 we adopt the 13.6% threshold as a preliminary basis to configure the matrix and estimate the compensation costs as a starting point. From this, subsequent studies will be possible to test whether this threshold is optimum in this north Borneo context. As more data are accumulated and predictions become more reliable, the most locally relevant threshold percentage or range can be scaled up or down depending on overall biodiversity of the target area, species of most concern and through transparent consultation processes involving all stakeholders (i.e. scientists, NGOs, funder, government agencies and land owners).

## SMALLHOLDER PARTICIPATION AND FINANCIAL IMPLICATION

A central advantage of the SHM concept is not all smallholders operating in the target area are required to spare land to participate for the project to succeed. As illustrated in the example (Fig. 4), the SHM comprises only 35 small terrestrial habitats (i.e. each habitat is 13.6% land spared from each smallholder plot) and nine aquatic habitats with a total area of 39.92 ha (average = 1.14 ha; range = 0.28–2.09 ha) and 12.12 ha (average = 1.35 ha, range = 0.92–2.18 ha), respectively.

The average smallholder plot in Sabah is only three hectares (Wilson et al. 2018; Fig. 5). Therefore, if we assume 13.6% spared for conservation, we are looking at an average of 0.408 ha (or 1 acre) set aside by each participating smallholder in a SHM project. Given an average yield of 17.1 tonnes per hectare per year of fresh fruit bunch (FFB) is the typical output produced by plantations in Sabah (Ministry of Primary Industries 2016), this translates to a loss of 6.97 tonnes of FFB per year.

Ismail et al. (2003) estimated that the production cost of FFB was USD27.95 or RM111.82 (USD1.00 = RM4.00) per tonne in 2003. As true production costs are typically closely guarded trade secrets, insofar as we were not able find any report or paper that reveals more up to date numbers. We therefore adopted an inferred production cost by factoring in a conservative annual inflation rate of 4% to the estimate provided by Ismail et al. (2003). The production cost of FFB was estimated to be USD52.36 or RM209.44 per tonne at the time of this writing. We acknowledge the true production cost may be higher but for our estimation purposes, the USD52.36 amount was applied. Based on the FFB market price of USD104.75 or RM419.00 per tonne (MPOB 2019) and the production cost of USD52.36 or RM209.44 per tonne, a smallholder stands to earn USD52.39 or RM209.56 for each tonne of FFB. Therefore, with 6.97 tonnes of FFB forgone to a SHM project, the smallholder's income is reduced by USD365.16 or RM1460.64 per year (i.e. USD30.43 or RM121.72 per month).

A survey showed that the smallholders of eastern Sabah overall median monthly income was USD375.00 or RM1500.00 (Wilson et al. 2018). Thus, with a reduction of USD30.43 or RM121.72 per month, the estimated median monthly income will be decreased to USD344.57 or RM1378.28 (representing a 8.1% income reduction). In other words, by devoting 13.6% of their land to conservation, a smallholder in this example may expect to lose 8.1% of his or her previous income level. Since the spared land fragments overall in this example total 52.04 ha (terrestrial = 39.92 ha; aquatic = 12.12 ha), that would mean an estimated overall revenue loss or cost of conservation per year of USD47 074.86 or RM188 299.44 collectively incurred by 44 private land owners hypothetically identified in Fig. 4.

While not a trivial sum, another key advantage of our SHM concept is it permits a real tangible cost estimation that can be reliably budgeted for compensation by government, private agencies or any funders in exchange for enhancement of overall ecosystem health and critical ecosystem services. Additionally, this provides a mechanism for landowners to also play an active role in preserving biodiversity heritage in a locally relevant context. The concept can also be extended further to include the potential for additional income generation from sustainable harvest of fish, fruits, medicinal plants, honey, raw materials for cultural craft-making and so on, providing an additional overall benefit to buy-in of the SHM concept in rural communities. These uses can be built-into provide an alternative landscape that may not strictly hedge against FFB market price fluctuation but will indeed provide useful income diversification.

Additionally, how will this SHM concept be funded? Besides conventional funding from green philanthropists and non-governmental organizations (NGOs), green investment funding is an uncharted sector in Southeast

**Fig. 5** The average smallholder plot size is only 3 ha in Sabah, north Borneo

Asia that warrants a closer look. This suggestion is reinforced by Ledford (2012) and Credit Suisse AG, WWF and McKinsey & Company (2014) that recommended any emerging conservation concepts should leverage public and philanthropic capital, namely in the form of environmental bonds, equities or trust funds. Exercised under the widely accepted mitigation hierarchy (Business and Biodiversity Offset Programme 2012), cash flow generated by these mechanisms may be utilised to sustain the conservation initiatives and offer investors the prospect of financial return. However, conservation-based revenue streams may be less competitive when compared to capitalist-based streams (e.g. forest conversion for agriculture). Given the complicated characteristics associated with linking conservation with capitalism, the stakeholders must also be cognisant of the limitations of such mechanisms. High-return oriented investors would not likely be attracted to conservation-based streams.

In Sabah, wealth-preserving investors may be a more suitable target group. These niche investors tend to only expect compensation for inflation but they are particular that cash flow is used prudently for conservation (JPMorgan Chase et al. 2014). Dedicated independent environmental investment fund managers (e.g. Verde Ventures, Eco Enterprises Fund, Root Capital, Freshwater Trust, Lestari Capital) could also be formed by the NGOs, scientist groupings, plantation co-operatives or government agencies to issue green bonds to the public, philanthropists and wealth-preserving investors and work together to support oil palm planter co-operatives participating in the SHM approach. Co-operatives formed to manage local RSPO smallholder group certification programs (RSPO 2010; Brandi et al. 2015) are a good start to explore this concept further. JPMorgan Chase et al. (2014) reported that, despite its relatively small size, the global conservation financing market has grown 26% annually from 2009 to 2013. Strong growth in this sector suggests it is timely to start engaging with the interested parties. Correspondingly, since the SHM concept has a grass-root origin, raising funds directly from the public through various "crowd-funding" platforms is also a possibility especially for start-up or specifically targeted needs.

## IMPLICATION TO GLOBAL CONSERVATION FRAMEWORK

CBD Aichi Biodiversity Target 11 mentions "other effective area-based conservation measures" (OECM) as an in situ option to meet CBD's objectives. OECM is defined as spaces, not classified as protected areas, which are managed for delivering biodiversity conservation, ecosystem services and cultural and spiritual values (IUCN-WCPA 2017). The core difference between protected areas and OECM definition is protected areas are designated with biodiversity conservation as the main objective but

OECMs is also concerned with the outcomes associated to ecosystem services and cultural and spiritual values. At the time of this writing, there is a strong interest in OECM to complement protected areas (Jonas et al. 2017; Gray et al. 2018).

There is additionally some groundwork to recognize territories and areas conserved by indigenous peoples and local communities (abbreviated to 'ICCA') as a component of OECM. We see the latest development as favourable since the indigenous peoples and local smallholders who wish to have some recognition at international level will most probably favour OECM designation for their SHM projects due to its somewhat open and non-binding nature. Unlike protected areas which are typically managed by the government agencies, OECM may be self-managed by the local communities (Mitchell et al. 2018b). This gives them more flexibility and control over land rights. Around the globe, communal conservancies are gaining popularity. For example, communal conservancies of size between 43 to 9120 $km^2$ (mean = 1953 $km^2$) in Namibia are already acting as critical ecological corridors linking the protected areas (Naidoo et al. 2016). In Nepal, community forestry parcels as small as 20 ha are copiously interspersed among the protected areas while yielding socio-economic returns (Wikramanayake et al. 2010). Exactly how the SHM can be integrated into the OECM framework for CBD recognition is a new discipline that remains to be explored and it is open for discussion.

Additionally, the SHM approach may be an answer to the High Conservation Value (HCV) conservation system for buffering areas identified as HCV Management Area (HCVMA) and HCV Area (HCVA). A HCVMA is an area within a landscape management unit for which actions must be taken to enhance an HCV. A HCVA is an area where one or more HCVs are present. Definitions and details on how the HCV system is applied can be found in website operated by HCV Resource Network (www.hcvnetwork.org). The HCV system is globally accepted as the gold standard for biodiversity conservation in monoculture landscapes and it is widely adopted by popular certification schemes such as RSPO® for sustainable palm oil production and FSC® for sustainable timber production. If embraced by the HCV system, SHM can play a prominent and practical role for enriching HCVMA and HCVA.

Landscape ecological degradation and biodiversity loss is occurring faster than any research, policy and legislative tool can keep up with. Conservation need not be entirely focused on big budget, large-scaled global or national top down approaches. Localized bottom-up movements supported by funders who understand the urgency are typically more affordable and potentially more sustainable.

Nevertheless, common to most new ideas, we recognize that the SHM concept is not without flaws. Prior to its implementation, the necessary socio-economic characteristics, biodiversity baselines and ecological risks of the target landscape should be ascertained by specialists. The concept should be exercised with some caution as the outcomes may be different in each locality due to the disparity in anthropogenic and natural settings. We anticipate questions would be directed at its effectiveness (e.g. would it work over long distances between protected areas?) and trials are necessary to test its strengths and weaknesses. However, by sharing the SHM concept widely, we hope biodiversity conservation proponents would also test this concept in other parts of Indo-Malayan region and globally. If a fraction of the global effort and funding for tropical biodiversity research and conservation can be redirected to investigate and support some bottom-up small-scaled emerging ideas like SHM, we believe there is hope for proactive change in conservation outcomes. The emerging findings and new insights of SHM application in different locations and under different circumstances are realistic prospects for furthering discourse and improving our response to the critical question—what more can we do?

## CONCLUSION

We justify and illustrate how small habitats can collectively enrich, connect and buffer larger existing protected areas to enhance biodiversity conservation. By being small-scaled and customisable, the SHM approach is both economically more affordable and well-grounded by design in a local context as the concept sees monoculture land owners as part of the solution rather than separate from it. Though the SHM approach is conceptual and will require trials to ascertain effectiveness under various focal species, socio-economic and regional contexts, we argue that done sensibly, the concept could be applied across monoculture landscapes in tropical developing countries globally. It would also provide key support to established international conservation framework.

Under prevailing space constraints and severe anthropogenic pressures, conservation needs more innovation. In desperate times, the capacity of science for supporting conservation now depends largely on the willingness to explore and the openness to new ideas. We call on fellow scientists, policymakers, funders, NGO activists and pro-environmental land owners to tap into the synergy of small habitats. We argue that no matter how small, these habitats should be included in conservation efforts. We do not dismiss the importance of large protected areas, nor suggest focusing exclusively on the SHM approach. Rather, our goal here is to present the SHM as a promising option. Given the alternative of a “business as usual” approach in conservation, the SHM concept is timely as our opinion it would be a greater mistake to continue the status quo and expect a different result.

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