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PERSPECTIVE

Reconciling farming and wild nature: Integrating human–wildlife coexistence into the land-sharing and land-sparing framework

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Abstract Land has traditionally been spared to protect biodiversity; however, this approach has not succeeded by itself and requires a complementary strategy in human-dominated landscapes: land-sharing. Human–wildlife conflicts are rampant in a land-sharing context where wildlife co-occur with crops or livestock, but whose resulting interactions adversely affect the wellbeing of land owners, ultimately impeding coexistence. Therefore, true land-sharing only works if coexistence is also considered an end goal. We reviewed the literature on land-sharing and found that conflicts have not yet found their way into the land-sharing/sparing framework, with wildlife and humans co-occurring without coexisting in a dynamic process. To successfully implement a land-sharing approach, we must first acknowledge our failure to integrate the body of work on human–wildlife conflicts into the framework and work to implement multidisciplinary approaches from the ecological, economic, and sociological sciences to overcome and prevent conflicts. We suggest the use of Conflict Transformation by means of the Levels of Conflict Model to perceive both visible and deep-rooted causes of conflicts as opportunities to create problem-solving dynamics in affected socio-ecological landscapes. Reconciling farming and nature is possible by aiming for a transition to landscapes that truly share space by virtue of coexistence.

Keywords Coexistence · Conflict reconciliation · Conflict resolution · Human-dominated landscapes · Land-sharing · Wildlife-friendly farming

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INTRODUCTION

Emerging approaches that integrate biodiversity conservation and the production of goods through wildlife-friendly farming have yet to consider potential human–wildlife conflicts as a factor influencing conservation outside protected areas. Habitat loss is the leading cause behind the global decline of biodiversity (Sala et al. 2000). Traditional strategies for biodiversity conservation have relied on sparing land for nature, segregating human activities from remnants of wilderness to avoid further human intervention. However, while protected areas are certainly necessary, they are ultimately insufficient and biodiversity loss has not declined (Butchart et al. 2010; Mora and Sale 2011). A large fraction of species and ecosystems are not covered by protected areas, which further do not necessarily offer surfaces large enough to sustain viable populations of most large-bodied species (Redford and Robinson 1991; Venter et al. 2014). Furthermore, the global siting of protected areas has so far been biased towards areas with lower maintenance costs than those with greater biodiversity representativeness (Venter et al. 2014). International collaboration has remained minimal, and lack of economic resources along with governance challenges result in many "paper parks", especially in less-wealthy countries (Di Minin and Toivonen 2015). Hence, wildlife is expected to survive beyond protected areas, and given these limitations, complementary approaches, such as wildlife-friendly farming, are required. Wildlife-friendly farming, or land-sharing between wildlife and agriculture, demands more area to satisfy production targets, but presumably allows wildlife to survive within these lands (Green et al. 2005; Fischer et al. 2008). Here, we aim to position the issue of coexistence by means of conflict reconciliation as necessary for land-sharing to work.

CONFLICTS AND THE FOOD-BIODIVERSITY TRADEOFF

The need to rely on unprotected areas for wildlife conservation is reflected by the Aichi Biodiversity Target 7 of the Convention on Biological Diversity, which expresses the need of providing the conditions required for the compatibility between biological diversity and the production of goods and services for human society on the same land, demanding that "By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity" (Convention on Biological Diversity 2010). Also, there are cases in which sparing land might not be a realistic option attending to long-term disturbances that have reduced natural areas to a minimum extent, below that which is required for sustaining minimum viable populations of wildlife, such as in El Salvador whose largest protected area cannot sustain populations of 87% of its carnivores (Crespin and García-Villalta 2014). Under these scenarios, nations where natural area is diminished may find that protecting wildlife with a land-sharing approach might be the most viable option.

Land-sparing remains a cornerstone for conserving global biodiversity (DeFries et al. 2005). However, carnivore home ranges are large, placing them in dire straits when confronted with restricted amounts of habitat such as the ones provided by protected areas and thus are prime candidates to inhabit unprotected lands (Woodroffe and Ginsberg 1998), as expected in Aichi Biodiversity Target 7. Moreover, land-sharing can result in conflicts as nature spills over unto farmland, exemplified by carnivores that permeate through the borders between protected areas and farmsteads conspicuously more so than other taxa, directly affecting human livelihood when the production of livestock is in contention, such as in buffer zones around protected areas, where human–wildlife conflict is usually exacerbated (Rao et al. 2002; Patterson et al. 2004; Wang and MacDonald 2006).

The land-sparing/sharing framework has so far ignored potential ill consequences for biodiversity, carnivores included. Such consequences are due to the subsequent interactions between humans and wildlife that generally result in negative outcomes, such as injury or loss of life for humans and wildlife, crop damage, and livestock predation (Baker et al. 2008). Ultimately, these losses render the need to conserve species and the protection of human interests in the same area to be at odds with each other in places where compensation schemes fail, or cultural norms do not accept any loss to wildlife (Woodroffe et al. 2005).

SHARING LAND: CONFLICT LADEN CO-OCCURRENCE OR PEACEFUL COEXISTENCE?

Despite the fact that achieving coexistence between human activities and wildlife outside protected areas is a requirement for land-sharing to be effective, conflicts have been a neglected component of such an approach. We support this claim with a literature review which we performed by collating and reviewing scientific papers up to September 2017 that dealt with land-sharing. We first targeted scientific articles registered on the Thomson Reuters Web of Science that cite Green et al. (2005), which formalized the land-sharing/sparing model (see also Law and Wilson (2015)). We then included articles on land-sharing which may not have cited Green et al. (2005), beginning with a search string using the keywords "land sharing OR wildlife friendly", following up with a second search by adding "AND conflict" to the string. Several filtering steps come into place. First, we excluded all articles that do not explicitly deal with land-sharing. Secondly, we identified (a) articles that mentioned conservation conflicts in some capacity even when not dealing with them, (b) studies which held any aspect of conservation conflicts as their aim. Finally, (c) we assessed whether conflict resolution is suggested in each article as necessary for a shared land. We provide a list of the assessed studies as Supplementary Information (Table S1).

We define conservation conflicts as opposing interests that result from the need of an affected party to eliminate biodiversity impacts, the negative effects of biodiversity on human wellbeing or vice versa (sensu Young et al. 2010). Conflicts generated at the ecosystem level generally focus around threats, such as habitat loss and the loss of ecological functions, and can be approached by land-use strategies such as the land-sharing/sparing model. Conflicts that specifically occur at the community level have classically been perceived as human–wildlife conflicts, focusing on the impacts of single species on human livelihoods or of human actions on specific species populations. It is these interactions that occur between specific species and humans in agro-productive systems that emerge once land is shared. This results in agricultural stakeholders wanting to satisfy their interests by eliminating their perceived loss, while conservation needs demand the protection of the interacting species, forming conflicting interests between the wellbeing of both humans and wildlife. Therefore, there is an urgent need to determine if and how the land-sharing literature has included conservation conflicts as an article's aim, as part of the discussion or even gone so far as to offer possible methods of resolution.

Our literature review reveals that conflict resolution and achieving coexistence are not currently considered in research concerning land-sharing. We retrieved 210 articles dealing with land-sharing, and although 35 mention conflicts in some capacity, and one handles identifying conservation conflicts as an aim, none pertain to resolving conflicts and achieving coexistence as necessary to sharing land (Fig. 1). After more than a decade since the publication of the land-sparing/sharing model (Green et al. 2005), which also does not include conflict resolution as a prerequisite, the situation remains unchanged. The expanding literature has so far managed conflicts separately from land-sharing or land-sparing, and at most, has treated conflicts as areas of high biodiversity and potential high agricultural yield juxtaposition (Baudron and Giller 2014; Shackleford et al. 2015). Research so far has overlooked the resulting conflicts and their resolution.

Advances in ecological research have skimmed just shy of integrating conflict resolution into land-sharing since the model's inception. Mattison and Norris (2005) pushed for a holistic approach towards the effects of land-use change on biodiversity and a context-dependent decision towards sharing or sparing land. Recently, Fischer et al. (2017) shifted the emphasis of agriculture from yield-only towards food security which when coupled with the state of biodiversity, means managing socio-ecological dynamics. Both mention conflicts pertaining to land use: potential gains for either conservation or social purposes, and impingements on social rights or biodiversity wellbeing. When considering research on conflict-prone species or systems, we have also missed the mark. For example, Lerner et al. (2017) discuss reconciling food production and conservation in relation to cattle production and include land-sharing as a potential fostering of ecosystem services but obviate the possible presence of predators, such as carnivores, that might prey on cattle and cause potential conflicts. Bouyer et al. (2015) implicitly integrate coexistence into the land-sharing strategy by assessing the tolerance of the Eurasian lynx (*Lynx lynx*) to use shared lands, finding that it has the potential to inhabit shared lands if tolerated by people. Even when pondering the beneficial consequences of land-sharing such as for use in biological corridors for carnivores, potential sources for conflicts have been overlooked (see Crespin and García-Villalta 2014). Although 17% of published articles on land-sharing mention conflicts, only one includes conflicts as part of its aim. Shackelford et al. (2015) identified conservation conflicts in agricultural contexts as places of juxtaposition between food production and wildlife conservation. All in all, no article outright suggests the resolution of a conflict in a land-sharing context.

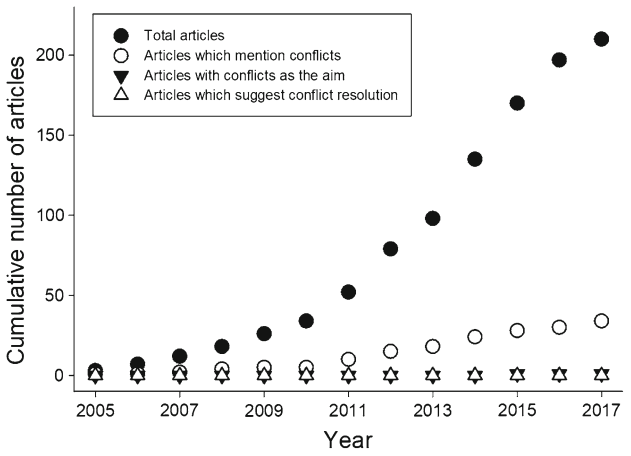

Fig. 1 Cumulative number of articles that deal with land-sharing or land-sparing (filled circle), mention conflicts in some capacity (open circle), identify conservation conflicts as an aim (filled inverted triangle), or suggest conflict resolution and coexistence as necessary to sharing land (open triangle)

DISCUSSION

Why are land-sharing and conflicts uncoupled?

Demand for food production has risen consistently as global human population has grown, and so have its impacts on biodiversity, giving way to the two competing solutions, sparing land by intensifying production, or wildlife-friendly farming but decreasing yield (Green et al. 2005). The research that followed focused mainly on comparing the effectiveness between both strategies regarding biodiversity, with land-sparing frequently considered a more promising option, *ceteris paribus*, although authors generally point out that their results are context dependent (Phalan et al. 2011; Hulme et al. 2013). All efforts so far have been directed towards determining whether one strategy is superior to the other, with little regard to the consequences of implementing either. The most likely cause behind conflicts having been passed over in land-sharing is precisely the context in which experiments have so far been immersed. Notably, other dimensions besides ecological context are missing from the sparing versus sharing debate, such as governance, where policy and implementation stakeholders prefer one strategy over the other (sparing and sharing, respectively), indicating that these decisions should be positioned in a socio-ecological context (Jiren et al. 2017).

Until now, coexistence in a shared-land scenario has been taken as a given, which should not be surprising. Most research on land-sharing has centered around birds, butterflies, ants, other arthropods, trees, and other plants (Balmford et al. 2015; Goulart et al. 2016), which are taxa commonly not engaged in human–wildlife conflicts, while

the most well-known cases worldwide involve large mammalian carnivores (Graham et al. 2005). The majority of assessed agro-productive systems in land-sharing are croplands and agroforestry systems (Goulart et al. 2016). Evidently, conflict-prone taxa and systems, such as carnivores and animal husbandry, have not been as well researched in the land-sharing context. Both make tough models to work with. Carnivores generally have large home ranges and tend to be hard to track. Livestock also move about, while keeping count and determining cause of death, especially when extensively managed, may not always be possible and lead to self-report bias when depending on stakeholder data. Avoiding conflict-prone species in the name of feasibility may explain why conflicts, their resolution, and coexistence in general, have been neglected by the land-sharing literature. On the other hand, simple oversight by researcher bias towards particular taxa may be to blame on behalf of researchers of land-use strategies, while human–wildlife conflict specialists with a more focused mindset on explaining livestock predation might overlook land-use strategies such as land-sharing. Basing the selection of the biodiversity component and agro-productive system assessed on ease of measurement has led to addressing biodiversity composition but forfeiting the inclusion of structure and function components, from which interactions such as predation of crops and livestock are derived.

Integrating conflicts and the land-sharing approach

Acknowledging the failure to unify the body of work on human–wildlife conflicts with the coexistence that is required to successfully implement the land-sharing approach is the first step to overcoming it. From an ecological standpoint, framing interactions between humans and wildlife by applying community theory to human-dominated landscapes can help describe the problem and pinpoint explicit factors available for future research (Chapron and López-Bao 2016). If farmland is to be shared, a minimum level of predation is to be expected even after reducing, mitigating, or compensating predation. Therefore, to avoid the persecution of wildlife, a minimum level of tolerance must exist on behalf of stakeholders (Dickman et al. 2011; Oriol-Cotterill et al. 2015). While compensation schemes may ease immediate monetary losses, this minimum threshold of tolerance may be hard to determine due to the non-monetary losses accrued by farmers, such as the loss of selected breeds, their genetic characteristics, potential gain in the form of future cohorts, and the time and energy invested in them. In fact, while most affected stakeholders approve compensation as a management strategy, compensation does not always increase tolerance (Naughton-Treves et al. 2003). Also, top-down strategies emanating from management may be perceived as disempowerment by local communities, creating enmity that is then directed towards wildlife, ultimately lowering tolerance (Dorresteijn et al. 2016). Indeed, beyond the visible impacts of direct injury and economic losses, the hidden impacts of human–wildlife conflicts in general are poorly understood and often ignored, residing in the form of psychological trauma, the interruption of daily living activities, and unfulfilled food security (Barua et al. 2013).

Resolving conservation conflicts in a land-sharing context requires understanding why conflicts arise in the first place. The ecology and underlying biological causes behind the emergence of conflicting interests in shared lands, loss of crops, and livestock by biodiversity can be generalized to whenever wildlife co-occurs with human-used resources, but reconciling interested parties for any conflict will require addressing its unique socio-economic context (Young et al. 2010).

Incentives such as profits, can cause changes in land uses that threaten conservation interests (Hanley 2015). Unpolished and unclear property rights can also lead to conflicting interests, such as in scenarios reminiscent of the *Tragedy of the Commons* (Hardin 1968), where everyone may have the incentive to add a small increase to their own profit. Translating the tragedy to conflicts, wildlife is interpreted as the common good. Egotistical sentiments and actions, such as thinking that killing just those individuals that affect one's own livestock should not inflict major damage on wildlife, may be mirrored by multiple stakeholders of a landscape's wildlife, from which large-scale problems may ensue (Hanley 2015). Market failures may also cause conflicts when biodiversity as a public good, be it forest cover or wildlife, lacks incentive to be maintained on farmed land, particularly when the market incentivizes activities that maximize individual gains (Hanley et al. 2007). Lastly, the market also fails when externalities emerge, such as the unforeseen consequences from eliminating the wildlife that prey on livestock or crop which may trigger loss of ecological interactions that lack redundancy, and result in other species populations or ecosystem functions ultimately being affected in tandem (Hanley 2015).

Profit incentives, misused property rights, and market failures need not remain a hindrance to coexistence. Incentives can be shifted towards conservation milestones, since outcome-based biodiversity payments for improving on private lands can be successful (McDonald et al. 2018). This incentive realignment means rewarding private landowners for environmental benefits, such as biodiversity and ecosystem services provided on their land, but also including negative incentives for actions against conservation targets and interfering with services, such as

taxation for persecution of protected carnivores or constricting waterways for communities downstream (Jack et al. 2008; Hanley 2015). Property rights can be arranged so as to regulate access to the commons, whereby rules and customs are developed from within communities by all those affected at local levels, and the establishment of multiple layers of nested communities coming together at larger scales to govern the complete system (Ostrom 1990). Market failures can be solved. For example, the creation of positive incentives can grant ecological benefits that can even out against profits from individual gains. Externalities affecting services enjoyed by others in or outside the community can be penalized.

Biodiversity inhabiting stakeholders' lands may not necessarily threaten their livelihoods, but the mere perception that a threat exists marks wildlife as detrimental to human wellbeing, generating conflicts all the same whether or not losses of crops or livestock actually occur (Dickman 2010). Therefore, while ecological approaches can determine whether arguments have empirical basis and offer experimental evidence of mitigation strategies, a combination of approaches from the social sciences (such as strategies emanating from the economic or sociological spectrums) can manage the conciliation of opposing interests in situations where conflicts cannot be resolved by successful mitigation strategies, or even when no biological basis is found. Admittedly, failures in conservation actions are often due to overlooking the historical and cultural levels in social conflicts that underlie conservation success (Madden 2004).

To summarize, we find multiple causes of problems for stakeholders whose short-term solutions clearly oppose conservation aims, leading to conflicts (Table 1). However, root causes are difficult to discern, since they underlie problems that when taken at face value may be overlooked. These can often be tightly linked to the hidden impacts of human–wildlife conflicts (Barua et al. 2013). Proximate causes of conflicts may be the immediate problems behind them, but root causes are distal causes that must be understood to explain a conflict and managed to prevent further conflicts from breaking out. For these reasons, as a complementary tool to ecological approaches, we submit to the land-sharing enterprise the use of Conservation Conflict Transformation (sensu Madden and McQuinn 2014), specifically, the Levels of Conflict model (Canadian Institute for Conflict Resolution 2000). Because managing tangible ecological variables to untangle problems that generate conflicts may not always resolve competing interests, the existence of root causes to those problems and how they may be approached must be considered in all attempted land-sharing strategies.

Reconciliation of farming and wild nature by Conflict Transformation

Conflict Transformation perceives disputes and problems as opportunities to enact change in social systems and seeks to manage conflicts in such a way as to create problem-solving dynamics (Lederach 2003). Conflict Transformation creates these dynamics by focusing on relations in a systemic context, working to reconcile negative relations by developing processes that establish conditions where all sides can understand each other, essentially moving from an antagonistic mentality to a collaborative "one team" mentality (Madden and McQuinn 2014).

The Levels of Conflict model allows assessing the complexity of a conflict in distinct settings by describing conflicts in three levels along with their matching processes of transformation which are used to address present and future conflicts (Fig. 2). Disputes are observable problems that may reach a *settlement*. Strategies based on ecological theory are capable of settling disputes. When disputes remain unsettled and enough frustrations and emotional reactions build up, an underlying conflict emerges, granting complexity to new disputes that need *resolution*. Lastly,

Table 1 Typification of conservation conflicts. Root causes, such as social identity needs and rights violations, may form distal drivers for resurging problems that may or may not have a biological basis, whose short-term solutions for stakeholders directly conflict with conservation aims. These are mere stereotypes of problems to exemplify the complexity of each case

Drivers	Problem	Biological basis	Solution	Conflicting interests
Social identity needs	Livestock predation	Carnivore prey switching for net gain	Persecution	Livestock rancher vs carnivore conservation
Unfulfilled food security	Crop raiding	Herbivore optimal foraging	Persecution	Subsistence farming vs herbivore conservation
Perception of rights violation	Poaching	None	Armed conflicts	Economic necessities vs park functioning
Increase in global food and commodity consumption	Land-use change	Habitat and protected area allocation	Land-sparing/sharing	Land development vs habitat conservation

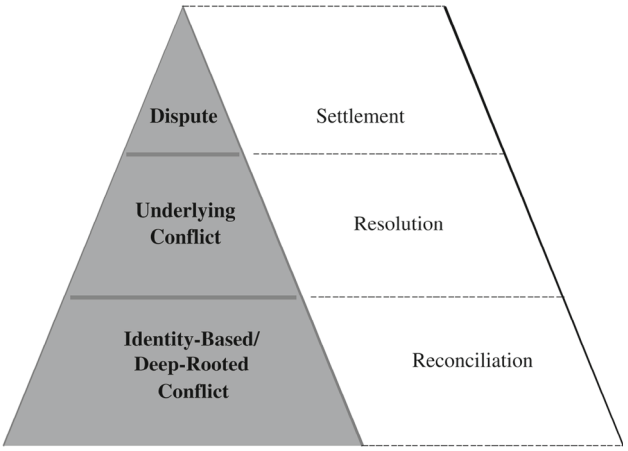

Fig. 2 Levels of conflict model. Conservation conflicts are classified according to complexity and intensity occurring at three levels, with conflicts of higher concern owing to a deeper and more established section of the pyramid. Matching processes used to address conflicts are next to each level. *Source* adapted by Madden and McQuinn (2014) from the Canadian Institute for Conflict Resolution (2000)

when prejudices take root and assumptions are rooted deep in a group's identity, long-lasting processes of *reconciliation* may be needed. This seems to be the norm, as most conservation conflicts exist in parallel with social and usually deeper interactions between groups of people, instead of between people and wildlife. The deep-rooted issue may not be related at all to wildlife and instead only pertain to threatening a group's identity. The same can be said for future shared lands. Newly formed productive landscapes integrating wildlife conservation might also benefit from a Conflict Transformation approach. Conflicts arising in a land-sharing context may be quickly settled, carefully resolved, or might even be a symbolic representation of a deeper conflict that will require conservation professionals to align with social scientists to help reconcile interests that conflict with the occurrence of wildlife on productive lands (Dickman 2010).

Madden and McQuinn (2014) identify the limitations facing current approaches to conflict management, coinciding with our observations from the land-sharing literature. Since conservation emerges from biology, professionals can be biased towards researching wild nature and not humans, resulting in a failure to account for the historical drivers of social conflict in a landscape and therefore do not address social–psychological needs during the formulation of solutions (Madden and McQuinn 2014). In essence, only by considering all dimensions involved in the birth a conflict, will it be possible to design strategies that counterattack problems at all levels involved, from addressing identity needs at deep-rooted levels to managing more mechanistic and biological factors to aid in settling disputes.

Multidisciplinary approaches will be key to reconciling farming with nature. It is up to a combination of ecology, economy, and sociology to settle the myriad disputes that will surface by integrating multiple uses of land with wildlife conservation before underlying conflicts can form. Extending land-sharing to already occupied landscapes for productive purposes will likely necessitate resolving underlying conflicts and reconciling deep-rooted and identity-based conflicts. Having established an agroecological landscape, and once land-sharing can be said to have been attained through processes of reconciliation, one must remain vigilant to avoid further conflicts from taking root. In fact, conflicts are fundamental to society and cannot be viewed as a single event (Lederach 2003), therefore deep-rooted conflicts should be considered an ever-looming threat that must be continually be kept at bay. Disputes about biodiversity should be settled quickly and attention should be paid to frustrations that may accumulate by repeated engagements with wildlife to avoid underlying conflicts caused by affected emotions. Once emotions are affected, the socio-ecological system is once again vulnerable to prejudices and assumptions taking hold. Sharing land with nature will require establishing a dynamic system capable of adapting to new disputes constantly and eschewing the creation of "sides" without fail by making sure that all involved understand the whole system, where production and biodiversity work towards the same goal of sustainability.

CONCLUSION

To be ecologically and economically sustainable, land-sharing needs more than conflict resolution, it needs reconciliation. Beyond biological and managerial aspects impinging upon livestock predation, which might resolve conflicts, addressing deep-rooted beliefs about wild animals that may even form identity needs is required to achieve reconciliation between humans and wildlife, fostering a landscape of coexistence between wildlife and humans, minimizing losses and agreeing on acceptable thresholds of loss on both fronts (Oriol-Cotterill et al. 2015). Despite conflict reconciliation and the resulting coexistence being tantamount to land-sharing, so far human–wildlife conflicts have not yet found their way into the land-sharing/sparing framework, and until they do, land-sharing strategies face the danger of becoming secret wars: wildlife and humans co-occurring, but not coexisting. A contested land is a land not shared, a scenario where all, biodiversity and humans, lose.

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