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Anticipated impacts of achieving SDG targets on forests - a review

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ABSTRACT

Sustainable development requires knowledge of trade-offs and synergies between environmental and non-environmental goals and targets. Understanding the ways in which positive progress in matters of development not directly concerned with the environment can affect the natural environment, whether for better or for worse, can allow policymakers and development agencies to avoid the negative impacts of their actions, while capitalising on mutually beneficial opportunities. Through a systematic review of the literature, we consider the impacts of UN Sustainable Development Goal (SDG) targets on forest ecosystems, and identify 63 targets associated with potentially beneficial, damaging or mixed (i.e. damaging and/or beneficial depending on context or location) impacts. Types of impact are not uniform within SDGs, nor necessarily within individual targets. Targets relating to energy and infrastructure are among the most damaging and best studied, while targets expected to potentially result in beneficial outcomes, typically associated with social progress and well-being, have been investigated to a much lesser degree, especially in the context of external interventions. Thirty-eight targets have some variation in the direction of their impacts (i.e. at least one record with mixed impacts, or two or more records with different directions), suggesting the potential to achieve beneficial over damaging impacts in many cases. We provide illustrative examples of a range of impacts and use our findings to provide recommendations for researchers, development agencies and policymakers.

1. Introduction

Achieving universal well-being and prosperity whilst conserving the natural environment is the central tenet of sustainable development. To best achieve this, policymakers and development agencies must understand how certain aspects of development present trade-offs that can undermine efforts to conserve biodiversity and ecosystem services, while conversely, other aspects can result in synergies that benefit the environment or facilitate its conservation. The 17 United Nations (UN) Sustainable Development Goals (SDGs) (Fig. 1) and their 169 constituent targets, which comprise a detailed, sector-specific breakdown of the current development agenda, provide a policy-relevant framework through which to explore such complexities. Indeed, shortly after publication of the SDGs, Nilsson et al. (2016) called for researchers and practitioners to identify and quantify the relationships between SDGs, recognising this as an important first step towards maximizing positive interactions and minimizing negative ones. A number of research efforts have since responded to this call, including Pradhan et al. (2017), who assessed synergies and trade-offs between SDGs at the level of goal, and Scherer et al. (2018), who analyse interactions between selected social and environmental goals. In the following review we aim to contribute to this growing field of research by assessing the impacts of meeting non-

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environmental SDG targets on forest ecosystems.

Forests are of particular interest in this regard as they support a significant proportion of global terrestrial biodiversity and provide important climatic and hydrological regulating services. Globally, around 1.6 billion people live in close proximity to forests (Newton et al. 2020), and hundreds of millions of these depend on forest products, in the form of fuel, food and timber, help meet their needs (FAO 2018). Although the roles that forests can play in helping to achieve non-environmental targets are relatively well understood (FAO 2018; Scharlemann et al. 2016), this is often less so for interactions occurring in the opposite direction. Katila et al. (2019) describe impacts of the SDGs on both forests and people and how these impacts may, in turn, enhance or undermine the contributions of forests to climate and development, but a systematic review of the literature on SDG targets is missing. To address this, our approach focused on two main questions: (i) is there published literature that suggests or demonstrates that achieving a given target can have implications for forests?; and (ii) what is the strength of this evidence? We use our findings to characterize identified impacts, making comparisons both between and within individual goals and targets. We give consideration to a subset of our data that focuses on external development interventions (i.e. governments, development agencies or NGOs seeking to achieve one or more SDG targets), which represent intentional (and therefore indicative) efforts to achieve development objectives. We also describe impacts on forests that arise via interactions between two or more targets, providing illustrative examples of these and discussing their importance in future research efforts. Finally, we summarise the key implications of our findings.

2. Methods: Identifying the impacts of SDG targets on forests

We conducted a systematic search of three literature databases (Web of Science, CAB Abstracts and Google Scholar) to identify peer-reviewed and grey literature relevant to our questions (details of our search protocol and other methods are provided in the Appendix A). Searches were based on 489 key words and phrases taken from the SDG targets and indicators developed by the Inter-Agency and Expert Group in Sustainable Development Goal Indicators (2016). Searches did not include terms from SDGs considered environmental (Goals 12, 13, 14 and 15) (Bengtsson et al. 2018; Waage et al. 2015), nor from targets from the remaining goals that have an environmental focus (Fig. 2a). We also did not include terms from Goal 17, which is considered 'cross-cutting' in nature (i.e. containing elements pertaining to all other goals (Waage et al. 2015)). Consequently, our investigation focused on a total of 104

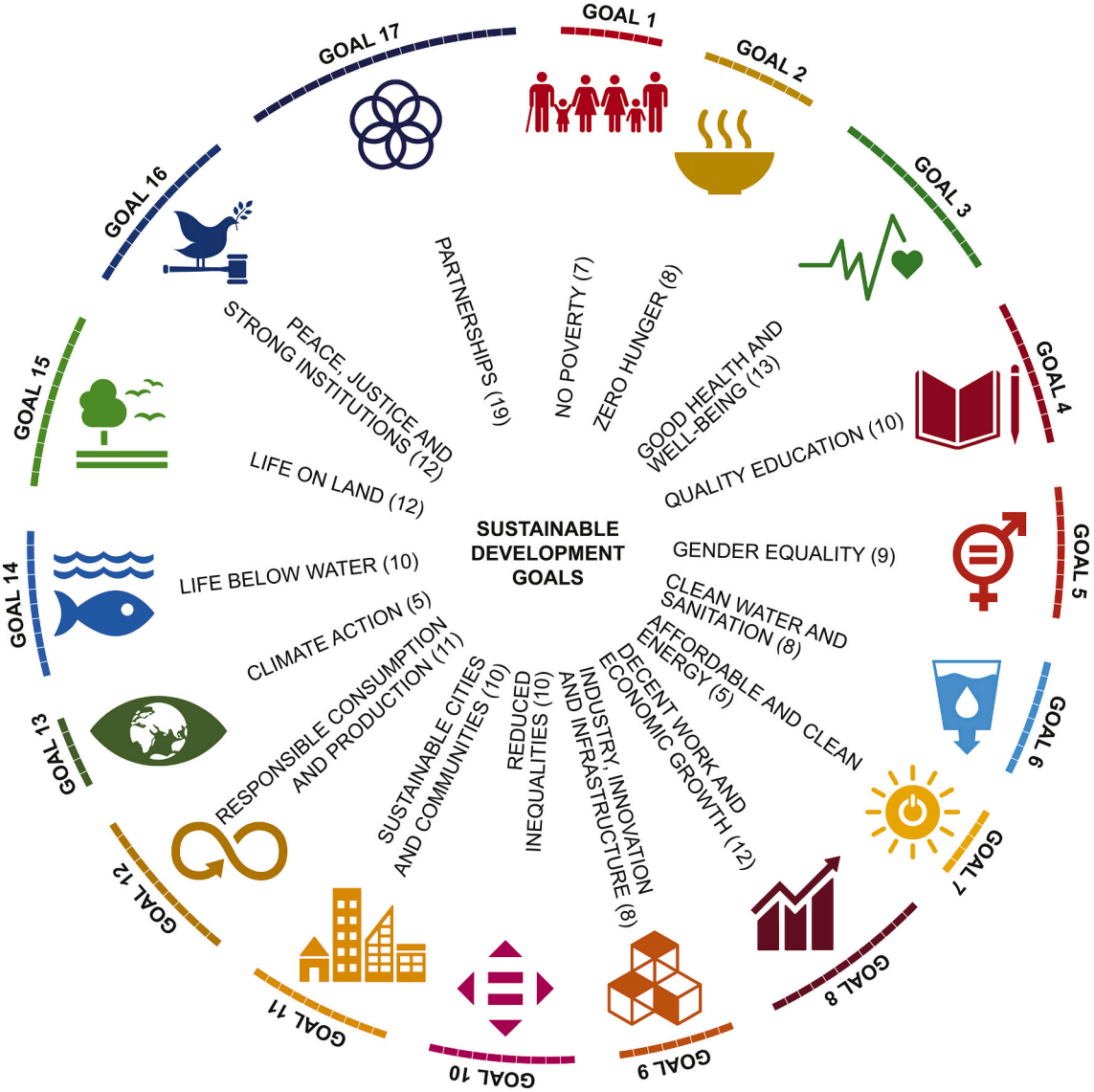

Fig. 1. The 17 UN Sustainable Development Goals (SDGs). Numbers following goal names indicate numbers of targets for each.

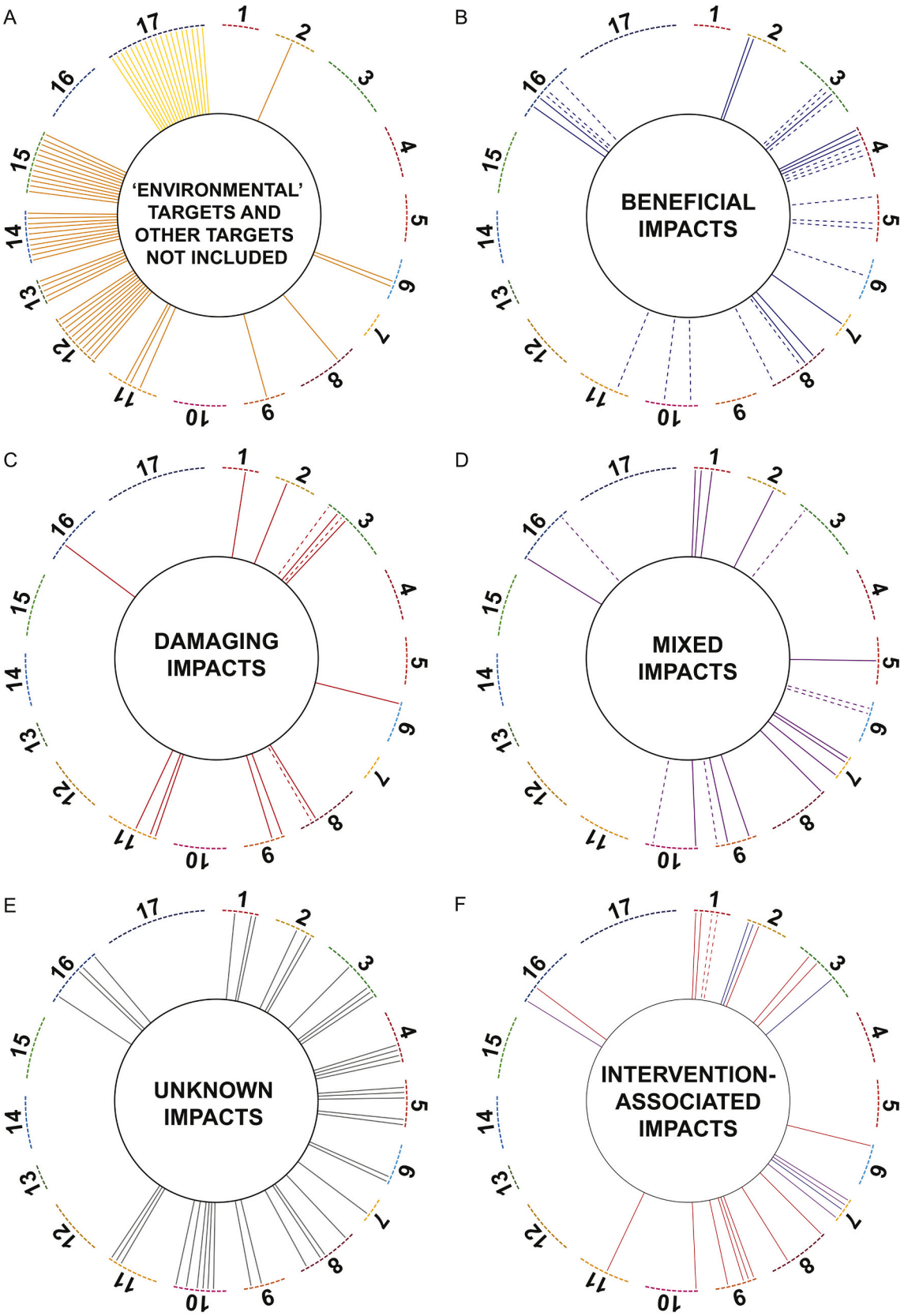

Fig. 2. Forest impacts associated with each of the 169 SDG targets. In 1a orange lines are 'environmental targets' and yellow lines are 'cross-cutting'. Solid and dashed lines indicate impacts with and without a confidence score of greater than or equal to one, respectively. 1f shows intervention-associated impacts only, using the same colour schemes for beneficial, damaging and mixed impacts as in other diagrams. Targets are ordered clockwise within each SDG. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

of the 169 SDG targets.

We focused on natural forests only, and did not include any work focusing on forest plantations, agroforestry plots or altered habitats. We otherwise used a broad definition of forest, which extends to include woodlands and mangroves. While we endeavoured to follow the established definition of a forest developed and used by the Food and Agriculture Organization of the United Nations (i.e. a tree canopy cover of >10%, an area > 0.5 ha and a minimum height of ≥5 m, but noting that their definition includes plantations (MacDicken 2013)), in practice few papers give such specific details, and so a certain degree of subjectivity was required. Nevertheless, literature for which the term forest was ambiguous and did not suggest that the habitat under investigation was both natural and an appropriate structure were excluded. The definition of impacts on forests (hereafter 'impacts') was left intentionally broad, so as to capture a wide range of interactions. Types of impact included any changes in forest size, structure or composition (including changes in non-plant taxa), including changes in the rate of change of any of the above, as well as changes in policy, protection status or human behaviours with implications for forests. Based on the above, the 'direction' of each impact recorded was classified as either 'damaging', 'beneficial' or 'mixed' (i.e. damaging and/or beneficial depending on context or location).

Impacts were also scored according to their associated confidence, as follows: Impacts based on speculative theories or notable assumptions (e.g. that an acknowledged driver of forest loss would result in forest gains if reversed), as well as changes in policy or human behaviour that were expected (but had not been demonstrated) to affect forests, were considered *low confidence*; impacts based on first-hand evidence, but with notable confounding factors, and impacts based on qualitative reports or proxy measures of forest change (e.g. quantity of fuelwood extracted) were considered *fair confidence*; and impacts based on direct observation of forest change arising from progress made towards a given target were considered *high confidence*.

For comparative and graphical purposes, each impact was assigned a score based on its confidence rating, with low, fair and high confidence impacts scoring 0.01, 0.1 or 1, respectively. For each target, confidence scores for each of beneficial, mixed or damaging impacts were summed, and the direction of those impact(s) with the highest level of confidence (within at least one order of magnitude) used as the final impact category. In cases where the best evidence comprised two or more impacts with different directions and the same level of confidence, the category of 'mixed' was given.

While conducting our searches we earmarked papers that made reference to impacts associated with external interventions, allowing these records to be analysed as a standalone subset and compared with the full dataset. We also kept notes of any impacts encountered that involved interactions between two or more SDG targets, although this last component cannot be considered exhaustive.

3. Results and discussion

From a total of 466 sources, we collected 963 records of impacts spanning 63 SDG targets. Summarising these findings at the target level, we identified 29, 15 and 19 targets with potentially beneficial, damaging and mixed impacts, respectively, of which 36 have a high level of associated confidence and 27 a low level (Fig. 2). No impacts were identified for 41 targets, and although these receive little attention in the remainder of this article, we do not dismiss the possibility that some associated forest impacts may exist, despite these not being evident in the literature encountered in our searches.

The following sections present and discuss different aspects of our findings, including how the predominant directions of target-level impacts vary between individual SDGs (section 3.1), how impacts can vary in direction at the individual target level (section 3.2), the knowledge biases observed between certain targets and goals (section 3.3), and, finally, a summary of our findings relating to the impacts of external development interventions (section 3.4). We illustrate our findings using examples spanning a range of goals and targets, but nevertheless direct readers to Table A1 (Appendix B), which provides a breakdown of findings for all targets.

3.1. Variation in impacts within and between SDGs

All SDGs contain a mixture of impacts of different types among their targets, though the predominant direction of these varies between goals. While some goals have predominantly beneficial potential impacts (e.g. SDGs 4 (quality education), 5 (gender equality) and 16 (Peace, justice and strong institutions)), some have mostly damaging and/or mixed potential impacts (e.g. 9 (industry and infrastructure) and 11 (sustainable cities and communities)), and the remainder have varying combinations of the three categories.

Six of SDG 4's ten targets were identified as having impacts, and all were evaluated as beneficial. Empirical observations (Godoy et al. 1998; Godoy and Contreras 2001) suggest that improving access to all levels of education, including from pre-primary to university (targets 4.1, 4.2 and 4.3, all high confidence) can result in a reduced tendency to clear forests. Mechanisms by which this occurs are not always clear, but are often related to one or more of the following associated outcomes: a higher proportion of people working in the service sector; an increased tendency to migrate from rural to urban areas; increased knowledge of new farming techniques/technologies resulting in agricultural intensification over expansion into new areas (although we acknowledge that agricultural intensification does not always result in land sparing (e.g. see Gutiérrez-Vélez et al. 2011)); or in an increased awareness of the 'Western' environmental movement (Burns et al. 1994; Ehrhardt-Martinez 1998; Godoy et al. 1998; Godoy and Contreras 2001). Targets relating to technical and vocational skills for employment (4.4), gender disparities in education (4.5) and literacy and numeracy (4.6) are also all suggested as having potentially beneficial impacts on forests (Arnold et al. 2011; Getahun et al. 2017; Singh et al. 2017), although the available evidence for these is less robust, and each was assessed with low confidence. Across this goal more broadly, the links with targets 8.3 (beneficial, high confidence), 8.5 (beneficial, high confidence) and 8.b (beneficial, low confidence), which are all concerned with increasing [off-farm] employment, are thought to have important implications for reducing encroachment into forests (Angelsen and Kaimowitz 2001; Parés-Ramos et al. 2008; Schmook and Radel 2008).

Four of SDG 5's nine targets were identified as having impacts on forests. Of these, three were assessed as potentially beneficial (targets 5.1 (end all forms of gender discrimination), 5.6 (increase access to sexual and reproductive health and reproductive rights) and 5.a (equal female rights to economic, financial and natural resources, and land/property ownership)), although none were supported by robust evidence (all beneficial, low confidence), and only 5.6 was supported by more than a single source. Records for target 5.6 were identical to those for the overlapping target 3.7 (ensure access to sexual and reproductive healthcare services and family planning), and the overarching suggestion of these records is that increasing [female] access to family planning and reproductive health services can help address issues of rapid population growth, and hence the demand for land and other natural resources (Bryant et al. 2009; Starbird et al. 2016; Wan et al. 2011). We note here, however, that the links between human population growth and environmental quality remain unclear, and much contested. Target 5.5 (female participation in leadership and decision-making) was evaluated as mixed overall (high confidence), supported by four empirical observations of beneficial outcomes and one with mixed outcomes. It is worth noting that all evidence found for this target was specific to participation in decision-making bodies related to forests, and hence provides a somewhat biased insight into how achieving this target in a wider, more holistic sense would affect forests, if at all.

Impacts relating to SDG 16 (peace, justice and strong institutions) were identified for eight targets, including five beneficial, two mixed

and one damaging. When considering these impacts, it is important to keep in mind that the political economies and legal/regulatory frameworks of the countries in question, including whether these tend to favour large or small scale actors, can be of critical influence on the resulting outcomes; a point which holds true for many targets under other goals. Records for targets 16.3 (promote the rule of law) and 16.5 (reduce corruption), which were the most numerous within SDG 16, suggest near-unanimously that progress towards achieving these targets is potentially highly beneficial for successful forest conservation (Assa 2018; Ifrani and Nurhayati, 2017; Koyuncu and Yilmaz 2009; Tegegne et al. 2016), although much of this literature on these topics is of a theoretical nature only (although a few empirical records meant both were assessed with high confidence). Targets 16.1 (reduce violence) and the related 16.a (strengthen institutions to combat violence, combat terrorism and crime) both have mixed impacts (high and low confidence, respectively). The implications for forests of ending civil or international armed conflicts can be highly complex, requiring consideration of a multitude of factors. For example, while ending a conflict may alleviate forest pressures relating to displaced peoples (Ordway 2015), armed groups residing in forests (Nackoney et al. 2014), exploitation of resources to supply funds to armed groups (Johnston 2004) and/or the breakdown of the rule of law, it may concurrently allow for other damaging activities to begin or resume, including agricultural expansion (Murillo-Sandoval et al. 2020) or increased exploitation of forest resources from formerly hostile environments (Ordway 2015). Target 16.4 (reduce organized crime) was assessed as having potentially damaging impacts (high confidence), with all empirical records pertaining to efforts to combat coca-associated crime in Colombia (which overlaps with target 3.5 (damaging, high confidence) on preventing narcotics abuse). Despite having some forest benefits, coca crop eradication has been shown to result in cultivators simply moving their damaging activities elsewhere or switching to agricultural practices that are more damaging themselves (Bradley and Millington 2008; Rincón-Ruiz et al. 2016). The remaining three SDG 16 targets with identified impacts were all assessed as beneficial and with low confidence. Targets 16.6 (effective, accountable and transparent institutions), 16.7 (inclusive, participatory and representative decision-making) and 16.10 (public access to information) (all beneficial, low confidence) are all thought to have mediating effects on other targets, particularly those relating to law enforcement and corruption (Ceddia et al. 2014; Jorgenson and Burns 2007; Suwarno et al. 2015).

SDGs 9 and 11 have five and four targets, respectively, with identified impacts, with two and three targets respectively assessed as damaging. In most cases damaging impacts were associated with hard infrastructure (including roads, railways, dams, housing and industrial areas (Doyle and Havlick 2009)). Regarding roads, there is good evidence to suggest that roads designed to boost access to markets (target 9.3: high confidence) are especially damaging (Perz et al. 2008). Despite this, occasional records suggest potentially mixed or even beneficial impacts of roads (Kaczan 2020), but such evidence is relatively weak. Possible exceptions to this include the process of industrialisation (target 9.2: mixed, high confidence), which, although often associated with damaging impacts due to infrastructure, industrial pollution and influxes of workers (De Castro et al. 2017), can result in agricultural abandonment leading to forest expansion (Parés-Ramos et al. 2008). The presence of communication networks and infrastructure (linked to target 9.c: mixed, low confidence) has been shown to correlate positively with forest declines (Lim et al. 2017; Wheeler et al. 2013), though the mechanisms are not well understood and the source materials do not provide information on the specific types of infrastructure. Moreover, there are arguments to suggest that better access to communication technologies can help develop and enforce rules around forest use (Poteete and Welch 2004). Although some of the impacts mentioned here seem almost unavoidable, it is often suggested that a more inclusive and participatory approach to planning (target 11.3 and the overlapping 16.7, both beneficial, low confidence) shows promise as a way to help minimize the damage (Suwarno et al. 2015; Valencia-Sandoval et al. 2010). However, few robust empirical observations to support this suggestion were encountered in this review, and one study (Feintrenie and Levang 2011) suggests that in some cases local communities may favour development over forest conservation.

Four of SDG 2's (end hunger and increase food security) eight targets were identified as having forest impacts. Targets 2.1 (end hunger) and 2.2 (end malnutrition) had largely overlapping records, and were both evaluated as beneficial (high confidence). Despite some (non-empirical) suggestions (often pertaining to agricultural expansion) of potentially damaging or mixed impacts from these targets, final evaluations were based on a single empirical record of a food aid program in Ethiopia which demonstrably reduced the need for agricultural expansion (Belay et al. 2015). Target 2.3 (double agricultural productivity and food producer incomes) was assessed as damaging (high confidence). While noting that there are arguments suggesting that agricultural intensification can in some cases reduce encroachment into forests (Pope et al. 2016; Shively and Pagiola 2004), records largely reported damaging impacts associated with agricultural expansion and irrigation schemes (Bélanger and Grenier 2002; Franks et al., 2017). Target 2.a (investment into agriculture) was evaluated as mixed (high confidence). Records for this target all relate to agricultural technologies, a topic comprehensively reviewed by Angelsen and Kaimowitz (2001), who conclude that although damaging impacts are more common than beneficial ones (especially in the context of export crops), positive forest outcomes can occur, for example, when technological changes occur away from forested locations and attract workers that would otherwise engage in forest-damaging activities.

3.2. *Differential impacts within targets*

To compare the variation of directions within the evidence collated for each target, damaging impact scores were converted to their equivalent negative values (i.e. -0.01, -0.1 or -1) and mixed impact scores divided by two and one resulting half converted to its negative equivalent (e.g. a mixed record with high associated confidence would result in two values: 0.5 and -0.5). This process allows the summed values of for each category (damaging, beneficial, mixed positive and mixed negative) to be more easily represented visually, as in Fig. 3. Fig. 3 shows that 38 targets have some variation in the direction of their impacts (i.e. at least one mixed record, or two or more records with different directions). This occurs for one of three main reasons:

Firstly, achievement of a particular target may have genuinely mixed impacts depending on context and other factors. Improving ownership and control over land (a component of target 1.4: mixed, high confidence), for example, may lead landowners to either exploit or conserve their forest resources, depending on, inter alia, exposure to market forces and immigration, local governance conditions, and starting forest condition (Graziano Ceddia et al. 2015; Katila et al., 2020; Hayes 2007; Larson and Dahal 2012; Naughton-Treves and Wendland 2014; Travers et al. 2015). Similarly, forest impacts relating to economic growth, as measured by GDP per capita (target 8.1: mixed, high confidence), can be mediated by a range of factors to potentially result in beneficial or damaging impacts. Among others, mediating factors are thought to include: the relative stage of economic development (Crespo Cuaresma et al. 2017) (although this remains a topic of much debate (Choumert et al. 2013)), the nature of the economy (closed vs. widely trading) (Foster and Rosenzweig 2003), and levels of income inequality (Koop and Tole 2001).

Second, a target's impact may vary in direction if there are different options available as to how it might be addressed. We note, for example, that records collected for targets 7.1 (access to affordable, reliable and modern energy), 7.2 (renewable energies) and 7.b (energy infrastructure and technology) (all mixed, high confidence) encompass topics ranging from the deployment of large-scale energy generation plants (predominantly hydroelectric schemes (Jolli 2012; Urruth et al. 2017), and to a

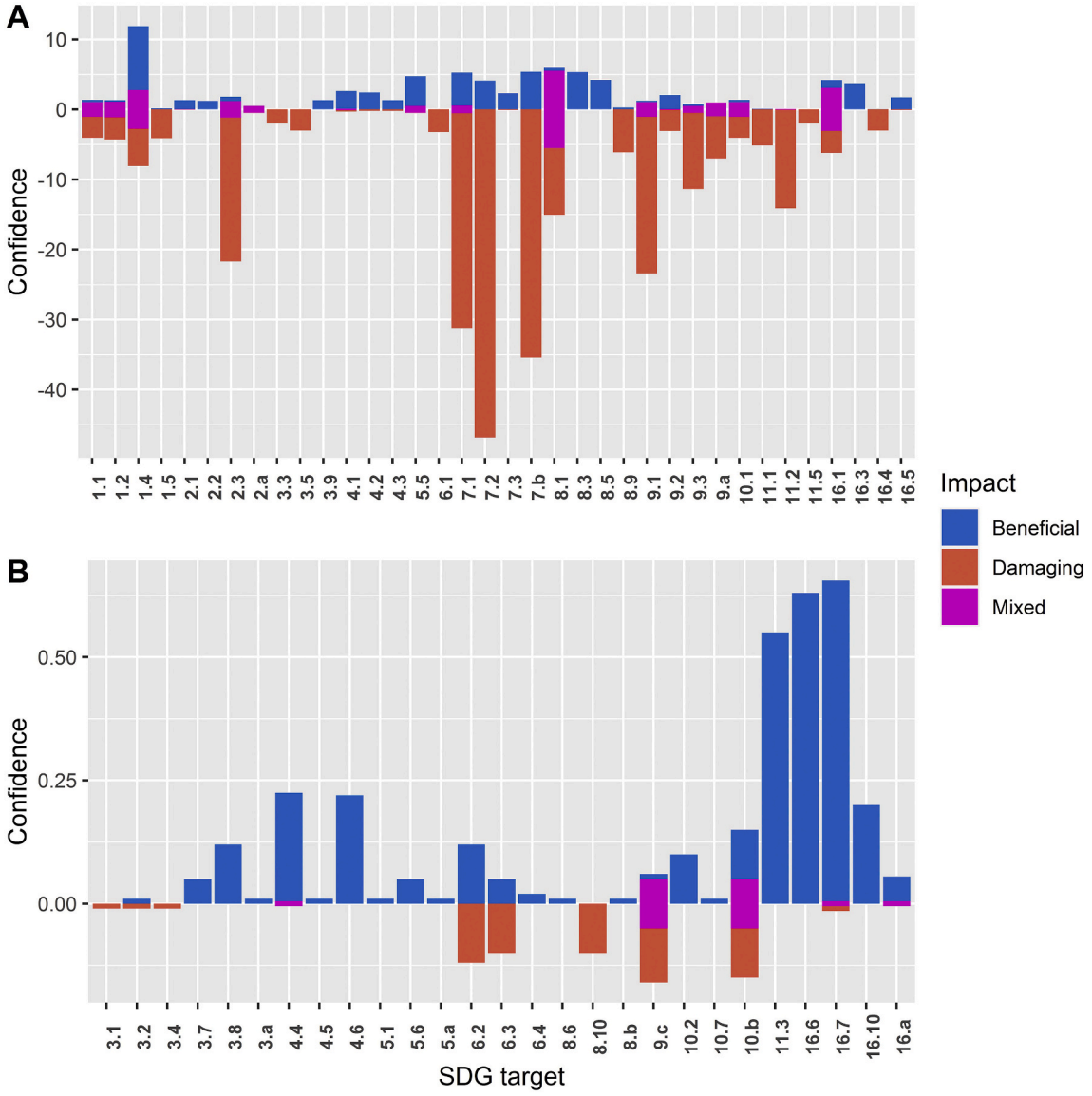

Fig. 3. SDG targets with identified impacts with high (above) and low (below) associated overall confidence. Bars show cumulative scores for all records found based on the confidence of each. Scores for mixed impacts contribute equally to positive and negative values.

lesser extent other renewable energies such as solar, wind (Gibson et al. 2017) and geothermal (Shortall et al. 2015)), which are typically damaging (Gibson et al. 2017), to papers looking at clean fuel options, including household-level initiatives relating to biogas or improved cookstoves (incidentally, the topic with most records for target 7.3 on energy efficiency (beneficial, high confidence)), which are acknowledged as having the potential to reduce the exploitation of forests for fuel (Agarwala et al. 2017; Dresen et al. 2014; Meeks et al. 2019). Though the example above implies that decision-makers working on such targets can simply choose the most environmentally sound option available, we acknowledge that, in practice, contextual and practical factors will limit some options.

Lastly, targets whose specifics are highly varied, or are perhaps ambiguous, may show mixed impacts depending on specific interpretations. Target 1.5 (reduce exposure and vulnerability to shocks) (damaging, high confidence) covers economic, social and environmental matters, and, depending on which of these one considers, impacts can vary. In this review we found mixed impacts associated with reducing economic shocks (Chibwana et al. 2013; Klepeis and Vance 2003), but damaging impacts relating to the use of hard infrastructure to reduce exposure to extreme weather events such as flooding (Doyle and Havlick 2009; Irving et al. 2018). Similarly, target 1.2 calls for the reduction of poverty according to 'national definitions', and provides little guidance beyond this. Our assessment of this target, therefore, being unable to explore all national definitions, included factors spanning wealth (Alix-Garcia et al. 2013) and household assets (Illukpitiya and Yanagida 2008), among others, which in part explains the mixed (high confidence) impacts identified.

3.3. *Knowledge-bias among target-level impacts*

In terms of research effort, we note that more than 50% of all records (486 of 963) were associated with just eight targets (all detailed elsewhere in this article): 7.2 (increased renewable energy, 83 records); 7.1 (modern and clean energy, 71 records); 1.4 (access to basic services, 70 records); 2.3 (double agricultural productivity, 58 records); 16.5 (reduce corruption, 48 records); 8.1 (per capita economic growth, 46 records); 9.1 (develop infrastructure, 44 records); and 16.3 (promote the rule of law, 41 records). Conversely, 26 targets contained five records or less, and a particularly striking observation is that 16 of these were

assessed as beneficial overall (albeit mostly with low confidence). As described in the following paragraphs, areas that seem particularly poorly researched include matters of health (SDG 3), between- and within-country equality (SDG 10), and water and sanitation (SDG 6). Matters of gender equality (SDG 5), and aspects of education (SDG 4), both discussed earlier in the article, also appear to be relatively poorly researched.

Matters of health provide an interesting case, as the links with forests are not necessarily obvious, yet, despite relatively few overall records, there is indication of a mixed range of impacts. Potentially damaging impacts of improving human health mostly relate to the idea that reduced mortality leads to population increases, and hence greater demand for land and natural resources (de Jong et al. 2010), but we note that this is not well substantiated, and that other findings have shown a negative correlation between child mortality and deforestation (Redo et al. 2012). Nevertheless, this underscores the importance of family planning (targets 3.7 and 5.6) in helping to mitigate population-related impacts (Bryant et al. 2009; Starbird et al. 2016; Wan et al. 2011). We also found damaging impacts arising from vegetation removal used to control tsetse flies (Nash 1948) and onchocerciasis (Baldry et al. 1995), although such impacts are unlikely to be commonplace. Beneficial impacts associated with health targets relate to environmental benefits of improved cookstoves (as a means to improve household air quality (target 3.9: beneficial, high confidence) (Agarwala et al. 2017; Bensch and Peters 2013; Dresen et al. 2014); the beneficial land-use implications associated with reduced tobacco cultivation (Jew et al. 2017) (target 3.a: beneficial, low confidence); and the (uncorroborated) suggestion that providing rural communities with access to healthcare (target 3.8: beneficial, low confidence) can improve people's perceptions of conservation activities, where the two are integrated (Chapman et al. 2015).

Records associated with SDG 10 (reduced inequality), all but one of which have low confidence, include the suggestion that reducing both economic inequalities (Andersson and Agrawal 2011; Koop and Tole 2001) (target 10.1: mixed, high confidence) and social inequalities (target 10.2: beneficial, low confidence) (in particular, inequalities between ethnic groups (Matin et al. 2014)) are important factors in minimizing negative effects on forests (Matin et al. 2014). We acknowledge, however, that Andersson and Agrawal (2006) tested the relationship between wealth inequality and three forest condition variables at the between-country level and found no relationships. Urban to rural migration, including that concerning refugees or migrants relocating in rural areas has been implicated in deforestation, suggesting that better planned migration (target 10.7) will result in less impacts on forests (Hugo 2008), though this assumption does not appear to have been well tested (low confidence). We acknowledge, however, that in some cases deforestation was a problem before refugees arrived, and other writers point to positive impacts of refugees in, for example, reforestation schemes.

We also note that financial development assistance (including foreign direct investment, FDI) (target 10.b) is thought to have potentially mixed impacts on forests (low confidence), which are mediated by governance factors such as corruption (Assa 2018). FDI can potentially be damaging when used for primary industries, but may facilitate forest transitions (i.e. a change from net forest loss to net gain) when not (Li et al. 2017).

Concerning SDG 6, impacts associated with water infrastructure (e.g. dams, treatment plants, pipelines) can be damaging (Benfield et al. 2005; Doyle and Havlick 2009; Perry and Praskievicz 2017), but can often be avoided with appropriate planning (Maughn and Harris 2009). Other impacts within this goal include suggestions that reducing open defecation (target 6.2: mixed, low confidence) and the release of hazardous chemicals and materials (target 6.3: mixed, low confidence) will reduce forest-damaging pollution (to which mangroves are particularly vulnerable) (Rakotomavo et al. 2018; Yim and Tam 1999), and that improvements in water-use efficiency (target 6.4: beneficial, low confidence) will help ameliorate impacts to hydrological systems (which can affect forests) that result from over-extraction of water (Pittock and Lankford 2010).

3.4. Impacts of development interventions on forests

As noted earlier, the intentionality of external development interventions means that they can provide 'real-world' case studies from which to assess the impacts of achieving specific development targets. Our review identified 55 sources that specifically considered the impacts of development interventions (which could be readily linked to SDG targets) on forests. Intervention types were predominantly large scale initiatives (i.e. with intended beneficiaries at the regional level or above), including two international projects (the Onchocerciasis Control Programme in West Africa (covering parts of Burkina Faso, Cote d'Ivoire and Mali) and the paving/completion of the Inter-Oceanic Highway in Peru and Brazil (two papers). Almost half of the sources (27 of 55) looked at energy/fuel projects, which ranged from large hydroelectric projects (17 papers, mostly projects led by national governments and/or the private sector) through projects to install biogas plants and disseminate cookstoves, as well as more policy-focused initiatives, such as the Indonesian Presidential Decree to establish the National Energy Policy. Other types of initiatives recorded included coca eradication schemes in Colombia and Bolivia (involving national and US governments); efforts to end civil conflicts (e.g. in Angola, Colombia and Mozambique, among others); provision of credit to small farmers (e.g. the En Nahud Cooperative Credit Project in Sudan); the Oportunidades Program, which aims to increase school attendance and health care among poor families in Mexico; the formalization of land rights in Brazil and China; agricultural development programs in Brazil and the Philippines; and the provision of food aid in Ethiopia.

From the 55 sources we extracted 142 impacts relating to 25 SDG targets (as well as nine cases where impacts were deemed negligible, and four cases where findings were inconclusive). Impact directions were recalculated for targets based on this subset (Fig. 2f), and seven targets (1.1, 1.2, 1.3, 8.1, 9.2, 9.a and 10.1) differed from the full dataset in this regard, all changing from mixed to damaging when considered in the specific context of interventions.

Possible reasons for this difference include that either (a) in the context of interventions, researchers have tended to focus on negative outcomes, possibly because their aim is to highlight damaging forest impacts with a view to reducing these in future, or (b) that impacts are simply more damaging when associated with an intervention than when changes occur autonomously. Explanation (a) is supported to some degree by the observation that only four (16%) of the 25 targets investigated in the context of interventions were evaluated as potentially beneficial in the full dataset (compared with a possible 29 (or 46%) of the 63 available for consideration). This suggests a research bias towards damaging interventions, implying that many (currently theoretical) positive impacts, and lessons that might be learned from these, are being overlooked.

This subset, similar to the full dataset, showed signs of bias towards only a few targets, with 88 (62%) of the 142 records covering just four (16%) of the 25 targets (7.1, 7.2, 7.b and 2.3). Targets 16.1 and 9.3 also received moderate amounts of attention with seven and five records each. In the following, we consider information compiled by AidData (Sethi et al. 2017) on Official Development Assistance (ODA) Commitments to the SDGs between 2000 and 2013 (a rough proxy for interventions) to our own findings and observe that some goals are reasonably well aligned in terms of commitments and research attention in the context of forests, but also see some notable mismatches. For example, SDG 16 (peace, justice and strong institutions) is by far the most well-funded of the SDGs, received US$342.5 billion (26%) of the approximately US$1.3 trillion commitments to goals considered in this work, and was accordingly well-represented in our data with 10 (7% of the 142 total) records. SDGs 5 (gender equality) and 10 (reduced

inequality) both received less than 1% of all ODA commitments, and accordingly account for zero and three (2% of the total) records in our data, respectively. Conversely, SDG 7 was the focus of 83 (58%) our 142 records, yet received only US$93.9 (7%) of all commitments. SDGs 4 and 11 accounted for zero and one of our 142 records, respectively, yet received relatively large amounts of ODA commitments (US$147.4 billion (11%) and US$144.3 billion (11%), respectively). In light of the impacts described throughout this article, and given the relatively low amount of ODA directed towards terrestrial conservation (US$19.1 billion, or 1.2% of the total for all SDGs), this imbalance clearly warrants attention.

4. Multi-target impacts

Although not an explicit aim of this review, we identified a number of ways in which two or more non-environmental targets may interact to result in forest impacts, and which highlight an additional layer of complexity in this topic. A non-exhaustive list of such interactions is provided in Table 1. Such interactions can be thought of as either facilitating (i.e. achievement of one target permits achievement of a second, which has subsequent impacts), mediating (i.e. achievement of one target mediates the expected impacts of a second) or synergistic (i.e. achievement of two or more targets results in impacts that are greater than those expected from a single target). We note that, of the examples given in Table 1, the greater proportion are facilitating or mediating in nature, and that fewer synergistic examples are given. While this is reflective only of our findings, and we do not necessarily expect this to be the case in practice, it does highlight the fact that such interactions are less considered, possibly because of the practical difficulties of designing counterfactual research that quantifies multiple target impacts with and without the influence of each other.

We also acknowledge that such complexities can extend beyond interactions between only two targets, and, in practice, diverse ranges of facilitating, mediating and synergistic factors likely interact to result in forest impacts. Identification of such interactions, even when specific mechanisms or other complexities are not fully understood, will provide useful insights that can help achieve multiple targets in the most sustainable manner possible.

5. Implications of our findings

5.1. Implications for researchers

This review has highlighted a number of research gaps, which, with some investigation, would help facilitate a more integrated approach to sustainable development that avoids damage to forests and capitalises upon mutual benefits wherever possible. The 41 targets evaluated as 'unknown' in this work may nevertheless still have roles to play in affecting the natural environment, and would be worthy of investigation in this regard. The 27 targets identified as having forest impacts, but with low confidence, are particularly interesting from a research standpoint as they represent potential trade-offs or synergies that may be being overlooked by policymakers and development agencies. It is worth noting again here that more than two thirds of low confidence impacts are thought to be potentially beneficial. In all cases we encourage studies across a range of contexts (especially external interventions), locations and scales, so as to fully elucidate the complexities surrounding those impacts identified, including the mechanisms through which they arise.

Gaining a deeper understanding of multi-target interactions will be especially useful for developing integrated approaches to achieving non-environmental development without jeopardising the environment. Numerous multivariate studies (e.g. Crespo Cuaresma et al. 2017; Koop and Tole 2001; Wang et al. 2019) have already made some progress in this area, highlighting key factors that can interact to result in forest outcomes (notably changes in deforestation rates). However, these are

Table 1
Examples of inter-target interactions with implications for forests.

Interaction type	Goals or targets involved	Impact mechanism	Expected direction of impact
Facilitating	16.10 (Ensure public access to information) 16.5 (Reduce corruption and bribery)	Greater access to information, in particular through freedom of the press, helps to expose and reduce corruption (Ehrhardt-Martinez et al., 2002). Corruption is a key determinant of forests loss (Sommer, 2017).	Beneficial
	16.1 (End violence and related deaths) 1.4 (Equal rights to ownership and control over land and property)	Cessation of war and conflict is typically required for land rights to be recognised (de Bremond, 2013). Increasing local and individual land rights has mixed impacts on forests.	Mixed
	SDG 4 (Access to education and learning opportunities) 8.3 (Promote job creation and entrepreneurship)	Increasing levels of education allows individuals a more diverse range of job options, including non-agricultural employment, resulting in less encroachment of agriculture into forests (Baland et al., 2006).	Beneficial
	11.3 (Inclusive and sustainable urbanization) 7.1 (Access to modern energy services)	Evidence suggests that urban households are more likely to use more modern, and less forest-degrading fuel types (DeFries and Pandey, 2010).	Beneficial
	9.3 (access to markets and financial services, including credit) 2.3 (Double agricultural productivity)	Access to credit provides the capital required for farmers to expand agricultural operations into new areas, but can also allow investment into new technologies that promote intensification (Angelsen and Kaimowitz 2001).	Mixed
Mediating	16.6 (effective, accountable and transparent institutions) 10.b (increase official development assistance and foreign direct investment)	Effective governance can help mitigate the negative impacts that often arise from foreign direct investment (Assa 2018).	Beneficial
	10.1 (Achieve in-country wealth equality) 8.1 (Sustain per capita economic growth)	Some evidence to suggest that reducing wealth inequalities can have a mediating effect on the damaging aspects of economic growth (Koop and Tole 2001).	Beneficial
Synergistic	8.9 (Promote sustainable tourism) 9.1 (Develop infrastructure)	Tourism typically requires increased infrastructure, and better infrastructure attracts more tourists. Damaging impacts of both are likely to be greater in combination than in isolation (Gaughan et al., 2009).	Damaging

often limited to macro-level analyses that can fail to (a) identify forest degradation, or (b) uncover the specific mechanisms through which change occurs, especially when it involves subtle changes in social contexts, such as those relating to equality or health. Studies that combine local-level measures of changes in a range of development indicators with on-the-ground measures of forest change could be particularly insightful in this regard.

Finally, though many of our findings will apply to natural systems other than forests, many will not, and many other important interactions are likely to exist. As such, we recommend similar target-level reviews to this one which investigate other ecosystem types. In particular, work focusing on marine and coastal systems, wetlands, mountains and drylands, which are all mentioned in the SDG targets (Inter-Agency and Expert Group in Sustainable Development Goal Indicators 2016), should be seen as priorities.

5.2. Implications for policymakers and development agencies

Institutions seeking to help achieve one or more non-environmental SDG targets must remain aware of the implications of their actions for natural biological systems and resources (illustrated here in the case of forests). Although our findings are broadly generalizable across locations, we remind readers that contextual factors (especially legal frameworks and political economies, relevant particularly to SDG 16) are of great importance in determining the consequential impact of development progress. While for some forms of development, such as those relating to infrastructure or agriculture, avoiding negative environmental impacts presents a seemingly huge challenge, damage may be minimized by capitalising on some of the potentially beneficial (and perhaps less conspicuous) impacts identified in this review. In particular, evidence suggests that widespread promotion of quality education to support environmental awareness and a diverse job market in the non-agricultural sectors would support forest conservation. Actions to support transparent and effective governance institutions, free from corruption and able to effectively implement the rule of law will be particularly useful in providing a background for successful achievement of environmental goals. Similarly, and although the evidence is less robust, creating a world with significantly reduced wealth and resource inequalities (including for women), as well as access to medical treatments and family planning services, could yield beneficial outcomes for the natural environment.

In cases where infrastructural developments seem likely to cause unavoidable negative environmental impacts, the evidence here suggests these might be minimized by adoption of participatory planning which is inclusive of diverse members of society. Roads in particular require careful consideration, and where increased market integration results from new roads (whether intentionally or otherwise) well-enforced policies, laws and other safeguards should be used to prevent overexploitation of nearby natural resources. For practitioners and policymakers working in the energy sector, evidence here also suggests the need for careful consideration of the environmental impacts that can result from their work (especially from the associated infrastructure) and supports the need for development of alternative options that provide clean, reliable energy in ways that minimize environmental damage.

Countries or development agencies wishing to invest in forest protection or restoration need to look beyond the conservation sector and address other competing and potentially conflicting development priorities while capitalising on those that can provide indirect benefits. A long-term solution for forests will necessitate a holistic approach where, among other factors, health, education, equality, and transparent and effective governance are treated as essential enabling conditions. To achieve this, a development planning landscape that is not only inclusive, but is, as best possible, free from silos that discourage dialogue and planning across sectors (and indeed across cultures and geographical boundaries) is important to avoid or capitalise upon the types of cross-target interactions described in this work (Nilsson et al. 2016; Timko et al. 2018). While this review has highlighted some of the most important sectoral silos that should be avoided (e.g. urban planning, deployment of energy infrastructure, agriculture), it seems reasonable to assume that even less obvious inter-sectoral dialogues, such as between matters of health and environment, will yield benefits. The removal of silos will not only facilitate well integrated planning and implementation of development interventions, but will also allow for better monitoring and research of cross-sectoral synergies and trade-offs, as described in the previous section. Continued interdisciplinary dialogue and research will yield an increasingly better understanding of ways to achieve the SDGs in a manner that is truly sustainable.

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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Appendix A. Supplementary methods

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2021.102423.

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