**Discussion**

*Opening paragraph*

Global funding for nature conservation is far below what is required (Freeling and Connell, 2020; Laufer and Jones, 2021), and the funding that is available is rarely stable or sustainable over periods of more than a few years. To maximise conservation gains it is necessary to provide conservation managers, and conservation funders, with insights into the trade-offs between different approaches to long-term investment of limited resources in the context of increasing anthropogenic pressure on natural resources. To our knowledge, no studies have investigated the potential long-term consequences of existing funding mechanisms for conservation projects and organisations. Our results therefore provide crucial quantitative evidence that funders, conservation bodies, and landscape managers can use to develop more effective long-term investment strategies.

*Primary scenarios (scenarios 1 to 3)*

Our results have demonstrated that in a situation where human pressure on a landscape is increasing over time, and assuming managers across all scenarios have access to the same total budget, the most effective funding strategy for a conservation manager is a stable, predictable budget. A constant budget is preferable to an increasing budget that starts too low, even when that budget increases beyond the value of the stable budget halfway through the study period. If a manager’s budget is too low at the start of the study period, initial forest loss is very high. The manager is able to reduce the rate of forest loss as their budget increases over time, but they are not able to make sufficient gains over 50 years to render the strategy better than a stable budget. Likewise, a fluctuating manager budget that reflects predictable grant cycles performs worse over 50 years than a stable budget. During periods of high budget, managers can develop effective policies that reduce forest loss. However, these periods are not sufficiently long, and budgets not sufficiently high, to offset the damage that is done during periods of low funding. Furthermore, the rate of forest loss during periods of low funding increases over time, as community resources increase. If the manager was focussed on the conservation of a wildlife population that exhibited reproduction and thus population growth, the periods of high budget, and therefore more effective protective policies, may be sufficient to maintain a healthy population as there would be periods of recovery. However, we assumed that the loss of primary forest could not be effectively reversed within a period of 50 years (refs). These simulations could be further parameterised to include realistic forest regrowth or regeneration based on a specific landscape or ecosystem, but this would decrease the generality of the results and therefore was not attempted here.

Providing a manager with a stable budget that allows the development and maintenance of policies that minimise deforestation over the long-term is the optimal approach. Stable, predictable budgets in the real world allow conservationists and landscape managers to maintain staffing levels, invest in long-term relationships and partnerships with stakeholders, maintain enforcement levels, and design policies and interventions that are strategic and adaptive over periods greater than short-term grant cycles. Conservation projects that are initially underfunded yet receive increasing resources will still spend many years working to reach the same levels of protection as they would have had, had they been provided an adequate, stable budget at the start. Our results suggest it could be several decades before the deforestation trajectories of the two alternative projects meet, and the increasing budget starts to pay dividends. Projects that repeatedly experience severe funding shortages due to grant cycles will not have the same capacity for long-term investment and strategic planning as projects with stable funding, resulting in greater losses for biodiversity.

*Uncertainty and unpredictability in funding*

Scenarios 4 and 5 highlight two common funding situations for conservation organisations and projects. Scenario 4 represents a situation where the management authority has some level of core funding that ensures the operational budget does not drop below a certain level, despite budget uncertainty over time. This is a common scenario for large, international conservation organisations or statutory authorities, which have long-term support for core operational budgets. They can increase their budgets at any given time through grant applications which can be used to support existing activities, initiate new programmes, bolster enforcement, or extend engagement and collaboration with stakeholders, all of which will have a positive effect on biodiversity conservation on the landscape. Likewise, grant funding will inevitably end within a few years, and there is no guarantee that future bids will be successful, resulting in decreases in overall budgets. However, the maintenance of budgets above a certain level means that core conservation activities do not cease, and the manager is able to minimise forest loss to a level similar to the manager in scenario 1. Conversely, scenario 5 represents a situation where the management authority has no core budget and is therefore entirely reliant on uncertain and unpredictable grant funding over time. This is the reality for many small organisations, grass roots projects, or poorly supported statutory authorities which rely on the ability of other partner organisations to leverage external funding. In this study, the manager in all scenario 5 replicates has the same cumulative total budget over the 50 years as the other scenarios, yet the shape of the budget curve is random. This leads to large and highly unpredictable positive and negative peaks in some cases. Our results show that there is large variability in the overall success of the manager from scenario 5 to minimise forest loss. In some cases, they can maintain a forest loss trajectory similar to scenarios 1 and 4, yet more often the rate of forest loss is worse, regularly leading to extinction.

The results from scenarios 4 and 5 translate logically to the real world; if a conservation project or organisation has no core budget support, it is entirely reliant on the success of fundraising efforts. Winning sufficient funding via short-term grants to support adequate long-term conservation management is neither reliable nor straightforward. When long-term budgets are unpredictable, uncertain, and highly variable, landscape managers are often unable to maintain core activities, guarantee continued support for communities and other stakeholders, plan investments strategically, or target investments at the most relevant drivers of biodiversity loss. In contrast, when core budgets are guaranteed, managers can maintain core activities and investments over the long-term which provides stability and minimises biodiversity loss.

*Key messages*

We have demonstrated that the dominant funding mechanism for conservation in the world today – the short-term grant cycle – is not optimal for conservation investment within social-ecological landscapes where there are competing objectives and increasing anthropogenic pressure on natural resources. In circumstances where project budgets experience negative peaks caused by gaps in grant funding, and where there is no core budget, biodiversity loss is accelerated. In these circumstances, managers are unable to maintain power to affect the system or set policies that benefit nature over the long-term. Increased uncertainty and variability around the shape of fluctuating budget curves inevitably increases uncertainty around the state of biodiversity over the long-term. Brief periods of high budgets in the grant cycle scenarios result in only brief periods of success where rates of forest loss decrease, and in the context of increasing human pressure on the landscape, these are insufficient to mitigate for the periods of low funding. Chronic underfunding, particularly in the early stages of a landscape conservation programme, can lead to serious negative effects on natural resources. Severe forest loss at the start of a project period, with all the associated losses of biodiversity, ecosystem process and services, leads to very poor project success over a 50-year period. Even when project budgets increase over time, the damage caused during initial periods of underfunding is difficult to remedy.

Simulation studies allow us to investigate possible biodiversity outcomes from a variety of scenarios over time periods much longer than for which we generally have empirical data for. Monitoring data for conservation projects rarely exist over timeframes as long as 50 years, and managers are therefore required to assess conservation actions using monitoring data from significantly shorter periods. This study has demonstrated that this can be misleading. For example, if a manager was provided forest monitoring data for scenario 3 between years two and six, or between years 14 and 18, it would be reasonable to conclude that the existing investment strategy and associated conservation interventions were working, as the rate of forest loss was decreasing. If a manager was given forest monitoring data from any four-year period from scenario 1, they could reasonably conclude that the investment strategy and associated conservation interventions were not working, as the rate of forest loss was increasing. Neither manager could be justifiably criticised for their inference; they are drawing conclusions from the best available data, which is what conservationists around the world must do every day. Nevertheless, our results have demonstrated that these inferences are likely flawed, and that the manager from scenario 1 will have greater success in minimising forest loss over the long-term if they maintain their strategy.

*Conclusions – what can be done?*

The global conservation community requires a huge increase in funding if it is to halt the decline in biodiversity and minimise the worst impacts of climate change (Echols et al., 2019; Larson et al., 2021). We have demonstrated that a funding model that relies on short term grant funding, which is a common mechanism in the conservation sector, is unlikely to be the most effective way of financing landscape conservation. In addition to the landscape-level challenges of short-term grants that we have demonstrated here, the lack of communication, cohesion, and national, regional, and global coordination between funders that administer conservation grants results in poor strategic allocation of funding across larger spatial scales (Laufer and Jones, 2021). Greater coordination between funders, or indeed less reliance on numerous, disparate funders, will allow more thoughtful and strategic assessments regarding allocation of conservation funds, thus maximising environmental return-on-investment (Echols et al., 2019). If global funding for conservation increases, the mechanisms by which this funding is distributed need to be carefully considered to ensure biodiversity gains per dollar are maximised. Our results suggest that simply increasing the number of short-term grants available within a competitive application framework is unlikely to provide the maximum gains. Alternative funding mechanisms are needed which provide stable and predictable budgets over multi-decadal timeframes thus allowing organisations and authorities to devise and implement strategic, long-term interventions and policies that benefit nature and people.

There is a wide range of funding sources available to conservationists, yet government and philanthropic sources are the most common (Clark et al., 2018). The fragility of government funding has been exposed during the Covid-19 global pandemic; around the world there have been shrinking national economies, dramatic increases in emergency government spending, and governments being forced to prioritise sectors of the economy for support and recovery (Evans et al., 2020). Despite the irony, a global pandemic that was most likely caused by overexploitation of the natural environment (Lytras et al., 2021), is likely to cause a decrease in government spending on conservation, at least in the short term (Corlett et al., 2020; Evans et al., 2020). There is increasing recognition that broadening the sources of conservation funding is necessary to both increase global spending on the environment and to diversify the sources, thus stabilising funding against inevitable future economic shocks (Echols et al., 2019).

There are numerous sources of funding that are available for conservationists to explore. Funding for the environment from philanthropic entities is increasing (Gruby et al., 2021), and the influence of private foundations is growing (Betsill et al., 2021). As independent organisations, foundations have the potential to adapt their funding strategies and mechanisms to maximise effectiveness. If conservationists can provide evidence to support certain investment strategies, private foundations and other philanthropic entities are theoretically able to adapt accordingly. The idea of charitable giving that is evidence-based and results-orientated is already growing with the social movement known as ‘effective altruism’ (Freeling and Connell, 2020), giving the conservation sector an opportunity to shape the charitable funding landscape using empirical evidence. Global environmental agendas have driven the creation of global funds such as the BioCarbon Fund managed by the world bank ([www.biocarbonfund-isfl.org](http://www.biocarbonfund-isfl.org)), the Global Environment Facility ([www.thegef.org](http://www.thegef.org)), and the Green Climate Fund (www.greenclimate.fund), all of which are large enough to operate at a variety of spatial and temporal scales (Clark et al., 2018).

Arguably the most promising avenue for environmental funding is private finance, the power of which is yet to be fully realised (Clark et al., 2018). This is largely because the environmental sector has thus far failed to provide projects that are investable, scalable, and low risk (McFarland, 2018). Leveraging of private sector finance is increasing, and is being achieved through a variety of mechanisms including 1) national development banks which provide credit and finance to underfunded areas of society (Torres and Zeidan, 2016); 2) blended finance, which combines public and private finance through traditional mechanisms such as public-private partnerships, and through more novel mechanisms including development finance institutions (Clark et al., 2018); 3) custom built partnerships between the private sector and governments, civil society, and non-governmental organisations, for example the Tropical Landscapes Finance Facility ([www.tlffindonesia.org](http://www.tlffindonesia.org)) which provide long-term financing to support sustainable land use; 4) green bonds, which raise funds for projects that contribute to a more sustainable economy and deliver benefits to the environment (Sachs et al., 2019), 5) conservation finance, which is a broad term that describes financial solutions that deliver conservation gains *and* financial return for investors. An undeveloped field, conservation finance has huge potential as a private sector investment opportunity that delivers conservation goals, using mechanisms such as substitute funds, marine protected area bonds, and conservation impact bonds (Huwyler et al., 2016); 6) carbon market instruments such as REDD+ and the Green Climate Fund (Sachs et al., 2019); 7) other ‘green finance’ mechanisms such as impact investing, fiscal policy, green central banking, and community-based green funds (Sachs et al., 2019).

Although in relative infancy, private sector investment for conservation and the environment is underway, with global players in both conservation and finance recognising the potential. An example is the NatureVest collaboration between The Nature Conservancy and JP Morgan Chase which focusses on identifying and financing investable projects that deliver for investors and the environment (Kaiser, 2015). To successfully leverage private sector finance, the conservation sector (and the environmental sector more broadly) needs to dramatically increase the number and scale of projects that have low-risk rates of return and conservation impacts that are clear and measurable, thus making them attractive investments.

There is currently a large gap between the global ambitions for environmental recovery and the money available to fulfil those ambitions. In this study we have demonstrated that stable, long-term funding is more effective for the management of social-ecological landscapes than short-term, unreliable grant funding. Yet funding streams that provide such long-term financial stability are rare. Increasing the quantity of funding available for conservation and moving towards more sustainable investment strategies is going to require paradigm shifts across national and global policies and economies. If the conservation sector wants sufficient and sustainable funding, we will need to embrace new, creative ideas and form novel collaborations and partnerships to unlock the private sector and leverage such funding within the private sector investment framework.