Biological Conservation 214 (2017) 168–175

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Designing protected area networks that translate international conservation commitments into national action

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ARTICLE INFO

Keywords:
Convention on biological diversity
Local communities
Marxan
REDD+
Systematic conservation planning
Tropical forest conservation

ABSTRACT

Most countries have committed to protect 17% of their terrestrial area by 2020 through Aichi Target 11 of the Convention on Biological Diversity, with a focus on protecting areas of particular importance for biodiversity. This means national-scale spatial conservation prioritisations are needed to help meet this target and guide broader conservation and land-use policy development. However, to ensure these assessments are adopted by policy makers, they must also consider national priorities. This situation is exemplified by Guyana, a corner of Amazonia that couples high biodiversity with low economic development. In recent years activities that threaten biodiversity conservation have increased, and consequently, protected areas are evermore critical to achieving the Aichi targets. Here we undertake a cost-effective approach to protected area planning in Guyana that accounts for in-country conditions. To do this we conducted a stakeholder-led spatial conservation prioritisation based on meeting targets for 17 vegetation types and 329 vertebrate species, while minimising opportunity costs for forestry, mining, agriculture and urbanisation. Our analysis identifies 3 million ha of priority areas for conservation, helping inform government plans to double the current protected area network from 8.5 to 17%. As part of this, we also develop a new technique to prioritise engagement with local communities whose lands are identified as important to conservation. Our study both provides a scientifically robust, politically acceptable protected area expansion strategy for Guyana, and illustrates the importance of conservation planning at the country-scale to translate international commitments into national action.

1. Introduction

Protected areas form the cornerstone of global biodiversity conservation efforts, and today there are > 200,000 terrestrial protected areas worldwide (Bruner et al., 2001; Chape et al., 2005; UNEP-WCMC and IUCN, 2016). In recognition of this, signatories to the United Nations Convention on Biological Diversity (CBD) have committed through Aichi Target 11 to ensure that 17% of the terrestrial realm is protected by 2020, with a focus on establishing protected areas and other effective area-based conservation measures (OECMs). Implementing this commitment involved each country setting a national target, with most adopting 17%. However, with less than three years until 2020, only 14.8% of global land area is protected, representing a total shortfall of 3.1 million km^2 (UNEP-WCMC and IUCN, 2016), an area nearly the size of India. This shortfall is because over half of countries are yet to reach their national targets (World Bank, 2017), and while between 1990 and 2012 the area of the global conservation estate grew rapidly, progress has since plateaued (UNEP-WCMC and

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http://dx.doi.org/10.1016/j.biocon.2017.08.024
Received 25 January 2017; Received in revised form 20 July 2017; Accepted 14 August 2017
Available online 21 August 2017

IUCN, 2016). Consequently, for countries falling short of their target, up-to-date protected area expansion plans are needed.

Signatories to the CBD have recognised that for protected areas to be effective, they must be well-connected, ecologically representative and conserve areas of particular importance for biodiversity (CBD, 2010). This is against the backdrop that many existing protected areas are biased towards locations that are less important for biodiversity and/or on remote and economically unproductive land (Brooks, 2014; Joppa and Pfaff, 2009; Venter et al., 2017). Therefore, the Aichi targets have created an opportunity for the conservation science community to guide protected area expansion, as there is a real need to develop evidence-based plans that prioritise biodiversity (Watson et al., 2016).

Several global spatial conservation prioritisations have been conducted (e.g. Butchart et al., 2015; Larsen et al., 2011; Pollock et al., 2017; Venter et al., 2014), and these provide broad insights into the optimal locations for future protection at the international scale. However, as Aichi Target 11 is implemented at the national-level (CBD, 2010), and as this is the scale most relevant for land-use policy development and delivery, national-scale spatial conservation prioritisations are needed. To undertake these, under the CBD, government agencies must develop National Biodiversity Strategy and Action Plans (NBSAPs), which, where necessary, include a roadmap to achieving the Aichi targets, including "…integrating biodiversity into spatial planning exercises through the mapping of biodiversity ecosystem services and through systematic conservation planning" (CBD, 2010). Systematic conservation planning is one of the most transparent and robust methods for informing spatial planning, as it aims to maximise conservation benefits while minimising impacts on other stakeholders (Margules and Pressey, 2000). In addition to global analyses, systematic conservation planning has been extensively used at the local, regional and landscape level (e.g. Smith et al., 2008; Venter et al., 2013). However, despite national CBD targets, it is less commonly applied at the national-level (Di Minin et al., 2017), even though this is generally the scale most relevant for the government agencies charged with delivering CBD targets.

To illustrate the benefits of such country-wide analyses, here we describe a national-scale systematic conservation planning process for Guyana, which was led by the main government agency for protected areas in collaboration with a range of stakeholders and conservation scientists. Our plan sought to identify priority areas for protected area network development in Guyana, to adequately represent biodiversity while accounting for other land-uses. Guyana forms part of Amazonia and combines economic poverty with some of the highest global levels of biodiversity (Jenkins et al., 2013), and lowest deforestation rates (Hansen et al., 2013). Over 80% of the land area is covered with tropical forest. However, as in many parts of South America, deforestation rates have risen over the last decade, primarily as a result of gold mining (Fig. 1; Howard et al., 2011; Laing, 2015). This was partly because forests produced little government revenue compared with mining. This situation changed in 2009, when Norway committed up to $250 million to Guyana over an initial five-year period for Reducing Emissions from Deforestation and forest Degradation (REDD+) (Gutman and Aguilar-Amuchastegui, 2012). The expectation was that the funds can shift the economy away from a reliance on resource extraction towards a more sustainable and low-carbon model (Office of the President, 2013). Therefore, under the REDD+ agreement, Guyana committed to fulfilling its CBD obligations, through the implementation of a national conservation planning process. Both the REDD+ agreement and Aichi Target 11 stipulate that protected areas should be established and managed in close collaboration with indigenous and local communities (CBD, 2010; Gutman and Aguilar-Amuchastegui, 2012; Office of the President, 2013), and this is highly relevant in Guyana because community lands cover c. 15% of the country (Fig. 1), most of which are owned by indigenous Amerindians.

The existing protected areas in Guyana were not selected systematically, representing just 8.5% of the land area, of which 3.1% is a community conservation area. In 2016, the President of Guyana pledged an additional 2 million ha of protected area would be established across the country, thereby addressing both the shortfall in the 17% Aichi Target, and making an important contribution to the reduction in deforestation required to receive performance-related REDD + payments. To guide this process, we formed a group of stakeholders from Government of Guyana agencies, academia, and Non-Governmental Organisations, and used a systematic conservation planning approach. We identify priority areas to achieve conservation targets for 329 species and 17 vegetation types, while minimising opportunity costs (i.e. the choice of the best lower cost alternative) from the forestry, mining and agricultural industries (Margules and Pressey, 2000; Venter et al., 2013). Given the importance of local communities, we also developed a method to identify the most important community lands for meeting conservation targets. This provides a technique to help prioritise the engagement process for free prior and informed consent during the creation of new protected areas. Our study serves as a benchmark for countries looking to undertake national-scale spatial conservation prioritisations to expand their protected area networks.

2. Methods

The study was initiated by the Government of Guyana's Protected Areas Commission in collaboration with academics who joint-led the systematic conservation planning process. Our team quickly grew to consist of representatives from all of the non-governmental conservation organisations in Guyana, including Conservation International, WWF, and the Iwokrama International Centre for Conservation and Development. We consulted with stakeholders and policy makers during every stage of the planning process to ensure the spatial prioritisation remained relevant (Smith et al., 2009). This began with a workshop formed of all government agencies and stakeholders responsible for forestry, mining, natural resource management, land-use planning, environmental protection, and indigenous peoples as well as our study team, and initial feedback was given on preliminary analyses. Recommendations from these consultations were that the conservation prioritisation should: i) focus on Guyana's habitats and biodiversity, explicitly including threatened species; ii) incorporate opportunity costs; and iii) consider the role of community lands. The stakeholders also agreed that due to data availability, species distribution maps would need to be developed, and that the planning analysis should use Marxan, a software package designed to identify sets of priority areas that meet quantitative targets for specified conservation features, while minimising costs and maintaining connectivity (Ball et al., 2009). All stakeholders were kept up-to-date and remained involved as the spatial conservation prioritisation was developed and completed.

2.1. Habitat and species distributions

The conservation features we used in the analysis were 17 vegetation types, as classified in the Guyana national vegetation map (ter Steege, 2001), and all of Guyana's vertebrates for which range maps were available or could be developed. Faunal communities in many parts of Guyana have not been extensively studied, so we generated species distribution models to fill these gaps. We assessed data availability for all the c. 1000 terrestrial vertebrate species known to occur in Guyana and produced a species distribution model if ≥ 15 spatially referenced records had been collected. Species locality data were obtained from the Global Biodiversity Information Facility and published studies and rapid biodiversity assessments (Appendix Table A1). To increase the sample size for each species and, therefore, the reliability of our models (Elith et al., 2006; Hernandez et al., 2006), we widened

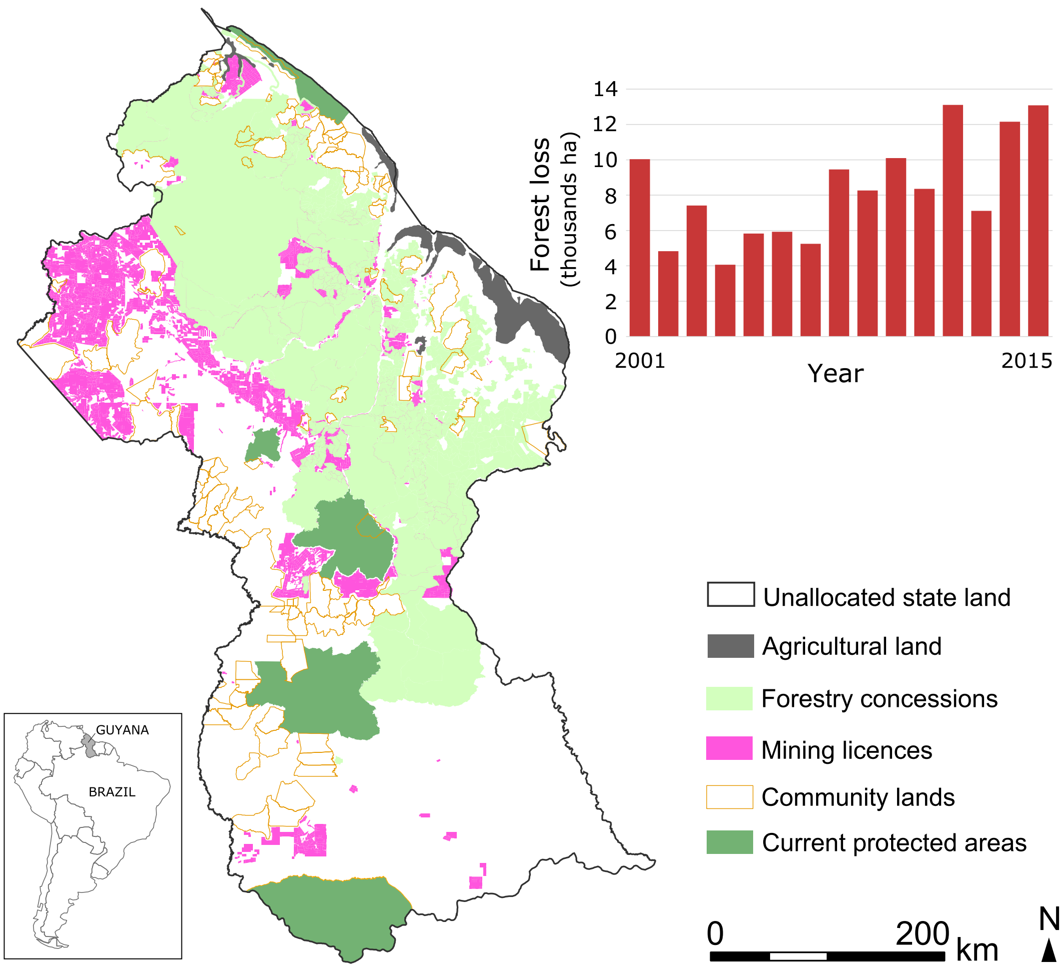

Fig. 1. Map shows current land-use in Guyana. Forestry concessions are indicated on top of mineral licenses, but many forestry areas also have mineral licenses granted within them. Forestry concessions and mineral licenses may have been previously exploited, in active use, or allocated for future extraction (data from various governmental departments in Guyana). Graph shows forest loss for the period 2001–2015 (Hansen et al., 2013). Inset shows the location of Guyana in South America.

the geographic area over which we obtained locality data to include a 200 km buffer around Guyana. We generated species distribution models using MaxEnt (Phillips et al., 2006), a widely used modelling package. MaxEnt has often been used to provide inputs for spatial conservation prioritisations, particularly in regions where data are sparse (Esselman and Allan, 2011; Moore et al., 2016). Our inputs to MaxEnt were species locality, and topographic and meteorological data (Table A3). Survey data are usually spatially biased and can cause inaccuracies if this bias is not properly accounted for when inputted into distribution modelling (Phillips et al., 2009). Therefore, to improve model predictions and reduce errors associated with survey effort bias (Syfert et al., 2013), we constructed species-specific bias grids in R (R Core Team, 2015). We ran the models by splitting each species dataset into separate training (70%) and testing (30%) components and measured performance using the Area Under Curve (AUC), based on 10 repetitions per species. Species were dropped from further analyses if their model had an AUC score of < 0.5 when predicting to the test dataset (data not used in model construction), making it a more robust measure than predicting to the training dataset (Fielding and Bell, 1997). We then split the resulting probability maps into binary presence/absence using the MinROCdist threshold, which has been shown to yield the most appropriate value based on predictive performance (Liu et al., 2005).

We also included threatened species (IUCN Red List: CR, EN, VU) even if we could not model their distributions. This was not only because of stakeholder feedback but also because omitting these species can result in a failure to recognise the irreplaceability of some sites (Platts et al., 2014). We did this by using their IUCN distribution maps. However, many of the maps were not suitable (e.g. the resolution was too coarse), so that only 13 of the 31 CR, EN, and VU species could be integrated into the spatial conservation prioritisation, the majority of which were highly localised endemics. One species, the red siskin (*Carduelis cucullata*) is endangered and has an extremely restricted range in Guyana, but no IUCN range map has been drawn. We therefore used a distribution published elsewhere (Robbins et al., 2004). The final dataset used in the conservation planning consisted of 329 species of terrestrial vertebrate (236 birds, 58 mammals, 35 reptiles and amphibians; Table A1, A2, A3), and the 17 vegetation types.

2.2. Spatial conservation prioritisation

Next, we developed the Guyana conservation planning system, by first dividing the country into planning units as required by Marxan. These planning units consisted of a series of hexagonal 1000 ha land parcels that we combined with the boundaries of the protected areas and community lands. We then calculated the amount of each conservation feature found in each unit. We collated data from various government agencies in Guyana to estimate the opportunity costs (US dollars) associated forestry, current mining concessions, agriculture, urbanisation and areas with bedrock predicted to be rich in gold deposits (which in Guyana is used to allocate mining licenses; Fig. A2 and Table A4). For forestry, mining and cultivated land, we calculated opportunity costs from the contribution to national Gross Domestic Product (GDP), divided by the area allocated to its production. To estimate the opportunity cost of areas predicted to be rich in gold outside of current mining concessions, using the geological map of Guyana, we calculated half the value of current mining concessions in areas dominated by greenstone (which is associated with gold). For urban land, we used the market area-based value for housing. We then converted these data into the Marxan format using the CLUZ plugin for QGIS.

We set targets for each conservation feature based on their geographic coverage. We did this separately for the vegetation types and species, using a set target percentage for the feature with the smallest and largest range, and calculating the targets for remaining features using linear interpolation between the two extremes (Maiorano et al., 2006). Informed by sensitivity analyses, and in collaboration with the stakeholders, we set a 20% target for the smallest range and 1% target for the largest range (Fig. A3), helping to ensure a viable amount of each feature would be protected and producing results that did not select an unfeasibly large proportion of the country. We then measured the extent to which these targets were met in the current protected area network.

Marxan analyses involve multiple runs to identify near-optimal portfolios of planning units that meet targets, while minimising opportunity costs and boundary lengths. Thus, the most effective portfolios meet the targets while containing large patches of low-cost planning units (Ball et al., 2009). Marxan then produces two main outputs: the 'best' portfolio, which is the one with the lowest cost and the 'selection frequency' output, which counts the number of times each planning unit appeared in one of the portfolios. Each of our Marxan analyses consisted of 100 runs of 50 million iterations. After sensitivity analyses, we used a Boundary Length Modifier value of five to calculate the boundary cost, based on the total external edge of the portfolio, which is subsequently used to select viable patch sizes that are not too fragmented (Ball et al., 2009).

In our first baseline analysis, we specified that the existing protected areas should be automatically included in every Marxan portfolio, and any of the other planning units could be selected if needed. The results confirmed the conservation importance of community lands in Guyana, as planning units within each of 50 different community lands had high selection frequencies. Consequently, we then measured the relative importance of each of these community lands by excluding them sequentially in 50 additional analyses, each time calculating the number of targets met, the total planning unit cost, external edge and median patch area of the best portfolio compared with the baseline analysis. In this way, we: (a) determined whether excluding specific community lands from the analysis affected target attainment and the ecological integrity of the portfolio compared to the baseline analysis; (b) could measure the extent to which excluding each community land increased the opportunity costs of protecting the set of priority areas identified by Marxan.

3. Results

3.1. Representation in the current protected area network

Guyana's current protected area network covers c. 1.8 million ha but meets the representation targets for only 48% of vertebrate species (60%, 24% and 11% for bird, mammal, reptile and amphibian species respectively) and just five of the 17 vegetation types (mangrove, marsh forest, mixed lowland forest and white sand forest in southern Guyana) (Fig. 2). Grasslands, highlands and wetlands are largely missing from the network. Of the threatened species, eight are completely absent

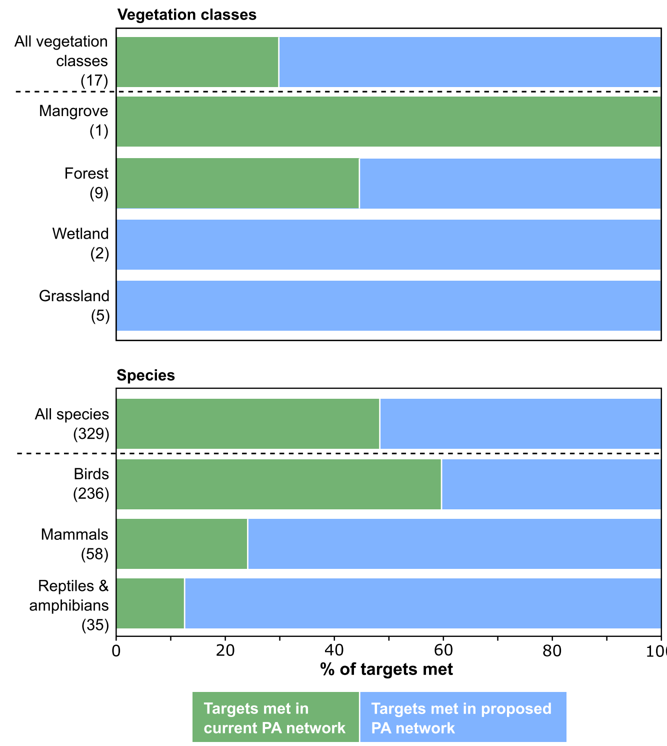

Fig. 2. Percent of conservation feature targets met in Guyana's the current protected area (PA) network in green, and the percent of targets that would be met by the conservation plan in blue (i.e. the proposed network meets all targets). Vegetation classes (top panel) are partitioned into broad categories of mangrove, forest, wetland, and grassland. Species (bottom panel) are partitioned into birds, mammals, and reptiles and amphibians. Number of species/vegetation types associated with each bar are show in parentheses. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

from the existing protected areas. These are, four birds: Rio Branco antbird (*Cercomacra carbonaria*; CR), hoary-throated spinetail (*Synallaxis kollari*; CR), Red Siskin (*Carduelis cucullata*; EN), white-bellied piculet (*Picumnus spilogaster*; VU); two amphibians: MacConnell's bush toad (*Oreophrynella macconnelli*; VU), Pebas stubfoot toad (*Atelopus spumarius*; VU); and two mammals: Reig's opossum (*Monodelphis reigi*; VU), and Venezuelan fish-eating rat (*Neusticomys venezuelae*; VU).

3.2. Priority areas for conservation outside of the current protected area network

To meet the CBD Aichi Target of 17%, Guyana needs to double the extent of its protected area network with an additional 8.5% (1.8 million ha) by 2020. Based on meeting representation targets for biodiversity and vegetation, our conservation planning analysis identified approximately 20 priority areas for protection (Fig. 3a). In order to meet all the targets, our baseline analysis shows that an additional 14% (3 million ha) of Guyana's terrestrial area would be required, bringing the extent of the protected area network to 22.5% (4.8 million ha) of the country. Of the additional priority area required for this, 8.8% (1.9 million ha) is state-owned land, and 5.2% (1.1 million ha) is community land. The analysis showed that to meet representation targets, approximately 750,000 ha would be required in the highlands; a little over 1 million ha in the south-western grasslands; 660,000 ha in the north-eastern mixed grasslands, forests and wetlands; 200,000 ha in north western wetlands; and 190,000 ha in the southern forests, with

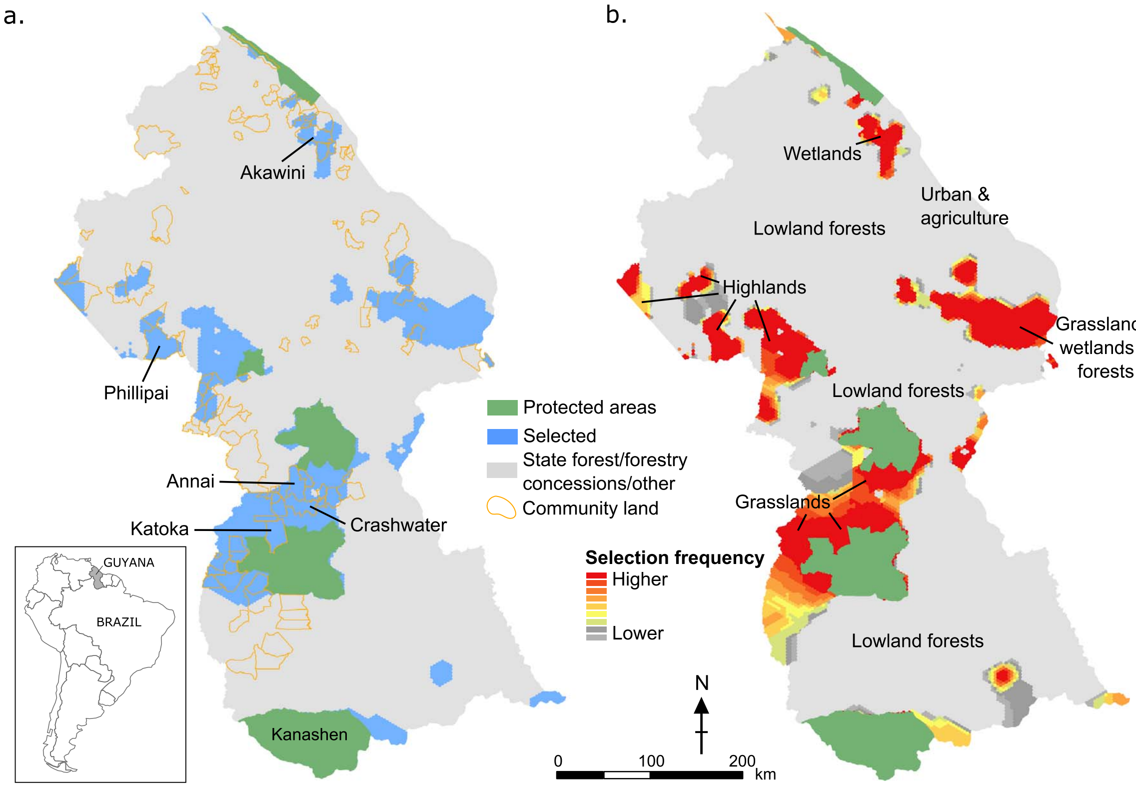

Fig. 3. A. shows the results of the baseline systematic conservation plan for Guyana. Blue areas are selected in the best solution of the analysis. B. indicates the selection frequency of each planning unit from 100 Marxan runs, with the darkest red showing those areas selected in ≥ 90 runs. Existing protected areas are shown in green. The unselected grey areas include unallocated state land, forestry concessions, mining concessions, agricultural land and urban areas (which are almost exclusively along the coastal belt) (Fig. 1). Areas and community lands mentioned in the text are labelled. See Fig. A1 for detailed habitat map. Inset shows the location of Guyana in South America. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Attributes of the baseline conservation plan for Guyana, where no community lands were excluded, and the five most important communities for meeting conservation targets with greatest ecological integrity (e.g. largest patches sizes, less edge, decreased opportunity costs). See also Fig. 4.

Analysis	Mean selection frequency in baseline portfolio (%)	Median patch size (ha)	Number of patches	Total edge (m)	Total opportunity cost (US$)	Portfolio area (ha)	Portfolio area (% of country)	Percentage of portfolio in community lands (excluding Kanashen)
Baseline	–	70,832	18	3,392,979	12,869,228	4,768,386	22.5	5.2
Excluded community								
Phillipai	85.38	58,798	18	3,530,605	13,578,233	4,668,840	22.0	4.8
Akawini	83.26	48,000	21	3,442,013	13,382,968	4,669,679	22.0	4.7
Katoka	99.92	51,050	22	3,491,226	13,060,845	4,595,027	21.7	4.4
Crash water	92.25	69,510	20	3,515,180	13,107,425	5,147,217	24.3	5.1
Annai	88.38	65,138	21	3,436,697	13,137,224	4,578,050	21.6	4.4

the remaining approximately 200,000 ha distributed in smaller patches throughout the country. To meet just the 17% target, the top priority areas are the largest patches with highest selection frequency scores, i.e. those selected in ≥ 90% of runs which are at least as big as the current smallest protected area in Guyana (Fig. 3b). These are two areas of highlands in the west, grasslands in the south-west that join two existing protected areas, mixed grasslands, forests and wetlands in the north-east, and wetlands in the north-west. Protecting these areas would mean every species and vegetation type would at least be represented within a protected area in Guyana.

3.3. Identifying the most important community lands for expanding the protected area network

The 50 analyses that excluded each community land in turn showed that no single community land was essential for meeting targets. However, excluding these community lands did have an impact on the opportunity costs and fragmentation levels of the portfolios, compared to the baseline analysis where all community land was available for selection. The five most important community lands were Phillipai, Akawini, Katoka, Crashwater and Annai, as their omission caused opportunity costs to rise by between 1.5% and 5.5% (Table 1; Fig. 4), and

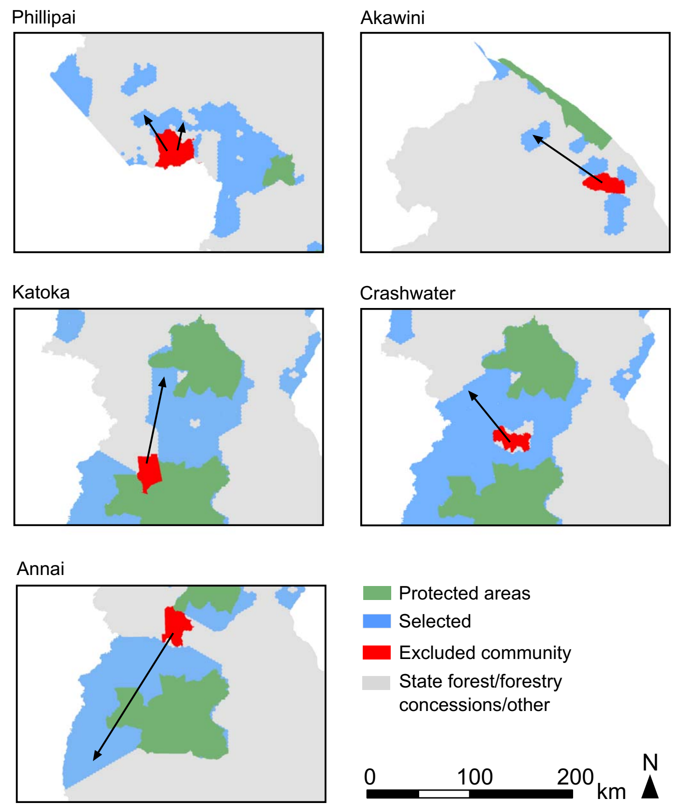

Fig. 4. Results of the spatial prioritisation when each of the 5 most important community lands are excluded from the analysis. The arrows show the areas where the analysis has selected to meet the targets in lieu of the community land being unavailable. See Table 1 for further details of each analysis.

resulted in the selection of areas that in the baseline analysis had comparatively low selection frequency scores (Fig. 3b). Likewise their omission increased the boundary edge of the sets of priority areas by between 49,000 m and 140,000 m, and decreased median patch size by between 1.9% and 32.2%, compared to the baseline analysis.

4. Discussion

With over half of CBD parties yet to meet their commitments under Aichi Target 11, the coming three years should represent the fastest terrestrial protected area expansion rate ever seen. To contribute to this, our study shows that the systematic conservation planning approach is suitable for national-scale prioritisations because it is based on a set of principles that are scientifically sound but flexible enough to adapt to national conditions (Margules and Pressey, 2000). Therefore, the value of these techniques depends on accounting for the implementation context (Knight et al., 2011), ensuring the results are relevant for guiding policy. For Guyana, this entails establishing new protected areas to fulfil Aichi commitments, and additionally to contribute to avoided deforestation targets under the country's REDD+ agreement with Norway. As such, our study illustrates a cost-effective, stakeholder-led and collaborative initiative that is now guiding conservation action because it was driven by national priorities, as well as biodiversity conservation. This not only provides a conservation plan to represent all biodiversity and vegetation types in this part of Amazonia, but also shows the value of national-scale and agency-led spatial conservation prioritisations.

In the near-term, Guyana has committed to expand its protected area network by 2 million ha (to 17%). To direct this, our analyses highlight several biomes that are currently unprotected, such as the forested highlands that are home to the unique, long isolated steep-sided mountains known as Tepuis. Their flat peaks are rich in restricted range endemic species (McPherson, 2008), and connect with the Canaima and Mount Roraima National Parks in Venezuela and Brazil. These highlands are shown to be critical to achieving conservation targets in Guyana, because they exhibit high selection frequency, and in addition, they are shown to be important in global spatial conservation prioritisations (Pollock et al., 2017; Venter et al., 2014). So alongside affirming the biodiversity value of these areas, our study provides maps at a suitable scale for use by policy makers to delineate protected area boundaries.

Our spatial conservation prioritisation also demonstrates that it is not just forests that need protection, as the biodiversity-rich grasslands are poorly represented in Guyana's protected area network. In particular, our analyses identified the Rupununi Savannas, which contain a range of under-protected habitats and species, and the Rio Branco Endemic Bird Area. This area additionally illustrates the importance of community lands in optimising the biodiversity value of future land-use strategies, as the Rupununi Savannas are predominantly community-owned, and encompass three of the five most critical community lands as identified by our analysis (Table 1; Fig. 4). If the communities in the Rupununi opted for protected area expansion (and this is currently being assessed), their lands would connect two existing protected areas to the Raposa Serra do Sol reserve in Brazil, and establish the largest protected area expanse in Guyana.

Our spatial prioritisation additionally contributes directly to Guyana's commitments under the REDD+ agreement with Norway, by incorporating biodiversity into Guyana's land-use planning process, which is centred on reducing deforestation rates and carbon emissions via sustainable economy initiatives. While our approach does not directly target areas of increased deforestation risk, country-wide deforestation targets will be delivered through policies that combine effectively managed protected areas (which are selected for biodiversity) with low-level resource extraction outside protected areas. If well managed, these extraction areas can be OECMs, which are recognised in the Aichi targets as playing a similarly important role as protected areas (Angelsen and Rudel, 2013; CBD, 2010). Indeed, most forestry operations in Guyana adopt low-intensity reduced-impact logging, which local and global studies have shown to maintain an almost full complement of tropical forest biodiversity (e.g. Bicknell et al., 2014, 2015; Roopsind et al., 2017). For this reason, the Government of Guyana is strengthening sustainable land management in general, and this can also be guided by our priority area map, which identified a further 1.2 million ha beyond the land needed to meet the Aichi Target. In addition, community areas may contribute to both protected area expansion and OECMs (Nepstad et al., 2006), and together with reduced-impact logging, could form a spatial conservation network aimed at reconciling development with the maintenance of high conservation values. As a national strategy, these might also help to shift the economy away from mineral mining, which is the principal source of forest loss in Guyana, towards a more environmentally sustainable and low-carbon model. Doing so would contribute to the reduction in deforestation required to receive performance-related REDD+ payments (Office of the President, 2013).

Given the importance of community lands in Guyana, successfully expanding the protected area network will involve working together with landowners, a process that underpins the principle of free prior and informed consent required by the CBD and REDD+ agreement. About 15% of Guyana's land is under the ownership of local communities, so support from these people is crucial for meeting the targets. Previous analyses have shown that incorporating data on landowner willingness to engage in conservation prioritisations is a powerful way to increase support for the identified priority areas (Game et al., 2011; Guerrero et al., 2010). However, because community lands in Guyana are large and remote, it would be prohibitively costly to measure willingness beforehand. Instead, we used our scenario analyses to identify the relative importance of each community, thus helping prioritise where consultations should first take place. We found no single community land was vital for meeting targets, and this flexibility means policy makers can make alternative plans if one or several communities choose not to participate. However, if any community decided not to engage with the conservation plan, this would have negative impacts on opportunity costs and levels of fragmentation in the resulting priority areas.

5. Conclusions

Our study is a stakeholder-led spatial conservation prioritisation process for Guyana, informed by science and underpinned by the systematic conservation planning approach. This has helped both to ensure that biodiversity is adequately represented in protected area expansion, and embed the results into broader land-use decision-making, including working with local communities. Once implementation is completed, Guyana will be a major contributor to long-term conservation in this part of Amazonia, alongside demonstrating exemplary accomplishment of its Aichi Target 11 commitments. As such, our work shows the relevance of using systematic conservation planning to design protected area networks that translate international conservation commitments into national action.

Acknowledgements

We would like to thank the following people for contributing to the spatial conservation prioritisation: H. Persaud, A. Roberts, P. Rampersaud, C. Hutchinson, C. Bernard, B. ter Welle, D. Singh, R. Singh, N. Nasir, A. Foo, C. Sookdeo, M. Paul, M. Kalamandeen, G. Agard, M. Saywack, R. Smith, D. Singh, P. Williams, S. Rose, R. Thomas, K. Mosley, A. Mohamed, T. Yussuff, J. Breems, A. Bayney, C. Harilal, A. Adams, O. Davis, V. Rajkumar. Thanks also to K. Metcalfe for Marxan guidance, and P. Mitchell and T. Laing for advice. Data used in the analyses are freely available on request from the Guyana Conservation Network (www.guycon.org). J. Bicknell, M. Struebig and Z. Davies are supported by NERC grant number NE/K016407/1.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.biocon.2017.08.024.

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