**V2**

**Rachel**

I've had a first crack at the draft.  What an incredible amount of work you've pulled together, Richard, well done. Also - super neat results. I really like the hopeful message about how incorporating uncertainty can fit within the post-2020 protection targets. I think it would be worth featuring this in the abstract - I've made an effort to cut down words so you can move it up, if everyone else agrees.

Sorry it's a little messy - I tried to shuffle the introductory material around to minimize repetition. This might be me being slow, but the wording in the results is confusing for a non-spatial prioritization specialist.  When you talk about percentages, perhaps you can try to clarify what you mean - the percent increase in protected area required to meet the 30% target for vertebrates? The percent increase in protected area above baseline required to meet the 30% target for vertebrates? Also - is it true that some of the scenarios with uncertainty incorporated require less protected area to meet the target than baseline? If so, this might be a result worth highlighting and discussing.  I'm still trying to wrap my head around why this would be the case - because new habitat is created for some species under climate change? Because land-use change is predicted to be more forested/natural than ag in some places in the future?

Just an idea for the results - what if we related the %variation in PA needed between scenarios to the different amounts of uncertainty. You do this informally for Libya and Indonesia, but what about doing this in a quantitative way? E.g., the relationship between countries probability of novel climates (or is it extreme climates now?) versus variation in PA between scenarios; predicted increase in X land-use type (e.g., agriculture) versus variation in PA between scenarios; and socio-political uncertainty versus variation in PA between scenarios.  Happy to discuss more, but might help discuss how these various sources of uncertainty affect results.

**Joe**

This is awesome. Super exciting to see it come together.

I’ve attached a bunch of comments, which I hope are not too out to lunch.

In general, I wonder if we should think about the main message. Right now it reads like it’s mostly about the framework, with the results being an interesting outcome. I think this is really cool, but I wonder if a reviewer may question whether our framework really unique. Or could a reviewer just say that it’s adding a couple of new things onto an established framework? I’m always thinking in terms of nasty reviewers, so I may be totally wrong.

One option is to shift a bit of the emphasis to the very interesting differences, depending on what is considered. It’s just a very subtle shift in emphasis. To me that’s maybe slightly less risky than making things mostly about framework.

I didn’t make this sort of change because of the issue of me being potentially out to lunch.

Another potential thing we may have to watch for is wording around what we test. Currently, it’s not super consistent, but here’s an excerpt:

“Here we introduce a framework that can simultaneously incorporate a range of uncertainties, including political instability and corruption; weak governance; systemic crisis; the probability of project failure; land use impacts…”

I feel like a reviewer may be expecting a clear test of each, and I wonder if a reviewer may question whether we really test something like “systemic crisis”. Do you think we should link this more directly with the datasets, and adjust the wording a bit to reflect their detail? Again, I think it’s just a very subtle shift and not a huge deal at all.

I’m happy to help with framing, if you think this is reasonable. But 100% no worries if you think I’m being paranoid. I know I do that with papers…

Also, I really like Rachel’s idea re testing differences among scenarios.

**Jeff**

Awesome work Richard - I think this is coming along really well!

I agree that it would be better to focus more on the "results" rather than the "framework". I worry that an Editor might not think a "methods paper" is right for the main Nature journal, and think  it more suitable for Nature Methods. I also think a reviewer might not think the methodological advance is a big enough break through to warrant a Nature publication.

I also think the introduction might read better if you provided more clear examples of why accounting for risk is important by describing how this might impact species. E.g. you could mention something about shifting species distributions due to climate,  "weak links" (I can't think of a better descriptor- can you?) due to political stuff (specifically, overall representing in a species in a  "risky country") , or lost opportunities due to land-use? I think talking about the spatial impacts of these uncertainties might also lead into the spatial prioritization stuff in the Introduction.

Also, in the results section, it might help "ground" the study a bit more if you pick a few VU/EN/CR case-study species and talk about how their representation differed among the scenarios. E.g. pick three species and spend 2-3 sentences on each one and talk about how the different scenarios affected "where" they would be represented and what this means for the future of these species. For example something like "species XXX  is a critically endangered skink that is especially sensitive to climate change because $PHYSIOLOGICAL\_REASONS. Explicitly accounting for climate change risks is important for this species because the scenarios that did not account for climate change risks represented it in $PLACES  that have very high climate velocity---places where it's long-term persistence is unlikey. " Or something like that?

**Viv**

I like Jeffs idea of picking some species (or ecosystems?) for a figure is a good one especially for nature – could make an interesting figure if we have pull out boxes with their distribution and a pretty photo of them and then a bar graph of the threats/protection level or something?

There are a lot of comments and edits in the attached - I started editing but it might be easier to comment on a fresh copy as its getting hard to see who’s edited what! I’ve attached it here for you Richard, am happy to have the first go at the next clean draft? Happy to workshop a pretty species pop out figure with you as well if that helps.

**V1**

**Rachel:**

#2: I think the main results are A) the differences that result from including different types of risk in how much land should be put aside for protection; and B ) a map of the spatial distribution of these differences. Are there any regional patterns that pop out? Any "risky" countries that get identified as high priority for protection without risk and flip to low priority for protection with risk or vice versa?  I think this should largely be based on our objectives, which we should spell out up front (sorry - I think this was my job and I just haven't had time). Richard and I talked about something like an objective of 'guiding investment in land protection in different countries and how anthropocene risk will affect investment prioritization'.

[JB: agree that this is what we can focus on. This might take the focus off the metrics themselves, and put it on how things differ when you include metrics.]

**Viv:**

Just a thought - I kind of see the “gap” as how risk averse we are trying to be. To most people talking about an optimality gap is not terribly informative (same as the MarProb “certainty target”) – but if we talk about how risky/risk averse we are trying to be, then we can use that to justify the low optimality gap (e.g. we are risk averse?). That helps us explain in more laymens terms why decreasing the gap results in increasing numbers of planning units (because we “buffer” the risk of climate change). Might be a nice way to talk about the results in discussion to bring it back to management/policy implications.

**Jeff response:** Yeah, I think that is a really nice way to describe the optimality gap stuff in the paper. I think we could include a "cost" objective as the final/last objective in the multi-objective optimisation process so that this description is closer to being technically correct (e.g. if we are just treating area as cost, then we just need area values in the last objective)?

Yeah, I'm think of including it as an additional objective in the multi-objective optimization. I really doubt that it will have much of an influence on the results, but methodologically/conceptually this would mean that our risk scenarios are identical to the baseline scenario - except that they have an initial step(s) that exclude feasible solutions that are relatively risky (i.e. they have additional preliminary objectives). If this isn't computationally feasible, then don't worry. But if we could add area=cost as the last objective to the multi-objective optimization, then conceptually I think this would help with describing the optimality gap as a measure of risk adverseness? For example, the reader could see that the difference between the baseline (cost=area objective) scenario and the climate risk (climate risk + cost=area objectives) scenario is that the climate risk scenario has an additional objective (rather than a different objective altogeather) which serves as a filter for excluding highly risky solutions. Does that make sense? But again, I don't know if this is computationally feasible or not?

[JB: I think they’re different types of risk aversion so I wouldn’t say they’re directly comparable as say including 2 is somehow double, but I doubt that’s what others mean anyway]

**Peter A:**

I sense in particular that more care is need to carefully develop and define 'socio-political risk' because it is vague an not clearly quantifiable on first mention, and I was not able to see what World Bank indexes you used, or combined, in your pilot runs. My particular comment in Methods after looking at the link is: Whilst I do think one can re-name and define 'risk' in many ways appropriate to the problem generally described, as a reader I am unclear how that is being done here, how the ‘units’ of risk as envisioned are linked to ‘costs’ valued monetarily, etc.

I think all this can reasonably be done, but I suspect one will need to think a) carefully about this; b) offer a clear rationale for metrics selected, and c) estimate results over perhaps 3 semi-independent measures of human well-being/risk to be able to address inevitable questions on this account, and perhaps present a fuller view of the issue using ‘risk’ indexes compatible with those likely held by a range of inter-disciplinary planners. I'm also happy to help as Chris Barrett and I considered these indicators and others in modeling risk of conservation failures in Serengeti and ICDPs generally in the late 90's.

[JB: I think he’s asking us to more clearly define risk. Perhaps better indicating how these things are incorporated into optimization would help.]

I think it needs to be very clearly stated how the multi-level optimization values costs and benefits were derived, what specific indexes were used (and why), and I think given many view of risk in the Lit, that it may be advisable to develop 3-4 similar but independent estimates of 'risk' to ask how they may correspond or not.

[JB: so more details in the methods. Seems like a good idea. I’m not sure what he means by developing the estimates… I think we use canned ones?]

In the economic/resource harvest lit, people calculate the Pareto Frontier, but often in 2D. However, this can also done for multi-dimensional problems, and I bet some reviewers will expect to see those here.

[JB: so many ways of doing things… I feel like we just need to acknowledge this. Peter will want one thing, but a reviewer will undoubtedly want another.]

*Richard’s better response: As for the governance data/indicators, Rachel and Jeremy can speak more to that, but in a nutshell, we built on the attached paper, which found that governance explained variation in responses to the biodiversity crisis. The spatial representation of what we used is also attached. The index goes from dark red (low values) to green (high values), in this case representing stability. When we use that data in the prioritization we assign higher cost to red and less cost to green.*

Lots of options - one might be a 'star' diagram with countries listed in alphabetical order around edge of circle/star, and then have lines indicating current and necessary increase to reach 30%.

[JB: sounds cool]

More dramatic/interesting might be to arrange countries vertically by GDP or CPP (consumer purchasing power) and use bars headed to right that show area protected, and increase necessary.

[JB: also cool]

**Peter V**

Thanks for sharing. This sounds like a nice approach, I like the framing. In the intro we need to be very careful as risks are not something like cost-benefit/returns to investment, these types of risk are not suitable for such 'economic' approach and there is of course a clear tradeoff of protecting the 'one' species versus the risk of not being successful. I think that is a great challenge to discuss.

[JB: I think he’s indicating that risk here is more than economic? But I’m not sure. In general, I agree – and I know you do too – that reviewers will get hung up on terminology. I’ve suggested things in the doc but happy to discuss.]

In the Netherlands there is now a big discussion of our previous policy in which very small areas with specific species were protected (leading to a very fragmented protected area network) that fails due to nitrogen deposition of nearby agriculture, ground water level changes due to nearby agriculture etc. So, in the design, while the protection itself is 'perfect', these risks of externalities impacting on the areas was not accounted for. I think it is important to state that the risks here accounted for have very different character: climate risk basically threatening the existence of the ecosystem directly, land use change pressure can be reduced by protection, but, in general in areas of high land use change protection is less efficient/effective, and the socio-economic risk is of course affecting multiple aspects: the stability of protected areas (some weird president suddently taking away protected status again); the enforcement of protection; the abundance of illegal activities/poaching etc. Now, the world bank indicator 'stability' is one that is indeed proven to be good and I think the strong point is that you have the other paper to refer to, so you can refer to that study. In the past we also tried some other indicators for several studies and found that the 'corruption/law enforcement' indices are sometimes also useful for certain processes (but hard to interpret). For poaching and illegal logging it may be a good indicator to capture that (so, subdividing the socio-economic risk in two: the risk of illegal activities (corruption index) and the risk of instability of governance (stability index).

[JB: Some advice re metrics]

**Scott Wilson**

*1) Is the current approach sound or do you think we need to tweak things?*

Overall yes but it would be good to discuss the threat scores, I’ve added some thoughts on that in the draft. I also wasn’t clear on climate risk and what that risk was separate from the influence of climate on land use change. I assume it’s more of the direct impact of a changing climate on species but I’m not sure how that risk is measured.

*2) Do you have ideas on how to best present the results? (a summary table is included on Line 101, which shows how much land each approach would require; the attached csv file shows how many 100x100km cells were selected per country in each of the eight scenarios investigated)*

I like the summary table on the area needs for each combination of scenarios. One possibility for a figure is a multi-panel global figure showing the change in area (color coded) relative to the base scenario in each country for each objective individually (socioeconomic, land-use, climate) and all objectives together. Similar to Fig 2 in the Nature Comm. paper but with change in area selected under different risk objectives rather than selection frequency. Absolute area amounts for each country and scenario could be in the Supplementary material.

I also like Peter’s thoughts on a table or bar figure showing current and required area amounts for each country to meet targets, although would be a lot to show it by country for the main paper. We could sum to the continental level to show general patterns and then refer readers to Supp. Material for the same in each country.

*3) Could you express your interest in joining a group call to discuss this is more detail?*

Happy to discuss by Skype or individually.

**Jeff**

1) Is the current approach sound or do you think we need to tweak things?

I think it's all great, except I worry that the current scoring approach for land-use might not fare well when subject to peer review and I wonder if there is a less subjective approach? I can't think of any ideas though with just the land classifications.

2) Do you have ideas on how to best present the results? (a summary table is included on Line 101, which shows how much land each approach would require; the attached csv file shows how many 100x100km cells were selected per country in each of the eight scenarios investigated)

I would show a multi-panel figure with each panel for a different prioritisation (baseline prioritization, prioritisations for each risk layer separately, and prioritization with all risk layers together). To help emphasize differences between the prioritisations, I would suggest having the baseline prioritisation map show the actual prioritisation, and the remaining maps show differences between each of the other prioritizations and the baseline prioritization. To further help emphasize differences between prioritisations in these maps, you could aggregate the prioritizations to a coarser resolution (e.g. `raster::aggregate(x - y, "mean")`) and then plot the values on a continuous color ramp. I wouldn't show/summarise the prioritisations at the country-scale because you can lose a lot of detail for large countries - but that's just my opinion.

**Peter V’s response:**

I think Jeffrey makes a very good point by indicating that the current scoring table approach for land use is not the best. When we applied it in previous papers they were always rejected by reviewers based on this approach. At the same time, we all know that many of the global assessments use very similar approaches and are a full part of IPBES (i.e. the MSA approach is not a lot more than a similar table, even only accounting for broad land cover classes; also the PREDICTS approach uses a similar rationale in the end).

In the past we also tried approaches based on individual species distribution maps, a lot more work but introducing another whoe set of assumptions. In a European project we are now testing a food web approach, but, far from being operational and I am doubting if it will work.

But, it might be good to try to use some of the very accepted metrics in global assessments and refine these a bit with the land system information. But, I am not an expert in this type of assessments.

**Peter V:**

If our factors are aligned with these: <https://royalsocietypublishing.org/doi/full/10.1098/rspb.2018.0792> we have a reasonable argument.

Similar is used by: <https://laurakehoe.weebly.com/uploads/9/6/1/9/96198238/kehoe_et_al_2017_nature_ecoevo.pdf>

However, when we did the same reviewers said it was not good enough….

**Amanda:**

Regarding the approach, I think it’s innovative and important. I agree that we need to be explicit about the kinds of risk we are considering and carefully justify why they are most relevant to the conservation targets we’ve outlined. I’m concerned that one criticism will be that risks are project/ecosystem/species-specific. For example, if one wanted to restore & conserve a healthy prairie or Ponderosa Pine forest, then fire is an essential component – not a risk to avoid (except at certain intensities or frequencies). Likewise, certain aquatic systems or riparian habitats require flooding, whereas others are destroyed by them. We might consider focusing on a few specific ecosystem types for which we can better estimate the risk of certain disturbances, land use transitions (e.g., development), or political unrest. With regards to CBD targets related to coverage and representation of different ecosystem types, then we may also need to account for how risk may result in land-cover transitions that might cause reduced coverage in one type but a gain in another type. I might be off-base here. If we think that is an issue, I wonder if focusing on something like forest cover specifically, given the recent and high-profile attention that global reforestation/restoration potential has received in the literature.

**PA:**

As usual, I agree with Amanda's points and think the idea to focus on a small number of systems for more detailed development has potential to address important context Amanda notes; Depending on outlet, perhaps as one or more 'boxed' examples?

Re: your specific

1) socioeconomic. This is a country specific layer and really speaks to the overall chances that conservation measures will be successful in a country (broadly speaking), which I was hoping would be a broad enough metric to encompass pretty much all ecosystems et al.

I think that if you keep targets at a high level, this is a fine approach.

2) land use: the way that we have done the ranking so far (which is still up for discussion) is reflective of degradation (conversion to urban, agriculture, ranching = negative). I do realize that conversion to say agriculture might not be bad for all species, but I think the general trend is that agriculture has negative effects on native biodiversity (which is what we are using in this study).

In this respect, I think we're better off keeping those categories distinct rather than aglomerated. The 'ranching' issue is somewhat related to Amanda's point; sprauge's pipit and upland sandpiper might need some, but disappear with too much or little given available mechansims of maintain short-grass prairie. Lots of papers from NA support you Ag statement, but our own Nature paper this summer indirectly suggests small-holder Ag is critical habitat in SA for Neotrops.

3) climate: currently we are using velocity, but this is really mostly a placeholder to figure out the best layer to use. Franks suggestion is that we use climate novelty as a climate layer. I think this one would work nicely for our broad approach as well, as novel climates will lead to potentially huge disruptions in biodiversity patterns currently present on the landscape. All we have is current information on biodiversity. So if we are presenting effects on current patterns of biodiversity, I think we are again in good shape with this layer, as it would speak to the impact on current biodiversity. There will be shifts in biodiversity into the future, but as we don't have any data on that, I don't think we can/should speculate on future distributions of critters, but focus on what we currently know.

I like climate novelty over velocity, but both can be tied to anticipated rates of evolution and the ability of spp to 'keep-up'. For your purpose, I think novelty is best.

Thank you!