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研究課題名（和文）Multidimensional risk diversification for conserving coastal wetlands under climate change uncertainty

研究課題名（英文）Multidimensional risk diversification for conserving coastal wetlands under climate change uncertainty

研究代表者
ＳＨＡＨ　ＰＡＹＡＬ（Shah, Payal）

沖縄科学技術大学院大学・サイエンステクノロジーグループ・サイエンス･テクノロジーアソシエイト

研究者番号：３０７７３２２０

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研究成果の概要（和文）：ポートフォリオ理論は、気候変動の不確実性によるリスクを軽減することを目的とした保全活動の指針として使用されます。 ただし、標準的なポートフォリオ理論には 2 つの大きな欠点があります。 1) 情報集約型であり、2) 静的で時間的な柔軟性がありません。 私たちは、十分な情報が得られていない気候変動に直面して体系的な保全計画に使用できる 3 つの統計的推定値を特定します。 最後に、プロトフォリオ理論とリアルオプション分析を組み合わせて、保全環境における気候変動に関連する空間的および時間的不確実性の両方を考慮できるフレームワークを開発します。

研究成果の学術的意義や社会的意義
Climate change poses dire threats to species, biodiversity and ecosystem services and creates challenges for conservation planning. The methods developed in this project can help conservation planners design effective policy that can efficiently manage the risk from climate uncertainty.

研究成果の概要（英文）：Modern portfolio theory is used to guide conservation efforts aimed at reducing climate chnage driven uncertainty in future conservation outcomes. However, standard portfolio theory has two main shortcomings: 1) it is information intensive and cannot be applied for fine-sclae conservation planning; and 2) it is static in nature and fails to accountfor temporal changes associated with climate uncertainty. We modify the portfolio optimization probelm to address these problems. We identify and compare three robust statistical estimators that can be used for systematic conservation planning under climate change with insufficient information. We also combine the standard portfolio theory framework with Marxan to minimize the risk of climate uncertainty for fine scale conservation planning. Finally, we combine protfolio theory with real options analyses to develop a framework that can consider both spatial and temporal uncertainties associated with climate change in conservation settings.

研究分野：Environmental Economics

キーワード：modern portfolio theory　climate change　conservation policy　real options

１．研究開始当初の背景

Climate change is the most significant environmental issue of our time and poses dire threats to species, biodiversity and ecosystem services. Protection of the environment for future generations and efforts to limit the impacts of climate change are of the utmost importance. However, uncertainty associated with future climate projections complicates decision making associated with the management and protection of the environment. New science is needed to manage the risk that climate uncertainty creates for future outcomes of current environmental conservation investments. Climate change–driven uncertainty in future environmental outcomes makes it difficult for conservation planners to undertake systematic conservation planning. Protecting places that currently have high conservation value does not ensure that the future conservation value of those areas will be high. Portfolio theory has been used in several branches of economic research on natural resources management under climate uncertainty, including biodiversity conservation, fishery management, forest restoration, and invasive species control. Existing risk management tool based on portfolio theory enables policy makers and conservation planners to exploit information on spatial covariances in future environmental outcomes to efficiently allocate conservation and environmental management investments across space. However, these methods assume a static conservation planning strategy that does not change over time and thus fails to take into account the dynamic nature of climate change uncertainty. Existing methods also do not allow for fine-scale conservation planning when the climate change information is insufficient.

２．研究の目的

Species, biodiversity and ecosystem services are declining globally at an unprecedented rate. Given the severity of this environmental crises, there is a new and urgent call to protect 30% of the world's ocean and land area by 2030. But climate change creates new challenges about when, where and what to protect to ensure future ecological outcomes and targets are met. This study will develop a new theoretical framework that can help identify when and what to protect and how much resources should be invested for protection to achieve the best risk-return tradeoffs over time and across space. The new methods will also address the problem of fine scale conservation planning that is especially challenging with limited climate change information. The methods developed are broadly applicable to a variety of environmental planning problems in the face of uncertainty. To demonstrate the applicability of this framework, we illustrate its use for several different case studies: including vegetation conservation in Hokkaido, wetland conservation in the USA and coastal wetland conservation in Australia in the face of a changing climate.

３．研究の方法

We identify three statistical approaches that can overcome the lack of sufficient information and enable the use of modern portfolio theory for fine scale conservation planning in the face of climate change uncertainty. Our methods are based on previous studies from the finance literature that have suggested several estimation strategies to efficiently use portfolio theory to derive optimal portfolio allocations even with insufficient information. We illustrate the use of three methods for identifying efficient portfolio allocation strategies using case studies of wetland conservation planning in North America and coastal conservation planning in Australia. These methods are applicable for a broad range of conservation planning scenarios where the ecological outcome faces climate uncertainty.

In a separate model, we develop a new decision framework for environmental protection under climate change by formally integrating two different risk-reduction strategies: (a) portfolio

theory to diversify across different environmental projects at a single point of time, and (b) real options analyses to determine dynamic modification of environmental actions through time. To develop this new decision framework, we integrate portfolio theory with real options theory in a two-step process.

4．研究成果

Information regarding climate uncertainty and environmental outcomes is often limited and difficult to acquire. We identify and compare three different estimators that can enable a conservation agent to conduct portfolio allocation among a large number of planning units with limited climate change information. These estimation techniques perform well compared to the full information MPT analyses and can lead to potential cost savings due to lower information requirements. We find that all three estimators perform relatively well in the absence of complete information and can provide risk-return trade-offs that are similar to the best possible risk-return trade-offs as determined by the "true" efficient frontier based on complete information. We apply our methods to two case studies to illustrate how to efficiently use portfolio optimization for fine-scale conservation planning with limited climate change information: 1) for the Prairie Pothole Region in the USA (see Figure 1) and 2) for coastal wetland conservation in Australia (see Figure 2).

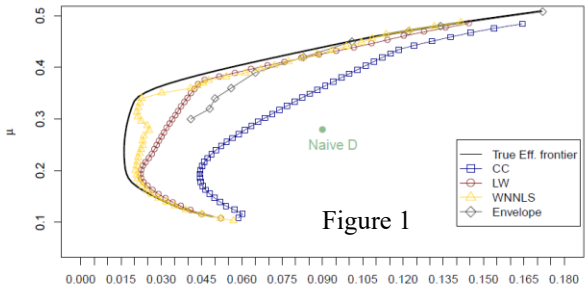

Figure 1

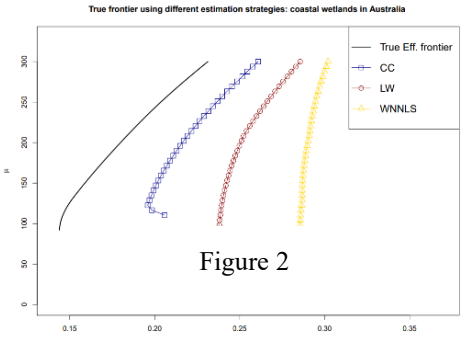

Figure 2

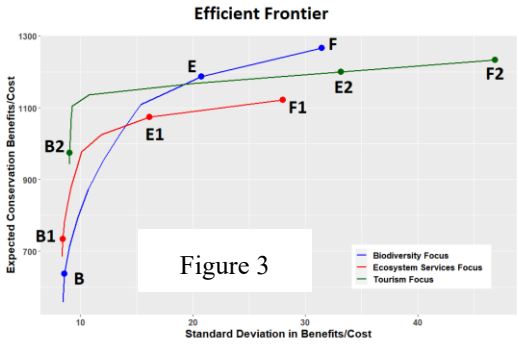

Figure 3

Finally, we also use the case study of Daisetsuzan National Park to illustrate how to combine Marxan and portfolio optimization to do fine-scale conservation planning. Daisetsuzan National Park is rich in alpine plant species that support biodiversity, provide a range of ecosystem services, and support the tourism industry. These alpine vegetations are expected to be particularly vulnerable to climatic changes. We evaluate the expected changes in four types of alpine vegetation (i.e. snow bed, fellfield, wilderness and shrubs) for three climate scenarios and two GCM models across the approximately 900 sq. km. study site. We then combine Marxan site prioritization with portfolio optimization to identify which grids are most important for conservation efforts (see figure 3 for preliminary results).

We have also developed a two-step process that combines portfolio optimization with real options analyses to allow for temporal variation in portfolio allocation strategy. For this framework, in the first step we use portfolio theory to identify how planning decisions can be optimally allocated across different environmental projects based on risk preferences at a given point in time using a predefined budget. We use the results from the first step as an input to the real options analyses in the second step to determine when the allocations from step 1 should be made to accommodate the risk of climate change across time. A combination of these two steps help us determine how much resources to allocate to a particular area or species and when to make that allocation. We have collected data on the predicted changes in the area and types of coastal wetland in the eastern United States. We will use this data to illustrate our two-step framework.

５．主な発表論文等

〔雑誌論文〕　計2件（うち査読付論文　2件／うち国際共著　2件／うちオープンアクセス　1件）

１．著者名 Valentin Popov, Payal Shah, Rebecca Runting, Jonathan Rhodes	４．巻 13 (1)
２．論文標題 Managing risk and uncertainty in systematic conservation planning with insufficient information	５．発行年 2021年
３．雑誌名 Methods in Ecology and Evolution	６．最初と最後の頁 230-242
掲載論文のDOI（デジタルオブジェクト識別子） 10.1111/2041-210X.13725	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 Rhodes, Jonathan, R., Armsworth, Paul, R., Iacona, Gwenllian, Shah, Payal, Gordon, Ascelin, Wilson, Kerrie, A., Runting, Rebecca, K., Bryan, Brett, A.	４．巻 5 (6)
２．論文標題 Flexible conservation decisions for climate adaptation	５．発行年 2022年
３．雑誌名 One Earth	６．最初と最後の頁 622-634
掲載論文のDOI（デジタルオブジェクト識別子） 10.1016/j.oneear.2022.05.010	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

〔学会発表〕　計4件（うち招待講演　3件／うち国際学会　1件）

１．発表者名 Payal Shah
２．発表標題 Application of portfolio theory to conservation planning with climate change uncertainty
３．学会等名 Japan-Tokyo Resource and Environmental Economics (J-TREE) Seminar Series（招待講演）
４．発表年 2021年

１．発表者名 Payal Shah
２．発表標題 How to design and evaluate conservation policy for a changing world
３．学会等名 Amity University（招待講演）
４．発表年 2021年

１．発表者名 Payal Shah
２．発表標題 Application of portfolio theory to conservation planning with climate change uncertainty
３．学会等名 Seminar for National Institute of Environmental Studies（招待講演）
４．発表年 2020年

１．発表者名 Payal Shah
２．発表標題 Combining Portfolio Optimization and Marxan for Robust Conservation Prioritization under Climate Change in Daisetsuzan National Park
３．学会等名 Heartland Environmental and Resource Economics Workshop（国際学会）
４．発表年 2023年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関