ON THE OPTIMAL MANAGEMENT OF WEAKLY INTERACTING NATURAL RESOURCES WITH TIPPING POINTS

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Abstract. We study the management of natural resources that are weakly connected and exhibit tipping behaviour in their dynamics. We obtain approximate feedback optimal management rules for networks of weakly connected natural resource systems by developing the value function with respect to the interaction strength. The method is general and rigorous, and allows to treat the effects of multiple interactions without suffering from the curse of dimensionality. We show that a system consisting of multiple interacting natural resource systems can be managed close to optimally if the interactions between the systems are weak. This is the case even if the system consists of many connected subsystems. Moreover, if the interaction strengths themselves can be controlled, managers can improve the outcome by only allowing beneficial interactions, and shutting down disadvantageous ones. This brings new options for the management of connected resources with tipping points.

1. Introduction

How should we manage multiple resources that can exhibit abrupt changes in their dynamics and that share connections with each other? The crossing of a tipping point can result in abrupt, persistent, and substantial changes called regime shifts (Biggs et al., 2012). Examples include dynamics of natural resources, ecosystems, pollution recipients, and many other types of systems in which humans and nature interact. Evidence suggests that regime shifts can spread to connected systems in multiple ways, generating a wide range of impacts, including passing tipping points that trigger new regime shifts in other connected systems (Anderies et al., 2006; Kinzig et al., 2006; Krönke et al., 2019; Mueller et al., 2009; Peters et al., 2007; Rocha et al., 2015, 2018; Wunderling et al., 2024).

The optimal management literature related to regime shifts has investigated a wide range of situations that lead to abrupt changes and made substantial progress on the optimal management of lakes and other types of natural resources that can exhibit tipping points; see Li et al., 2024 for a recent overview. There is also a growing literature on the management of spatially connected resources (Brock & Xepapadeas, 2020) but with a few exceptions (Crépin & Rocha, 2021; Rocha & Crépin, 2024), those studies almost never focus on tipping points.

There are multiple ways to measure connectivity between landscapes or ecosystems (Correa Ayram et al., 2016; Keeley et al., 2021; Uroy et al., 2021) mirroring the multitude of ways in which connections between ecosystems can influence their dynamics. The strength or intensity of these[1] connections may vary substantially, some systems being highly connected, while others having only relatively weak connections. Human activities can also, voluntarily or not, influence the degree of connectivity between ecosystems, either by creating barriers such as roads or by promoting connections