Applying the social-ecological system framework to construct a biophysical-social forest model: Application to the Quatre-Montagnes forest

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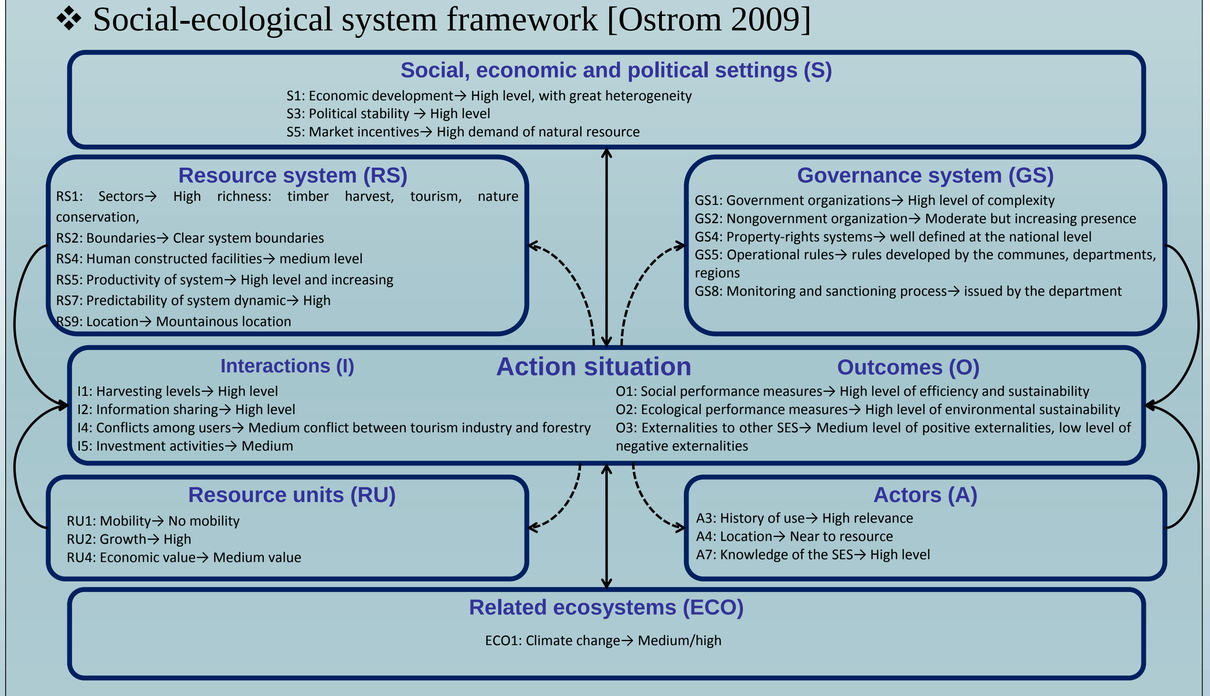
Introduction

Forest policy and management are subject to various and often conflicting demands, which internationally have led to distinct policy responses and related management paradigms. The ever increasing demand on the forest ecosystem to produce wood and other goods and services poses a corresponding demand on a forest decision support system. Forest ecosystem components interact with each other and with the external environment in many different ways and over multiple spatial and temporal scales [Messier et al. 2013]. The capacity of societies to address forest sustainability hinges on their capacity to deal with several social dilemmas associated with integrating their activity and cooperating with respect to the provisioning and use of the forest and human-made infrastructure [Muneepeerakul and Anderies 2017]. Nevertheless, Forest ecological modelling studies often view humans as external disturbance or drivers of ecosystem processes while economic modelling studies often treat ecosystems only as input to a production process. Neither generally takes into account that humans and societies may or may not adapt their behavior as a response to ecological changes. The specific reconciliation and integration of both sides (social and ecological dimensions) of the spectrum have been at the center of scientific discussion on forest policy and management for several decades. Nevertheless, Ostrom [2009] proposed a framework that analytically combines these two aspects. The social-ecological system framework (SES) helps scholars and policy makers to accumulate knowledge from empirical studies and assessments of past efforts at reforms and to organize their analytical, diagnostic, and perspective capabilities. This research centers on understanding the nature of economic-social-ecological interactions through infrastructures point of view. Specifically we seek to study, by means of concise mathematical expressions, the interaction between infrastructures associated with different forest aspect within the dynamics of the robustness framework [Anderies 2004].

Methods

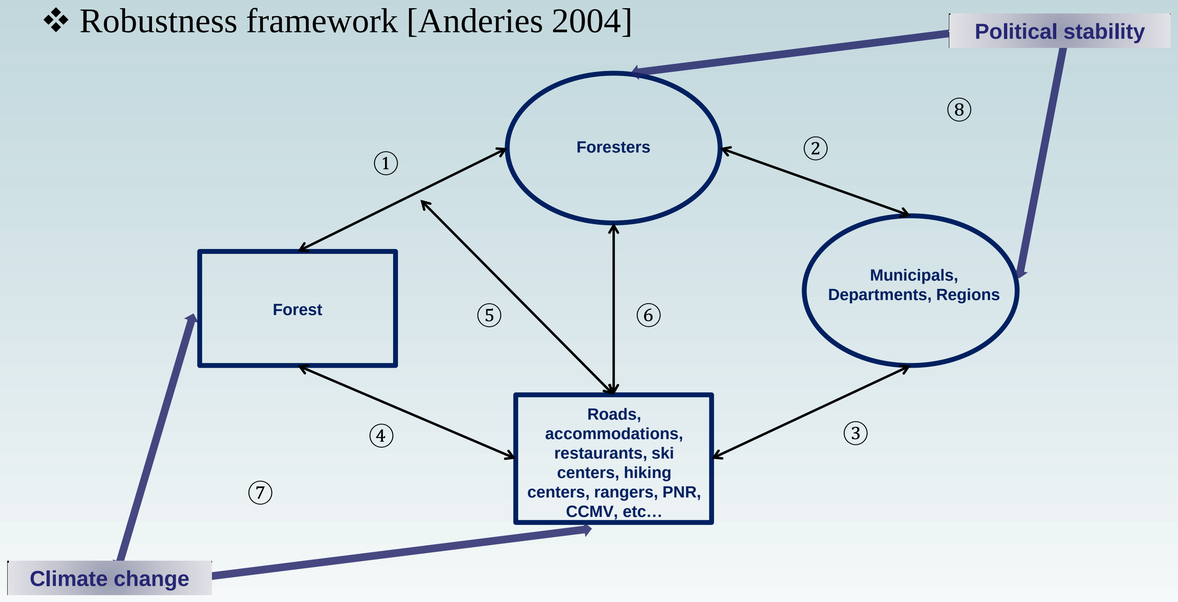
As the literature review the SES framework [Ostrom 2009] as an appropriate tool for examining forests, we first describe the Quatre-Montagne case study area through the SES subsystems lens, emphasizing characteristics that are known to affect the viability of common property institutions.

❖ Social-ecological system framework [Ostrom 2009]

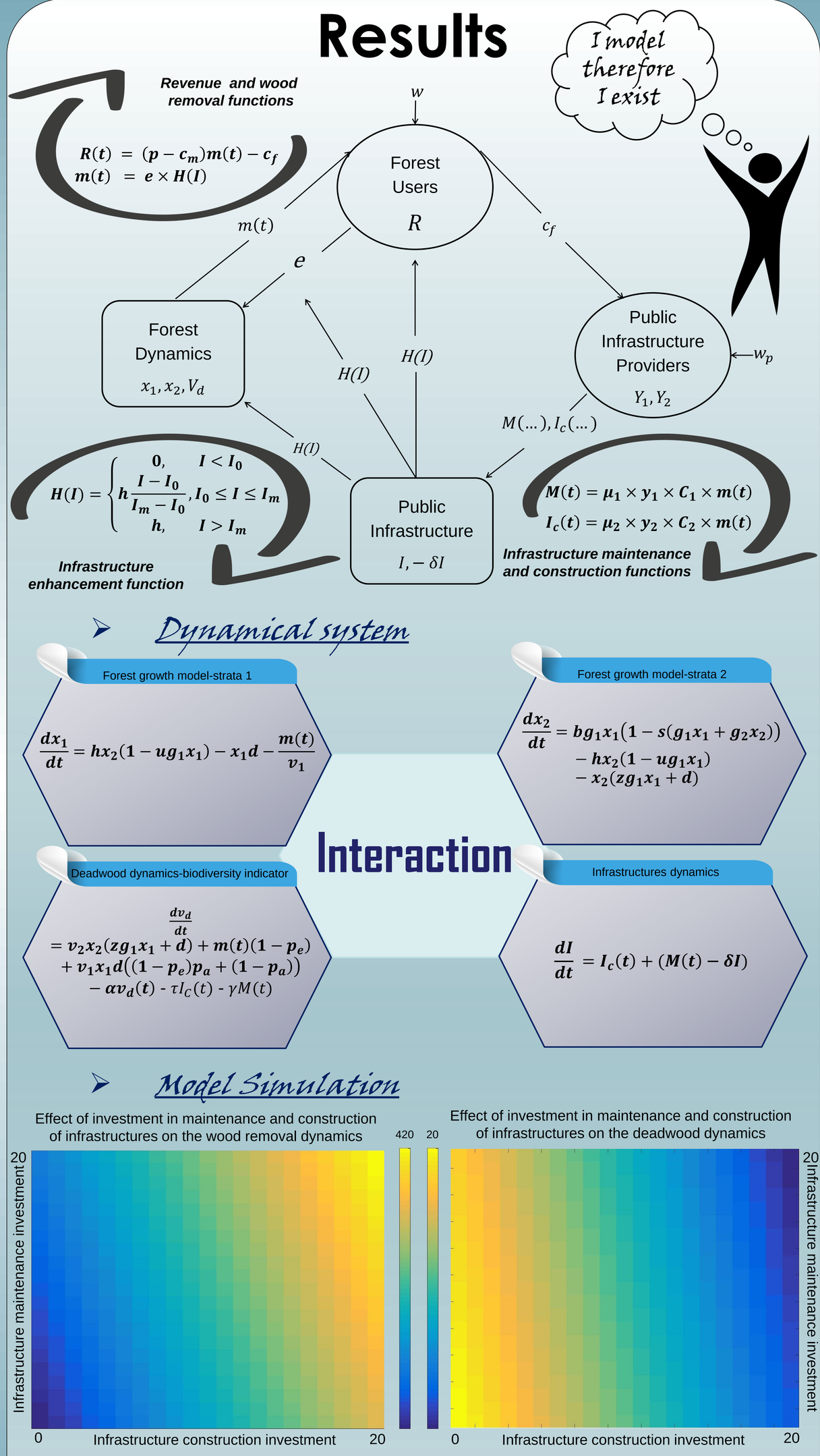


The main goal is to construct a mathematical model that operationalizes the robustness conceptual framework to analyze the interactions in the forest. Particularly, we seek to present the forest management through the lens of the robustness framework. The model brings to clear focus the exchange between diverse forest users, functionality of human-made infrastructure, dynamics of the forest, and governance influence. We derive a variety of trade-offs between investments in construction and maintenance of public infrastructure for forestry.

❖ Robustness framework [Anderies 2004]



Results



➢ Dynamical system

Forest growth model-strata 1

$$\frac{dx_1}{dt} = hx_2(1 - ug_1x_1) - x_1d - \frac{m(t)}{v_1}$$

Forest growth model-strata 2

$$\frac{dx_2}{dt} = bg_1x_1\big(1 - s(g_1x_1 + g_2x_2)\big) - hx_2(1 - ug_1x_1) - x_2(zg_1x_1 + d)$$

Interaction

Deadwood dynamics-biodiversity indicator

$$\frac{dv_d}{dt} = v_2x_2(zg_1x_1 + d) + m(t)(1 - p_e) + v_1x_1d\big((1 - p_e)p_a + (1 - p_a)\big) - \alpha v_d(t) - \tau I_C(t) - \gamma M(t)$$

Infrastructures dynamics

$$\frac{dI}{dt} = I_c(t) + (M(t) - \delta I)$$

➢ Model Simulation

Conclusions

We applied the SES framework to examine the multiple social and ecological factors that potentially affect the biophysical outcomes of the forest in Quatre-Montagne area, France, and we found out that the main aspect influencing the outcomes of the forest is the availability of infrastructure. Thus, we apply the robustness framework to enhance our infrastructural point of view of the forest. Nevertheless, we use the framework's conceptual map to guide our model development. The model shows a clear tradeoffs between maintenance and construction of infrastructures for forest biodiversity as well as wood removal.

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