Introduction

Alpine regions, together with polar and tundra ecosystems, are among the most vulnerable to climate change, and many studies have reported vegetation shifts in these environments (@Gottfried2012NatClimChange, @IPCCSR2019HM). Shifts in timberlines and distributional limits of vegetation types in alpine areas vary across regions, driven by complex interactions between geological and biological factors (@Grabherr2010GeoComp, @Klanderud2005JEcol).

One major driver of vegetation change is the presence of competitively dominant species, which can accelerate shifts by outcompeting other plant communities. For example, grass communities in snowbeds (@Grabherr2003book) and shrub communities in alpine grasslands (@Dullinger2003AAA) are strongly affected. In Japanese alpine ecosystems, dwarf bamboo (*Sasa* spp., hereafter Sasa) is a representative case, known for its vigorous expansion that often excludes rare alpine plants. Indeed, @Kudo2011EcoEvo demonstrated that climate change, particularly earlier snowmelt, promotes Sasa invasion into snowbed communities, reducing plant species richness by 75%. Furthermore, vegetation recovery has been observed following Sasa removal (@Kudo2017AlpBot), underscoring the importance of high-resolution monitoring and prediction of its expansion for conservation planning.

Alpine ecosystems are often remote and topographically harsh, making traditional vegetation surveys costly and logistically difficult. To address these challenges, we previously developed a method for producing high-resolution vegetation classification maps using ground-based time-lapse cameras (@Okamoto2024RSEC). This method utilizes temporal changes in vegetation color captured by time-lapse imagery for classification and further incorporates a procedure for precise orthorectification of ground-based photographs.

In this study, we applied this method to quantify Sasa expansion into alpine meadows on the western slope of Mt. Tateyama in the northern Japanese Alps. In the nearby Murodo-daira plateau, Sasa (including *Sasa kurilensis*, *Sasa spiculosa*, *Sasa senanensis*, and *Sasa palmata*) expanded by 44–260% between 1977 and 2015 (@Yoshida2016SasaTateyama). However, previous studies relied on field surveys or manual interpretation of aerial photographs, which limited the spatial coverage of analysis. Here, by employing automated processing of time-lapse camera imagery, we created the first high-resolution and large-scale distribution map of Sasa in the targeted area.

The key advantage of time-lapse cameras lies in their ability to capture frequent and high-resolution records of snowmelt timing, a critical factor influencing alpine vegetation distribution. By leveraging this capability, it becomes possible to model Sasa distributions derived from time-lapse imagery using environmental variables including snowmelt timing, and to predict patterns of expansion under scenarios of earlier snowmelt. Habitat Suitability Models (HSMs), statistical models that predict species occurrence based on environmental variables, have been widely used for understanding habitat preferences (@Guisan1998JVS), guiding conservation efforts

(@Larson2004EcolModel, @Xue2021GEC), forecasting the spread of invasive species (@Gallien2010DD, @Gallien2012GEB), and assessing distribution shifts and extinction risks under climate change scenarios (@Thomas2004Nature, @Bakkenes2002GCB, @Amagai2022AVS).

Here, we constructed HSMs based on quantified Sasa distributions and their changes to address two key questions: (1) whether snowmelt timing is a critical driver of Sasa distribution in Mt. Tateyama, and (2) how Sasa distribution may shift under future scenarios of earlier snowmelt. High-resolution predictions of Sasa distribution derived from time-lapse cameras could provide substantial contributions to conservation practice, such as prioritizing areas for Sasa cutting and strengthening monitoring activities.

This study represents the first attempt to detect vegetation distribution changes and make future predictions using ground-based time-lapse cameras. Our results highlight that time-lapse cameras, with their advantages of high temporal frequency and spatial resolution, offer powerful tools for understanding and forecasting vegetation dynamics in alpine ecosystems.