# Extreme Climate Variability Should be Considered in Forestry Assisted Migration

Authors: Benito-Garzón, Marta, Ha-Duong, Minh, Frascaria-Lacoste, Nathalie, and Fernández-Maniarrés, Juan F.

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Recently, Pedlar and colleagues (2012) stated that assisted migration in forestry (forestry AM) differs from species rescue assisted migration (species rescue AM) because the risks of invasiveness, hybridization with local species, and the spread of diseases are minimized in managed forests. The rationale behind this assertion for forestry AM is that it involves the translocation of populations within the existing geographic range of the species, whereas species rescue AM involves the introduction of exotic species.

However, although we agree that forestry AM is less risky than species rescue AM for the recipient ecosystem, not only can forestry AM fail, but it can also incur enormous financial costs. The failure of efforts that involved planting maritime pine (*Pinus pinaster* Aiton) trees in southwestern France (Aquitaine) with seeds from more southerly populations from Portugal for production purposes is a textbook case.

The climate variability in Aquitaine includes periods of intense frost that are sufficiently rare (every 10–20 years) to be overlooked when establishing tree populations. The frost of the winter of 1985 was the most intense frost event since records began, with temperatures dropping as low as –22 degrees Celsius (°C; Boisseaux 1986), affecting about 350 square kilometers of tree plantations in the region (Doré and Varoquaux 2006). The highest mortality related to frost was observed in populations harvested from Leiria, in Portugal, for which nearby records show that the absolute minimum temperature was only –7.8°C in the last 60 years. Climate averages over the last 30 years differ only slightly between Leiria and Aquitaine, which would erroneously suggest that samples from Portugal would have survived in the Aquitaine region.

Newly emerging climates (Williams et al. 2007) and the uncertainty related to extreme climate events (Easterling et al. 2000) will make the search for southern locations with climatic conditions similar to those of northern populations of trees extremely difficult. Policies of forest adaptation to climate change should account for extreme cold events in the target populations, even if climate change will likely decrease the number of extreme cold events (Easterling et al. 2000), which remain, in our opinion, the hidden element behind the maladaptation of southern populations to northern locations.

MARTA BENITO-GARZÓN
MINH HA-DUONG
NATHALIE FRASCARIA-LACOSTE
JUAN F. FERNÁNDEZ-MANJARRÉS
*Marta Benito-Garzón (marta.benito@gmail.com) and Juan F. Fernández-Manjarrés are affiliated with the French National Center for Scientific Research's (CNRS) Laboratoire d'Écologie, Systématique et Evolution (ESE), at the Université Paris-Sud, in Orsay, and MB-G and Minh Ha-Duong are affiliated with the CNRS Centre International de Recherche sur l'Environnement et le Développement, in Paris. Nathalie Frascaria-Lacoste is affiliated with both the ESE and AgroParisTech, in Orsay.*

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## Extreme Climate Variability Should Be Considered in Forestry Assisted Migration: A Reply

Responding to our recent article (Pedlar et al. 2012), Benito-Garzon and colleagues point out that extreme climatic events should be taken into account when selecting regenerative material for forestry-related assisted migration (AM) operations. Although technical considerations around seed movements were not the focus of our paper, we concur with their position and welcome the opportunity to expand on this topic.

Benito-Garzon and colleagues emphasize the importance of considering extreme minimum temperatures when matching planting material and planting sites under climate change. Drought, heat waves, and spring freeze phenomena (Gu et al. 2008, Reyer et al. 2013) should also be recognized as extreme weather events that potentially play critical roles in determining the outcome of AM efforts. Although Benito-Garzon and colleagues raise the issue of climate extremes in the context of forestry AM, climate extremes are likely to play an important role in other types of AM, as well (e.g., species rescue; Pedlar et al. 2012).

The considerable uncertainty regarding projections of extreme climatic events warrants further attention. Summarizing the accuracy of global circulation model (GCM) projections over the twentieth century, Seneviratne and colleagues (2012) reported that the highest accuracy was associated with broadscale, temporally averaged estimates of mean temperature, whereas the lowest accuracy was associated with estimates of climatic extremes at fine spatial and temporal resolutions. Although the latest round of GCM projections shows promise with regard to temperature extremes (Sillmann et al. 2013), accurately predicting extreme cold events (such as the one described by Benito-Garzon and colleagues), droughts, heat waves, and late frosts at specific locations remains extraordinarily challenging.

Our focus on climate extremes and their associated uncertainty is not