Dear Dr. Wake:

We propose a *Perspective* piece on to buffer many crops from major climate change impacts through improved use of existing diversity. We believe this piece would have broad interest to readers of *Nature Climate Change.* For researchers studying climate change impacts on crops it would suggest a major new approach to crop modeling, and relatedly alter how researchers collect and share data—with implications for growers and breeders. Beyond agricultural research, we believe the piece will inspire interest and research in both ecology and evolution—by highlighting the role of plant traits in improving climate change research and by the need to better understand the underlying genetic drivers of this diversity.

Predictions for many plant crops in the future suggest large declines and large spatial shifts, with much agricultural land moving poleward and up mountains to track cooler climates (1; 2; 3). These projections, however, often ignore the existing diversity within crops—despite the fact that different cultivars often vary in critical traits related to climate, such as the timing of fruit ripening or response to drought (4; 5). We argue that incorporating existing diversity into these models would highlight how current agricultural land could maintain the same crop through shifting the cultivar(s) planted in step with climate change. Our perspective would outline the major benefits of this novel approach and the challenges in implementing it in one major crop, winegrapes (*Vitis vinifera* subsp. *vinifera*).

Winegrapes are the the world's most economically-important horticultural crop and one that has shown large temporal and spatial shifts with climate change (6; 7; 8). Most of this work, however ignores the tremendous standing diversity of winegrapes (9; 10; 11), with over 1,200 different planted cultivars (e.g. Pinot Noir or Cabernet-Sauvignon). Yet little of this diversity is exploited today. Instead the winegrape industry has focused in on a small set of recognizable varieties (cultivars), and most countries growing winegrapes today plant 40-80% of their total hectares with only 12 varieties—representing just 1% of the total diversity (see Figure 1, included below). Growers are thus reducing diversity across the globe at exactly the time when diversity is most needed. We highlight areas of the globe where this problem is most acute, translate what this means for several climate-related traits (see Figure 2), then suggest how shifts in viticultural practices, and new initiatives by growers and researchers to gather shared data could better prepare the industry to adapt with climate change. Though our focus here is on one crop, the challenges and benefits that we outline extend to many other crops, which we would discuss throughout the paper.

The paper brings together an international and interdisciplinary author group. The four co-authors bring expertise from global change ecology (E. M. Wolkovich, Harvard University, USA) crop modeling and projections (Dr. I. García de Cortázar-Atauri, INRA, Provence-Alpes-Cte d'Azur, France), climate change impacts on the wine industry (Dr. K. A. Nicholas, Lund University, Sweden), and winegrape diversity (Dr. T. L. Lacombe, INRA Domaine de Vassal, France). We expect the title of the manuscript would be 'From Pinot to Xinomavro: Challenges & opportunities for the world's future winegrowing regions.'

Thank you for your consideration.

Sincerely,

Contact details:
Elizabeth M. Wolkovich (First author)
Arnold Arboretum
1300 Centre Street
Boston, MA 02131
Ph: (617) 384-5494
lizzie@oeb.harvard.edu

References:

[1] Lobell, D. B., Schlenker, W., and Costa-Roberts, J. Climate trends and global crop production since 1980. *Science* **333**(6042), 616–620 (2011).

[2] Hannah, L., Roehrdanz, P. R., Ikegami, M., Shepard, A. V., Shaw, M. R., Tabor, G., Zhi, L., Marquet, P. A., and Hijmans, R. J. Climate change, wine, and conservation. *Proceedings of the National Academy of Sciences of the United States of America* **110**(17), 6907–6912 (2013).

[3] Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A. C., Mueller, C., Arneth, A., Boote, K. J., Folberth, C., Glotter, M., Khabarov, N., Neumann, K., Piontek, F., Pugh, T. A. M., Schmid, E., Stehfest, E., Yang, H., and Jones, J. W. Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. *Proceedings of the National Academy of Sciences of the United States of America* **111**(9), 3268–3273 (2014).

[4] Weller, J. L., Liew, L. C., Hecht, V. F. G., Rajandran, V., Laurie, R. E., Ridge, S., Wenden, B., Vander Schoor, J. K., Jaminon, O., Blassiau, C., Dalmais, M., Rameau, C., Bendahmane, A., Macknight, R. C., and Lejeune-Henaut, I. A conserved molecular basis for photoperiod adaptation in two temperate legumes. *Proceedings of the National Academy of Sciences of the United States of America* **109**(51), 21158–21163 (2012).

[5] Bota, J., Tomas, M., Flexas, J., Medrano, H., and Escalona, J. M. Differences among grapevine cultivars in their stomatal behavior and water use efficiency under progressive water stress. *Agricultural Water Management* **164**, 91–99 (2016).

[6] Webb, L. B., Whetton, P. H., Bhend, J., Darbyshire, R., Briggs, P. R., and Barlow, E. W. R. Earlier wine-grape ripening driven by climatic warming and drying and management practices. *Nature Climate Change* **2**(4), 259–264 (2012).

[7] Cook, B. I. and Wolkovich, E. M. Climate change decouples drought from early wine grape harvests in France. *Nature Climate Change* **6**(7), 715–719 (2016).

[8] Fraga, H., García de Cortázar Atauri, I., Malheiro, A. C., and Santos, J. A. Modelling climate change impacts on viticultural yield, phenology and stress conditions in europe. *Global Change Biology* **22**(11), 3774–3788 (2016).

[9] Lacombe, T., Audeguin, L., Boselli, M., Bucchetti, B., Cabello, F., Chatelet, P., Crespan, M., D'Onofrio, C., Dias, J. E., Ercisli, S., Gardiman, M., Grando, M. S., Imazio, S., Jandurova, O., Jung, A., Kiss, E., Kozma, P., Maul, E., Maghradze, D., Martinez, M. C., Munoz, G., Patkova, J. K., Pejic, I., Peterlunger, E., Pitsoli, D., Preiner, D., Raimondi, S., Regner, F., Savin, G., Savvides, S., Schneider, A., Spring, J. L., Szoke, A., Veres, A., Boursiquot, J. M., Bacilieri, R., and This, P. Grapevine european catalogue: Towards a comprehensive list. *Vitis* **50**(2), 65–68 (2011).

[10] Myles, S., Boyko, A. R., Owens, C. L., Brown, P. J., Grassi, F., Aradhya, M. K., Prins, B., Reynolds, A., Chia, J. M., Ware, D., Bustamante, C. D., and Buckler, E. S. Genetic structure and domestication history of the grape. *Proceedings of the National Academy of Sciences of the United States of America* **108**(9), 3530–3535 (2011).

[11] van Leeuwen, C., Schultz, H. R., Garcia de Cortazar-Atauri, I., Duchene, E., Ollat, N., Pieri, P., Bois, B., Goutouly, J. P., Quenol, H., Touzard, J. M., Malheiro, A. C., Bavaresco, L., and Delrot, S. Why climate change will not dramatically decrease viticultural suitability in main wine-producing areas by 2050. *Proceedings of the National Academy of Sciences of the United States of America* **110**(33), E3051–2 (2013).

[12] Anderson, K. and Aryal, N. R. *Which Winegrape Varieties are Grown Where? A Global Empirical Picture*. University of Adelaide Press, Adelaide, e-book edition, (2013).

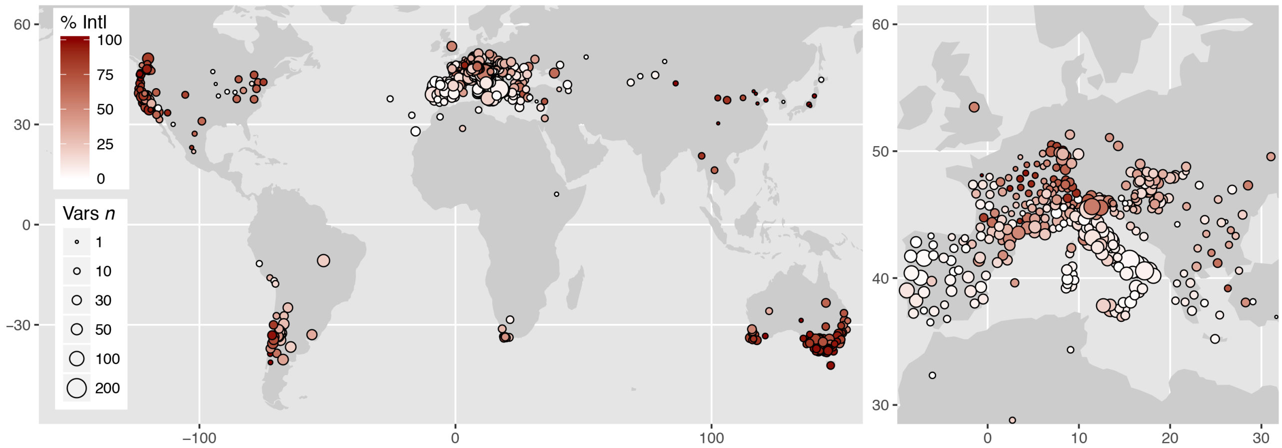

Figure 1: Planted diversity of winegrapes from 2010. The number of varieties (‘Vars *n*’) by region, and the percentage of each region’s hectares planted with common 12 varieties (called international varieties) varies across the globe, with Europe growing the greatest number of different varieties (largest circles) and New World wine regions growing the greatest proportion of international varieties (darkest circles). Data from 13.

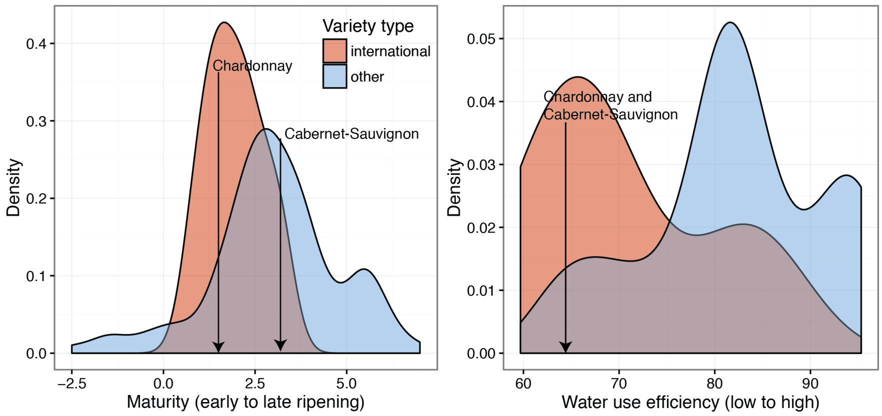

Figure 2: Variation across varieties in two functional traits relevant for climate change. Variation in the fruit ripening phenology (left) of the 12 international varieties versus a sample of 112 other varieties, maturity measured as weeks from when a reference variety (Chasselas) reached maturity (data from INRA Domaine de Vassal Grape Repository), and the water use efficiency (ratio of water used versus lost, right) of seven international varieties versus 16 local varieties (from Balearic Islands, Spain, reported by 5). In many regions growers will need later-ripening grapes with higher water use efficiencies with climate change, yet the data here show that international varieties are skewed towards earlier ripening and lower water use efficiencies. Values for two of the most planted varieties—Chardonnay and Cabernet-Sauvignon—are shown; on right they are shown by only one arrow because their values only differ by 0.1.