Notes on Geomorphology and STZ development

The effects of climate on plants is mediated both directly and indirectly by landforms, and directly by soils, across a range of spatial scales (Giaccone et al. 2019, Moesland et al 2013, Swanson et al. 1988). Landforms directly influence climate to produce micro-climates such as cold pools and micro-rain shadows, resulting in variation in evapotranspiration and soil moisture availability gradients in even (Pastore et al. 2022, Minder et al. 2008). Topographic slope and aspect control the amount of incipient solar radiation altering both soil temperatures and soil moisture, affecting both soil moisture and soil microbial composition and activity (Dearborn and Danby 2017). Topographic features have also been shown to influence the amount of soil water availability, at various depths and across time, by altering the amount of overland, and subsurface, water flow leading to areas with either elevated or reduced amounts of water (McAuliffe 1994, Wondzell et al. 1996, Qui et al. 2001). Soil water content has been shown to be influenced by the amount of coarse fragments in soil (Katra et al. 2008), as well as soil textural (English et al. 2005, Fernandez-Illescas et al. 2001, Singh et al. 1998), and chemical properties (e.g. carbonates, and soil organic carbon) (Duniway et al. 2010, Rawls et al. 2003). Collectively, these factors can lead to an apparent decoupling between the resolution of climate variables generated by spatial modelling and interpolation approaches, and the responses of plant populations (Potter et al. 2013, Lenoir et al. 2016).

Effectively, this may result in idiosyncratic results whereby the source populations used in common gardens, may either be adapted for more dry conditions (e.g. coarse soils, on south facing aspects) or wetter conditions (e.g. fine soils, northern aspects, at toes of slope) than would be accounted for using climate variables alone. In the development of provisional STZs based on ecological niche models (e.g. Shyrock et al. 2017)

Further it is possible that The effects of soil moisture may also lead to maternal effects in common garden studies . . .
However this apparent discord in scale may be ameliorated by a proactive approach many steps of which are already utilized by STZ developers.

Section 1.

The direct effects of topography on climate are a well known phenomena and a variety of approaches for downscaling gridded climate data from moderate resolutions (e.g. ~800m, ~1km) to fine resolutions (e.g. 30m) have been developed (Potter et al. 2013, Wang et al. 2016). Essentially these models . . . They can be used by analysts to develop high resolution gridded surfaces which can be used to help explain Indeed, this approach is already implemented by a majority of researchers (e.g. Johnson et al. 2017, St. Clair et al. 2013, Shyrock et al. 2017). However, Given recent advances in computational power, predicting fit eSTZ models onto similarly high resolution surfaces is now an achievable task for most research groups. However, while these tools are more effective for modelling the variability in localized climate, they do not address the localized effects of geomorphology on precipitation which has reached the soil surface.

Inclusion of landform characteristics, such as topographic position, and topographic wetness indices, aspect and slope are achievable with data products such as (Geomorphon 90,), or may be rapidly calculated using a variety of GIS. . . Given recent advances in remote sensing, in particular LiDAR, these products - especially the latter have great accuracy, and as covariates may help explain responses between populations; for example many populations from more arid portions of ranges may actually be located in refugial areas (e.g. northern facing toe's of slope) where they are buffered from the realized micro climate. High resolution soils data are available for a variety of physical and chemical components, as well as soil moisture, however in our experience these data are less accurate than the aforementioned topographic data sets due to a lack of equatable remote sensing approaches (Hengl et al. 2017, Vergopolan et al. 2021).
Gibson et al. 2019 used soil covariates from the SSURGO database and found variables which moderate soil

water content, such as soil organic carbon and percent clay, and were able to decrease variance in models relating common garden results to source populations. However, within their region of analysis the climate only models suggested three zones, and the the climate + soil models generated eight zones with four of them collectively constituting less than 5%, relative to XX pSTZ (*REED GET THIS NUMBER*) treating the same area (Bower et al. 2014). While utilization of these covariates may increase predictive abilities they may also create more seed zones than are practical, and their incorporation may require post processing steps where STZs with very small total geographic coverage are removed from downstream applications, e.g. by reassignment to their nearest neighbors.

Note that, aside from 'extreme' or harsh soils such as mine tailings and serpentine, evidence for adaption of plant populations to individual soils appears to be seldom documented in the literature (Macel et al. 2007, Ellis & Ågren 2024, O'Dell & Rajakaruna), indicating that most populations for most species appear suitable for restoration sites.

Section 2.

Restoration practitioners, when presented with multiple seed source options for a restoration and which have similar climate similarity to the site, have expressed interest in matching seeds using additional criteria. In scenarios where a practitioner has reason to believe that a population from a soil with more similar textural properties is desired spatially modelled products such as SoilGrids can be used to determine the similarity between major textural components. Under certain scenarios, the use of Ecological Site Descriptions (ESD's) will articulate the relationship between climate, geomorphology, and the response of vegetation to sites. The use of ESD's will not only lead to a match between geomorphology, but also foster the selection of seed lots where the focal species has been in a similar vegetation context to it's desired outcome, i.e. the population will have been exposed to other species likely to recruit at the site, or to be seeded. However, the development of ESD's across Western North America has been a long process, and the status of their mapping is variable, and to date no gridded surfaces for them exist. A solution has been the development of Ecological Site Groups (ESG's), these data sets combine local expertise with geospatial modelling approaches and have been developed for at least one large geographic expanse. While this product does not offer the same resolution as ESD's, they provide a solution which reflect the interactions between climate and geomorphology, and may be used at least temporarily to express these relationships.

Environmental maternal effects stuff - *I suspect this will be covered in another section, e.g. on seedling, so I want to move through at a brisk pace. Just relating it's role here, and possible costs for experiments (and perhaps increase…).*

Maternal plant phenotypes influence their progenies seed mass, which has been shown to influence germination in a range of species, however the effects of seed mass generally taper off with plant age, and are most pronounced on progeny in low nutrient or stressful environments (Bischoff & Müller-Schärer 2010,). Beyond the direct maternal effect of seed mass, environmental maternal effects - a suite of responses shaping a variety of proposed seed physiological parameters, have also been shown to influence early stages of plant growth for some species investigated (Galloway 2005, Galloway & Etterson 2007,), but not others (Monty et al. 2009).
While it is possible that environmental effects at the source population affect the results of common garden studies, we find it implausible that they do so given the relatively long duration of experiments - which tend to be conducted on perennial species, and the relatively hospitable environment during establishment.

'Seed mass and population characteristics interact to determine performance of Scorzonera hispanica under common garden conditions' 'Effects of maternal and paternal environment and genotype on offspring phenotype in solidago altissima' 'Environmental maternal effects on seed morphology and germination in Sinapsis arvensis (Cruciferae)' 'Maternal effects should be considered in the establishment of forestry plantations'

THREE RESEARCH THINGS: - Can old eSTZs be re-analyzed and soil information included in modelling approach, how does this change the hypothesized STZs? - Are populations across ranges better adapted to certain soil types? (big commitment, seems not a lot of evidence to go on…, but common garden suitable (in pots, and requiring many many more replicates)) - - Is there evidence of maternal environmental effects in seed lots and carrying over into common gardens (Leah Lenzo's work a good starting point? Surprisingly not much in the literature on single species? Or i suck at the lit reviews? Definitely the latter maybe also the former.) - This one has implications for ag increase; farmers get tiny seed from drought years - maybe they are hosed.