RESILIENCE AND ADAPTATION TO CLIMATE CHANGE IN FORAGE SYSTEMS

Valentin D. Picasso, Ph.D., Assistant professor in Agronomy, University of Wisconsin – Madison, USA

INTRODUCTION

Climate change is a major challenge for agriculture and food security. Historical climate trends and future model projections show that climate variability is increasing at global and local scales. More frequent water excesses and deficits are expected, which will affect agriculture in general and forage production in particular (IPCC, 2013). On the other hand, warmer weather means extended growing season, which can increase potential forage and pasture yields, and decrease the need for forage storage during winter for dairy and beef farmers. Sustainability of agricultural systems involves economic, social, and environmental dimensions and can be evaluated by various attributes. Resilient, stable, and productive forage systems are needed to endure increasingly frequent climatic extremes.

Most research on forages has historically focused on maximizing productivity. Stability and resilience are concepts less understood and sometimes confused. Stability is the minimal variability of yields over time under normal conditions. Resilience is the ability to withstand a short-term crisis, perturbation, or shock, like a drought or cold winter. Resilience comprises two complementary dimensions: the ability to remain productive during the perturbation (i.e., resistance), and the ability to recover from a crisis (i.e., recovery). Cold tolerance or winter hardiness are plant traits that promote resistance. Stability and resilience are different dimensions, explained by different traits and mechanisms (Picasso et al., 2019).

STRATEGIES TO INCREASE RESILIENCE AND STABILITY

Choice of cultivars and species

Tolerance to extreme temperatures is becoming more of a need when choosing forage varieties to realize the higher yield potential. With less consistent snow cover in winter, and more periods of alternating freezing and thawing, greater winter hardiness has become necessary. At the same time, with warmer summers, greater heat tolerance is also needed. Insect and disease pressures have also increased, so resistance to biotic stresses is a priority. Forage breeding plays a key role in all developing more resilient varieties.

Productivity, stability, and resilience differ among cultivars of alfalfa, across 11 US states and one Canadian province (Ontario) over 19 years (Picasso et al., 2019). Locations with an extreme crisis year were identified, and quantitative measures for resilience and stability for each cultivar were calculated. Cultivar stability was not associated with productivity, and it was negatively associated with disease resistance. Cultivar resilience was negatively associated with productivity, and not associated with other traits. Cultivar productivity has increased with year of release of cultivar, stability has not changed, and resilience has decreased. Choosing cultivars with greater resilience to drought and/or winter stress is a relevant strategy for adaptation.

Forage species differ in their tolerance to subfreezing temperatures and anoxia caused by the presence of ice on fields (Bélanger et al., 2006). Among the legumes red clover is susceptible, followed by alfalfa, Birdsfoot trefoil, and Kura clover. Among the grasses, ryegrasses are the most susceptible, followed by orchardgrass, tall fescue, reed canarygrass, smooth bromegrass, and timothy (Balasko and Nelson, 2003). Drought tolerance also differs among species, being smooth bromegrass very tolerant, followed by tall fescue, reed canarygrass, orchargrass, timothy, and ryegrasses. Among the legumes, alfalfa is most tolerant, followed by Kura clover, red clover, Birdsfoot trefoil, and white clover (McGraw and Nelson, 2003). Choosing forage species more tolerant to drought or winter stress is another important strategy for adaptation.

Forage mixtures

Perennial forage communities with four and six species were more stable across environments than the highest yielding monoculture, across eight perennial forage species assembled in fifty different experimental communities at two locations in Iowa, USA. Consistency (i.e., the ability to achieve higher yields in better environments) and reliability (i.e., the ability to yield close to the expected mean, with minimal deviations over time) increased linearly with species richness (Picasso et al., 2010). Forage mixtures like alfalfa-grass mixtures can be as productive as a pure stand of alfalfa in good weather conditions, and are more stable over the years, because of complementarity between different species in the mixture (Picasso et al, 2011). Alfalfa-grass mixtures had shown lower heaving than pure stands in some soils. In Canada, mixtures of alfalfa with meadow fescue, bromegrass, and tall fescue produced comparable yields and nutritive value to alfalfa-timothy (Pomerleau-Lacasse, et al., 2018). In scenarios of increasing variable climate, resilience and stability of production are becoming more relevant goals, and forage mixtures provide an insurance if any single species in the mixture would fail.

Harvest and grazing management

To increase the resilience of alfalfa to winterkill it should not be harvested in the 4-6 weeks preceding the first killing frost (about -3°C) in order for roots to accumulate carbohydrate reserves for winter survival and spring regrowth, and for plants to grow back to a height 20-25 cm in the following season to retain snow (Michaud and Allard, 2005).

Harvesting and grazing management affect the resilience of grazing systems to droughts at the paddock and farm scales. Results of a grazing experiment controlling herbage allowance showed that resistance of herbage accumulation and animal live weight to drought was higher for paddocks with higher pre-drought herbage allowance than for those managed to low herbage allowance (Modernel et al., 2019). Forage harvest under wet conditions in spring is more challenging, and grazing provides expanded opportunities for forage utilization, therefore, grazing is likely to grow in livestock systems.

Crop rotation diversity and perennialism

Yield stability significantly increased when corn and soybean were integrated into more diverse rotations with small grains, red clover, alfalfa, in a 31-year long term rotation trial in Ontario, Canada (Gaudin et al., 2015). Crop diversification strategies increased the probability of harnessing favorable growing conditions while decreasing the risk of crop failure. Results from the Wisconsin Integrated Cropping Systems Trial, show that stability increased with more years of perennials (alfalfa) in the crop rotation, while resilience to drought increased in more complex (diverse) crop rotations including alfalfa, oats, and winter wheat (Sanford et al., in prep.).

Increased rainfall causes waterlogging of soils, and lowers the chances of planting corn for grain or silage on time in spring. Minimizing the farm area to plant each year becomes a higher priority, so longer forage rotations may be preferred. More years of perennial forages in the rotation reduces the area to plant every spring, and therefore it increases the harvestable forage area on the entire farm.

Perennial forages and dual-use crops

Increased summer heat stress requires more water storage in the soil. Perennial forages and pastures also increase soil organic matter and structure, which in turn increases water infiltration, and improves the ability to withstand summer droughts. With increasing climate variability, perennial forages and pastures provide a more reliable source of feed. Perennial forages and pastures are the long-term solution to soil erosion and nutrient leaching, because they provide continuous cover year round, and their roots absorb nitrogen and phosphorous as long as there is water in the soil. With increasing intensity of rains and storms, expanding the area in pastures and perennial forages is a much greater need, and is increasingly required by conservation and regulatory agencies. Recently developed perennial grain and forage crops like Kernza intermediate wheatgrass provide additional benefits to farmers looking to expand their perennial cover and still harvest grain for human use.

CONCLUSION

Present climate variability and future climate trends provide significant opportunities to increase perennial forages and pasture area and production in North America. Higher forage production would be realized if both researchers and farmers focus on increasing tolerance to cold, heat, and disease stresses. More farm area in perennial forages and pasture can enhance farmers' resilience and stability of production, as well as reduce the environmental impacts of extreme climatic events.