

Functional Diversity and Benchmarks

While each plant functions differently in an ecosystem context, the degrees of dissimilarity which exist between all species are unequal allowing them to clump together into groups. This observation has given rise to the notion of *Plant Functional Types*, shared attributes which unite similar species, and which bind how they affect ecosystems. Oftentimes, form follows function, and functions are hence referred to as forms. For example, Trees provide large amounts of shade, which in combination with their transpiration lower the temperature of areas. Plant functional types are quite often the easiest form of vegetation data to measure, and accordingly great amounts of work have been conducted on how they affect ecosystem function.

In Western Colorado, five major forms of plant functional types are often used to evaluate range conditions. These forms are: Trees, Shrubs, Grasses, and Forbs (or herbs), and each has been linked to affecting rangelands in multiple ways; theoretically their distributions and abundances are driven by variations in soil moisture throughout horizons (O. Sala et al. (1997)). Accordingly, in nearly all instances a mix of each of these groups, less trees, is best to maintain ecosystem services on BLM Land. In our area which features massive extents of Pinon-Juniper Woodland, trees when present, are included in this mix on ecological sites which they are more capable of surviving on over long periods relative to shrubs.

Semi-arid lands which are utilized as rangelands across the world are experiencing several common issues relating to shifts in the composition of their plant functional types (Archer & Predick (2014), Eldridge et al. (2016), Maestre et al. (2016), Diaz et al. (2007), Dalglish et al. (2010)). Namely, decreases in grasses whilst increases in woody species are occurring. In certain areas, the increases - or encroachment of - woody species may be split into encroachment of trees, and the transition to a shrub state in ecological sites which do not support trees. In nearly all lands utilized as rangelands around the world the cover of and species richness of perennial forbs decreases, while the cover of annual forbs increases (Diaz et al. (2007), West & Yorks (2006)).

The current increases in shrub cover relative to the cover of the herbaceous strata, grasses and forbs, are problematic for a variety of reasons. The increase in Trees at mixed grass-shrublands sites may decrease water available to grasses and shrubs but not non-native annual grasses (McIver et al. (2022)), as cattle depend on grasses and wildlife shrubs these decrease the ability of our lands to support either. Increases in shrubs at the expense of perennial grasses and forbs may increase the severity of site level drought (Wilson et al. (2018)), further shrubs and trees may foster higher severity fires (CITE). Increases in shrubs decrease soil stability, allowing increased erosion, increasing DUST ON SNOW, and is an irritant to human breathing (Munson et al. (2011)). Decreases in perennial grass may reduce competing non-native annuals from overtaking sites (Sheley & James (2010), Corbin & D'Antonio (2004), although a diversity of species may be best (Belnap & Sherrod (2008)). A decreases in forbs adversely affect wildlife feeding both directly and indirectly, and by decreasing the quality of habitats, the lack of perennial forbs are widely evident for species such as the Gunnison Sage-Grouse (Pennington et al. (2016)). These issues we are currently facing may be compounded in the future by problems which are only begin to become apparent.

While the major functional groups are capable of capturing considerable variation which predicts rangeland responses, they often maintain large amounts of variation with them (Lavorel et al. (2007), Funk et al. (2017)). And we believe that additional functional groups warrant attention in our area. As mentioned above C3 and C4 grasses have different responses to many environmental cues. Sprouting and non-sprouting shrubs differ widely in their responses to wildfire, and sites require different post fire management strategies. Annual and perennial forbs (life cycles), differ in their responsiveness to precipitation, with annuals declining rapidly in times of low precipitation.

Methods

Append Functional group information

Results

Forb Cover

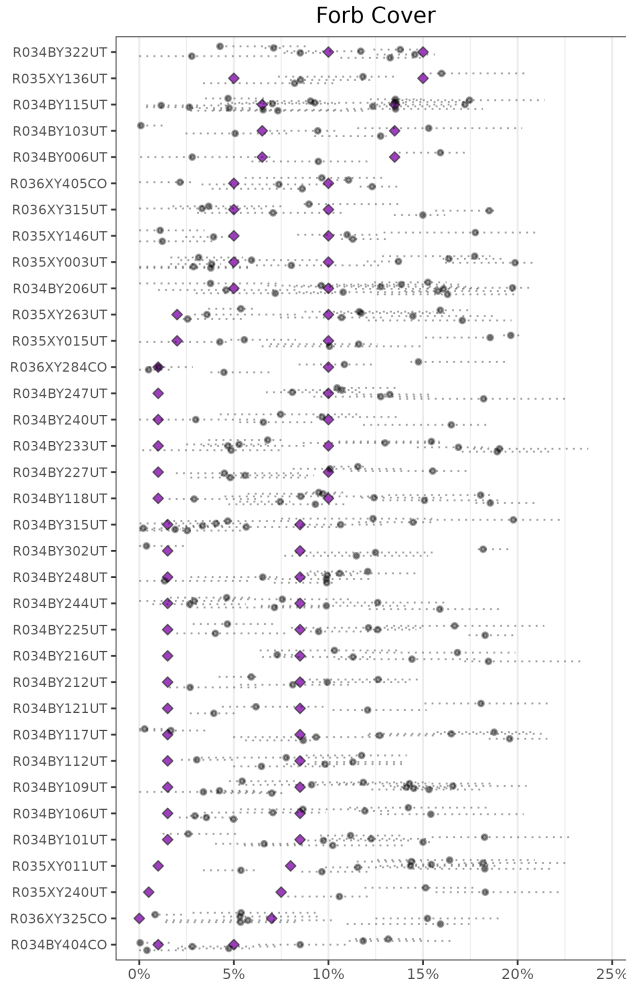


Figure 1: Benchmarks and Observed Values

Benchmark forb cover is generally low across all Ecological Sites in the study area, with a maximum expected cover at any site of 15% and the median mean value across all sites being 5.5%. In general these estimates focus on perennial species, as after they germinate nearly all of these species will retain some above ground biomass across each active growing season of their lives, whereas annual forbs may not germinate in drier years and hence have more across year variation in their abundance. As these values are intended to capture the variation of these Ecological Sites, and these estimates were presumably created within the last 20 years (see SECTION XX on ESD development), we would expect that the covers observed on AIM plots were close to the lower estimates of variability.

While nearly all plants produce less above-ground biomass during drought, additional complications with natural and climate induced mortality and the subsequent lack of recruitment of perennial forbs from the soil seed bank may contribute to sites not meeting benchmarks (Eziz et al. (2017), Casper (1996) Munson et al. (2022) ???). The establishment of both long and short lived forbs seems hampered during drought periods, and it may take several years after the cessation of a drought for the cover of perennial forbs to return to pre-drought conditions (Anderson & Inouye (2001)).

In particular it is probable that short lived perennial forbs, which generally only live a total of 2-4 years past their germination (Dalgleish et al. (2010)) have widely decreased in areas during the drought (Torang et al. (2010), Anderson & Inouye (2001)). While their appear to be few scientifically conducted observations on perennial forb longevity,

many perennial forbs seem to generally persist for one to two decades (but up to four are noted), and once established (i.e. they reach reproductive maturity) are able to survive a couple types of disturbances, such as drought (Treshow & Harper (1974), Lauenroth & Adler (2008), Morris et al. (2008)). However, given the duration of the current drought, and the merely episodic periods of normal moisture balances (SECTION XX), required to recruit new individuals, it is possible many of the long lived perennials have suffered non-drought induced mortality, and have not recruited individuals from the seed bank. Recovery of the

above ground cover of both forms of perennial forbs may require periods of from 2-5 years in more mesic sage-steppe areas (Anderson & Inouye (2001)).

Particular areas across the field office which may be the most affected by forb declines may be those inherently lower water storing capacity; such as those with skeletal soils and short depths to bedrock, e.g. Salt Desert and considerable portions of Pinyon-Juniper Woodland. It has been observed that the soil depth of sites can be a highly, or the most, influential factor on survival of perennial forbs during times of drought (Davison et al. (2010), Nicole et al. (2011)). Accordingly, sites supporting Wyoming Big-Sage, some of which constitute our Gunnison Sage-Grouse habitat should be less affected.

Shrub Cover

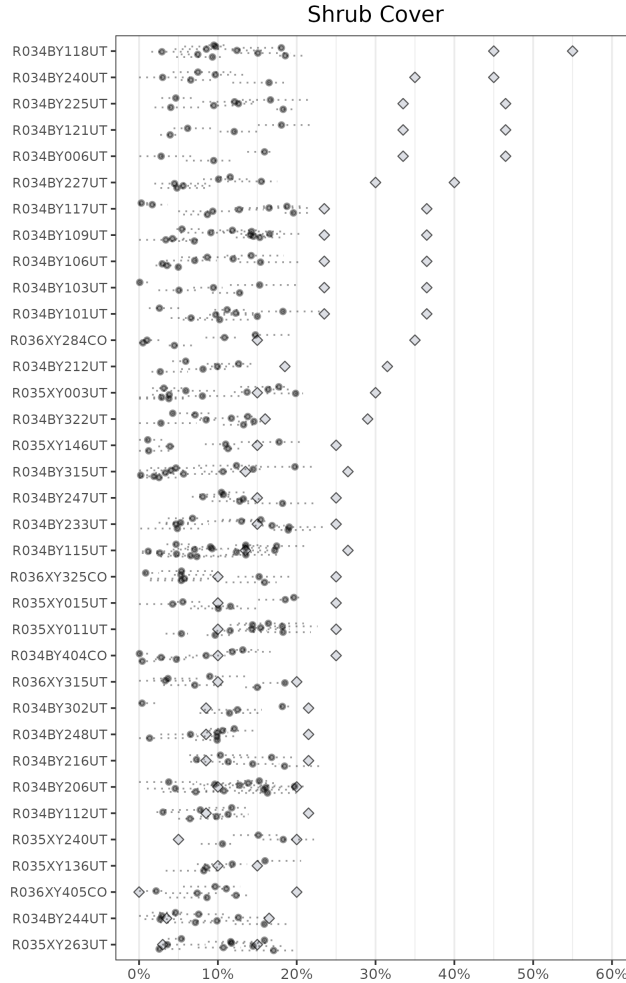


Figure 2: Benchmarks and Observed Values

The cover of woody plants is expected to be at the upper end and beyond the reference benchmark values (Figure XX). We anticipate that the cover of woody plants is elevated relative to the reference state, a common occurrence in all semi-arid lands utilized as range (Bestelmeyer et al. (2018), AND...) . While some disagreement over the mechanistic causes of increases in woody plant cover exist in the literature, from a management context the drivers may largely be attributed to: 1) An altered fire-cycle 2) increasing atmosphere CO₂ 3) improper grazing by livestock (Bestelmeyer et al. (2018)). All of these initial drivers may lead to feedback loops enforced by changes to soil fertility which cause the shrub-encroached status of these sites to continue (Bestelmeyer et al. (2018)).

We do not expect that the drought had a noticeably negative effect on total woody plant cover, although varying levels of mortality are likely across the study area. Shrubs are considered less responsive to droughts due to depths which many of their roots are able to reach to draw soil moisture (Winkler et al. (2019), CITE). Further, given the much slower time it takes woody plant parts to break off and decompose, individuals are still likely to be recorded via the AIM methods (CITE)...

Reductions in woody plant cover, while maintaining and enhancing other functional groups, is difficult to implement at a landscape scale, and varies considerably by ecological site (CITE). Accordingly, we expect that many areas of the field office which had been treated before the advent of the current Ecological Sites have already had shrub cover return...

Tree Cover

As a component of woody cover, the same general trends, expectations, and reasoning behind an increase in tree cover is shared as discussed in the shrub section. Mortality of portions of trees is expected less on trees than shrubs.

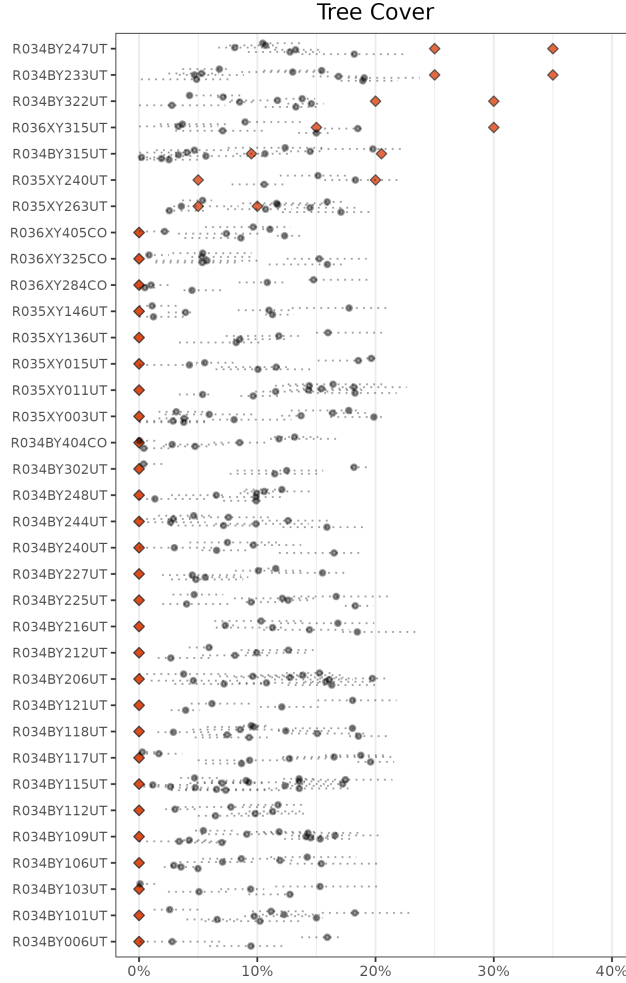


Figure 3: Benchmarks and Observed Values

Many historical vegetation treatments, especially for Pinyon-Juniper forests, were conducted throughout the study area (). However, akin to a great proportion of other such treatments globally, most of these were marginally effective (@). This is likely due to the potential of those ecological sites not including a mixed grass and shrubland more desirable for livestock use (). Many portions of the study area ARE Pj sites.,

Currently three trajectories for Pinyon-Juniper cover exists in the study area. The **first** is the re-growth of Pinyon-Juniper on sites which were historically treated, and cannot support mixed grass-shrublands, and which are being allowed to naturally re-vegetate. The **second** is that a lack of certain disturbances, e.g. fire, at certain Ecological Sites is resulting in increases in Pinyon-Juniper as natural process of *succession*, i.e. these are parts of the landscape where the final vegetation community is PJ, but which via certain disturbances may be kept in a grass-shrub condition. The **third** trajectory is that Pinon-Juniper are encroaching upon lands which been largely devoid of naturally occurring processes, and are starting to promote their own expansions via feedback loops ((CITE?)). In areas such as this multiple functionalities of the land are reduced, and are sites where vegetation treatments are highly desirable from a variety of ecosystem services perspectives (@), and which are capable of regaining ground for livestock usage (Anadon et al. (2014), Archer et al. (2017), Morford et al. (2022)).

The higher cover of trees than expected throughout the study area identifies ecological sites which vegetation treatments which involve tree removal can be implemented. Due to the effects of woody encroach-

ment on the production of species which are used as forage by livestock, removals of low percentages

Prioritization of sites where treatments will offer the most ecosystem services, such as the most productive sites in terms of forage production, and areas with species of wildlife which are susceptible to higher predation via tree encroachment.

Perennial Grass Cover

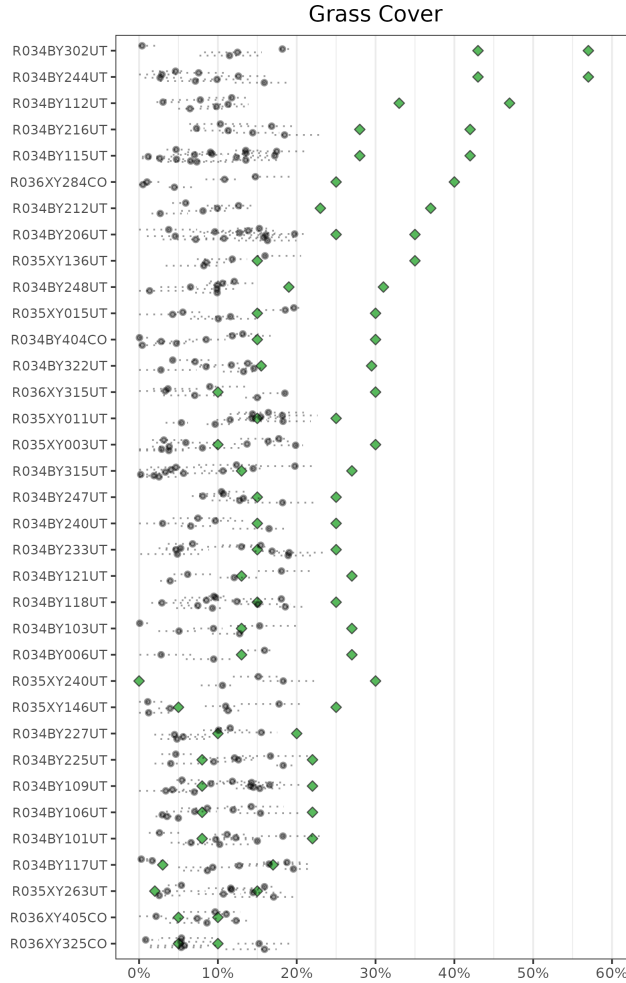


Figure 4: Benchmarks and Observed Values

It is difficult to determine the extent to which grasses of the Colorado Plateau will reduce their above ground growth in response to drought. Various studies have found that grass production decreases during drought, and during periods of highly variable precipitation, however the extent of reductions are variable (Gherardi & Sala (2015), Staver et al. (2019), Munson et al. (2022)). While other studies show that the amount of biomass produced by grasses is quite resilient to drought (Byrne et al. (2017)), and that moisture limitation reductions in grass growth are largely buffered by legacy effects (in this case, a single normal year of precipitation, e.g. 2018, can offset the next few years of dryness and *vice versa*; SECTION XX) (O. E. Sala et al. (2012), Reichmann et al. (2013)). More recent studies limited to the Colorado Plateau have shown reduced growth of C4 grasses, partially due to variability in Monsoons, and C3 grasses via reduced cool season precipitation (Munson et al. (2022), Hoover et al. (2021)). However, given the distinctive growth forms of grasses (i.e. generally columnar), it is unlikely that their cover would be found to be much lower via the methods employed by AIM, unless high levels of mortality occurred.

Compared to perennial forb duration perennial grasses in general appear to live for considerable longer, many from 4-7 decades (Lauenroth & Adler (2008), Treshow & Harper (1974)) but purportedly many of the local grasses only persist 1-1.5 decades (WHERE WAS THIS?!?! - USGS local). Many clonal grass species, such as some species of *Bouteloua* appear much less likely to undergo mortality of the whole plant or many clones (De Witte & Stocklin (2010)) relative to bunch-grasses (but see

Winkler et al. (2019)). Mortality due to drought is expected to reduce cover measurements of grasses more than reductions in above ground biomass. While grasses tend to have deeper roots than forbs, soil textures and depths (Chamrad & Box (1965), Griffin & Hoffmann (2012)) still mediate drought effects. A manipulative experiment which sought to determine the effect of drought on five grass species in the Colorado Plateau observed mortality of roughly 25% of all individuals under the ambient treatment (similar conditions to what the UFO experienced), largely attributed to Indian Rice Grass (*Achnatherum hymenoides*), tracked in ambient conditions over the time period 2011-2018 (Winkler et al. (2019)).

Similar to forbs, we expect little to none recruitment of new grass individuals from the soil seed bank. However suspect it is unlikely that has considerably high a proportion of the members of this functional group would have died off over this period, independent of drought induced mortality (Morris et al. (2008), Winkler et al. (2019)) as perennial forbs, and given their average rooting depths relative to forbs should be more drought tolerant (O. Sala et al. (1997)). Accordingly we expect estimates of grass cover to be at the lowest end of the benchmarks.

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