Does Supplemental Feeding of Deer Degrade Vegetation? A Literature Review

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Abstract: Artificially feeding deer is controversial, particularly in North America. Our objective was to determine if published literature supports the hypothesis that supplemental feeding of deer leads to overuse of palatable plants and vegetation degradation. We found 16 papers regarding the feeding of deer through a search of the literature since 1989. Recent studies have not provided conclusive evidence that supplemental feeding of deer enables herbivores to concentrate feeding on the most palatable native foods in their environment or that it results in degradation of vegetation within the area. Providing supplemental feed does promote localized vegetation degradation by congregating animals near feeders. Long-term research is particularly needed in semi-arid and arid regions where supplemental feeding of deer is commonly practiced to determine effects of deer supplemented with artificial feeds on vegetation dynamics at the landscape level and to determine how localized overuse of vegetation near feeders influences ecosystem processes. Research should move towards devising strategies to improve nutritional quality and survival of deer without the vegetative effects that supplemental feeding programs may provide.

Key words: Supplemental feeding, vegetation degradation, literature review, deer density, ungulate.

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A current area of debate is whether wildlife managers and private individuals should offer supplemental feed to wild ungulates (Russell et al. 2001, Brown and Cooper 2006, Knox 2011). In North America, supplemental feeding was originally utilized during winters to help prevent deer from starving because of severe weather, reduced winter range, and depleted forage (Doman and Rasmussen 1944, Christian et al. 1960, Ozoga and Verme 1982). Supplemental feed (in pelleted form) is now used to improve the nutritional plane of deer (Cervidae) diets to increase deer productivity, particularly in southern regions of the United States (Knox 2011), in addition to reducing nutritional stress during winter. Supplemental feed may increase reproductive success, deer population densities, and adult body condition (Boutin 1989); however, many biologists do not feel the practice is ethically, ecologically, or economically justified (e.g., Brown and Cooper 2006). One argument expressed by researchers in opposition to supplemental feed is that feeding may facilitate long-term vegetation degradation by deer (Murden and Risenhoover 1993; Russell et al. 2001, Brown and Cooper 2006).

Reasons why supplemental feeding has the potential to cause vegetation degradation include 1) deer may overuse the most palatable plants in their habitat because they forage more selectively when feed is provided; 2) increased deer nutritional status results in increased population density, in turn resulting in increased foraging pressure on vegetation; 3) deer concentrate near feeders resulting in localized overuse of vegetation; and 4) supplemental feeding induces changes in deer behavior such as migratory patterns and homerange use which in turn may also lead to localized overuse of vegetation.

Deer eat a diet higher in nutritional quality than grazing ruminants. Most vegetation in their habitat is relatively low in nutritional quality; therefore, deer must spend a large portion of each day foraging to meet nutritional needs. Time spent seeking high quality forage is costly in terms of energy expenditure and exposure to predation, but deer may satisfy most of their nutritional requirements quickly when they consume supplemental feed (Murden and Risenhoover 1993). However, despite access to supplement, deer will continue to forage on natural vegetation, particularly those species that have the potential to optimize nutritional intake (Stephens and Krebs 1986, Berteaux et al. 1998). Deer then have time to selectively forage on the most palatable plants in the habitat, which may consequently become overused and decline in abundance. A plant community shift from more palatable to less palatable species may occur as a result of competitive displacement of preferred forages by lower quality species (Anderson and Katz 1993).

Providing supplemental feed may lead to increasing deer density if it results in greater reproduction and survival. Deer continue to consume natural vegetation even when provided supplemental feed and damage to vegetation may therefore occur if deer become sufficiently abundant (Illius and O'Connor 1999).

In addition to changes in diet selection and population size, supplemental feed may alter patterns of habitat use at the feeder. Distribution of foraging pressure may change because deer may spend most of their time foraging on vegetation adjacent to feed sources rather than foraging uniformly across the landscape (Putman and Staines 2004). Finally, the availability of supplemental feed may promote changes in deer behavior such that migratory patterns and homerange use is changed as a result of changes in food abundance.

Our objective was to determine if the available literature since Boutin (1989) supports the following hypotheses: (1) supplemental feeding relieves time constraints on foraging, enabling herbivores to concentrate feeding on the most palatable foods in their environment resulting in loss of palatable plants from the vegetation, (2) increased densities of deer resulting from supplemental feeding leads to degradation of vegetation, (3) concentration of deer around feeding stations results in habitat degradation, and (4) supplemental feeding induces changes in deer behavior such as migratory patterns and home range use which in turn may also lead to localized overuse of vegetation

Methods

We reviewed papers published since 1989 in which researchers measured effects of supplemental feeding of deer on vegetation communities. We chose papers published since 1989 to expand on a review done by Boutin (1989) which included the effects of supplemental feeding on vegetation and deer behavior. Unlike Boutin's (1989) review, we chose to focus specifically on the effects that supplemental feeding via feeders may have on vegetation communities. Search engines that we used included JSTOR, Wildlife and Ecology Studies Worldwide, Wiley Online Library, Springer Link, Science Direct, Google Scholar, and bibliographies from papers found. Search strings utilized combinations of "deer density," "deer density and vegetation," "supplemental feeding deer," "supplemental feeding and vegetation," and "vegetation communities with supplemental feed." We included only studies in which the food supply was pelleted feed to exclude papers that consisted of the researcher chopping down natural vegetation then giving it to animals. Additionally, papers were included that described feeding as "supplemental feed," "emergency feed," "winter feed," and "intercept feed."

Results

We located 16 studies on deer that included a supplemental feeding component (Table 1). Of these, researchers measured effects of supplementally fed deer on vegetation in 10 studies and made predictions about effects on vegetation in six studies.

Supplemental Feeding and Diet Selection

In eight out of 11 studies in which researchers compared diet composition between supplementally fed and unfed deer, deer

Table 1. Summary of 16 vegetation articles reviewed and relation to the hypothesis.

Hypothesis	Supporting	Non Supporting
Feeding increases selective foraging	Anderson 2007 Murden and Risenhoover 1992 VanBeest et al. 2010a VanBeest et al. 2010b Cooper et al. 2006 Doenier et al. 1997 Peterson and Messmer 2006 Barnett and Stohlgren 2001	Timmons et al. 2010 Schmitz 1990 Barnett and Stohlgren 2001
Feeding results in an increase in population densities and subsequent damage to vegetation	Peterson and Messmer 2006	Barnett and Stohlgren 2001
Deer degrade vegetation around feeding stations	Anderson 2007 Doenier et al. 1997 Cooper et al. 2006 Van Beest et al. 2010 Murden and Risenhoover 1992 Schmitz 1990 Van Beest et al. 2009 Kilpatrick and Stober 2002 Gundersen et al. 2004 Webb et al. 2008 Pérez-González et al. 2010 Barnett and Stohlgren 2001 Sahlsten et al. 2010	Lewis and Rongstad 1998
Changes in animal behavior:		
Migration	Peterson and Messmer 2006 Lewis and Rongstad 199	Sahlsten et al. 2010
Home range	Pérez-González et al. 2010 Webb et al. 2008 Cooper et al. 2006 Sahlsten et al. 2010 VanBeest et al. 2010b	Cooper et al. 2006 Kilpatrick and Stober 2002

with access to supplemental feed tended to exclude non-palatable forages from their diet and increase consumption of the least common and most nutritious plants (Murden and Risenhoover 1992, Doenier et al. 1997, Cooper et al. 2006, Peterson and Messmer 2006, Anderson 2007, VanBeest et al. 2010a, VanBeest et al. 2010b). Deer utilized less browse in the diet (Peterson and Messmer 2006), included a higher amount of rare forages and proportionately fewer species common to the environment (Murden and Risenhoover 1992, Doenier et al. 1997, Anderson 2007), and selected for plant seedlings (Cooper et al. 2006) and forages higher in nutritional quality (VanBeest et al. 2010b) when provided access to supplemental feed. Anderson (2007) found that mean willow (*Salix* spp.) cover (0–2 m) cover that was 0–2 m off the ground decreased in stands close to elk (*Cervus* spp.) feed stations (88.2% willow segments browsed; <5 km) when compared to stands distant to feed stations (28.5% willow segments browsed; 16–36 km). Conversely, Timmons et al. (2010), Barnett and Stohlgren (2001), and Schmitz (1990) found no evidence of selective foraging. The authors provide no evidence that supplemental feed will cause large increases in the proportion of high quality plants in deer diets or large declines in consumption of poor-quality forage. In some cases, however, it may be difficult to detect changes in diet composition resulting from access to supplemental feed because deer will continue to forage on a mixed diet to avoid digestive problems associated with secondary plant compounds (Schmitz 1990). Timmons et al. (2010) observed no change in diet species richness between supplementally fed and unfed deer; however, proportion of mast in diets of supplemented deer was 25% and 7% that of diets of unsupplemented deer during spring and autumn respectively. Over time, the decline in mast within deer diets potentially could affect reproduction of plants for which deer act as seed dispersers or seed predators (Janzen 1971). Additionally, they found that fed deer had five times the proportion of forb content in diets during autumn and two times the proportion of browse in the spring, Timmons et al. 2010), indicating that while diet richness does not change, proportion of forage classes may change. Barnett and Stohlgren (2001), found no significant difference between the number of regenerated aspen (*Populus tremuloides*) stems between three different winter range densities of elk; however, within this study feeding sites were not evenly distributed within and among treatments.

Deer Responses to Supplementation: Increase in Population Densities

Negative effects of high deer densities on vegetation are well documented in the mesic portion of their range, but are virtually unknown in semiarid regions (Russell et al. 2001, Horsley et al. 2003, Stockton et al. 2005, Gubanyi et al. 2008, Rooney 2009). We found only two articles in our review of the literature that discussed changes in deer densities and consequent effects on vegetation as a result of supplemental feeding. Fed mule deer (*Odocoileus hemionus*) exhibited 12% higher body condition and lower mortality and produced more fawns than non-fed deer (Peterson and Messmer 2006). Less browse was consumed overall when feeding occurred, which prolonged the availability of food in the area and subsequently postponed winter migration. Despite a reduction in overall browse utilization, the cascading effect to migratory changes has the potential to impact winter browse abundance when deer remain in the vicinity for long periods of time and have increased survival. In the study, most recorded causes of death were malnourishment. Over the three-year study, 17 of 52 fed deer died while 16 of 29 unfed deer died (Peterson and Messmer 2006). Conversely, Barnett and Stohlgren (2001), found no significant difference in aspen regeneration at different elk densities.

Deer Responses to Supplementation: Concentration around Feeding Stations

Providing supplemental feed concentrates deer into smaller areas, and this concentration results in localized overuse of forage plants compared to forage plants away from areas of concentration (Schmitz 1990, Doenier et. al 1997, Cooper et al. 2002, Tarr and Perkins 2002, Pérez-González et al. 2010, VanBeest et al. 2010a, VanBeest et al. 2010b). In addition to the increase in deer numbers, localized areas of overuse are an issue because of the progressive loss in plant species that has potential to result in habitat fragmentation and reduced biodiversity (DeCalesta 1994, Doman and Rasmussen 1944). However, based on the reviewed studies, there is no evidence that these feed-induced habitat effects extend further than areas directly adjacent to the feeder. For example, Pérez-González et al. (2010) determined that female Iberian red deer (*C. elaphus hispanicus*) aggregation at the feeder was consistently and significantly higher in sites where female distribution was associated with food supplementation. Supplementation generated female aggregation not observed with natural factors (Pérez-González et al. 2010). Presence of zones of heavy foraging close to feeder sites indicate that over-browsing at the feeder may lead to both the inability of seedlings to become established and depletion of palatable plants (Casey and Hein 1983).

Fourteen of 16 papers we reviewed reported effects of supplemental feeding on spatial distribution of deer around the feeder. Of the 14 studies in which researchers discussed the effects of supplemental feeding on the congregation of deer around a feed site, 13 provided evidence that deer will congregate at the feed site. At the population level, pellet counts revealed that moose utilized the vicinity of feed sites (up to 100–200 m) more than the surrounding area (up to 1,000 m; Sahlsten et al. 2010). Fecal pellet counts have shown that 79% (45 of 57 pellet groups) are reported within 300 m of a feed site while 95% (54 of 57 pellet groups) are found within 600 m (Doenier et al. 1997, Gundersen et al. 2004, VanBeest et al. 2010a). The probability that a deer using feeding sites will select habitat within 500 m of feeding sites may be almost five times higher than the probability the animal will select locations beyond 1.5 km from the feeding sites (VanBeest et al. 2010b). Food supplementation is a strong determining factor of animal distribution and is frequently the most important resource (Pérez-González et al. 2010).

While 13 of 14 researchers concluded a concentration of deer occurred around the feed site, seven papers incorporated vegetation measurements at the feed site and in all seven cases deer congregation led to overuse of highly palatable forage plants near feeders. For example, browsing pressure on seedlings increased with increasing proximity to feeders year-round in southwestern Texas, despite availability of green vegetation in spring (Cooper et al. 2006). In Norway, researchers reported a negative relationship between leader stem and lateral stem browsing of Norway spruce (*Picea abies*) and distance from feed sites (50% at 50 m and 0% at 100 m; VanBeest et al. 2010a). Norway spruce is generally not eaten by moose (*Alces alces*), but its presence in diets indicated a higher demand for browse close to the feed site (VanBeest et al. 2010a). Continuous browsing at a feed site after 15–20 years also led to a decrease in size and quality of shoots (VanBeest et al. 2010a) and percent browse on aspen stems (<2 m) was nearly significant ($P = 0.070$) 1.5 to 3 km from elk feeding grounds (Barnett and Stohlgren 2001). Additionally, the most palatable plants tend to be smaller, less likely to flower, and less likely to survive relative to the same species further from feed sites (Fletcher et al. 2002, Ruhren and Handel 2003, Anderson 2007).

Deer Responses to Supplementation: Changes in Deer Migration and Home Range

Supplemental feeding induces changes in deer behavior such as migratory patterns and home range use which in turn may also lead to localized overuse of vegetation. In our literature review, 8 of 16 papers discussed changes in animal home range and migratory patterns as a result of access to supplemental feed. In only two of these eight papers did the authors find that provision of supplemental feed resulted in no change in home range or migratory behavior of deer (Kilpatrick and Stober 2001, Cooper et al. 2006, Sahlsten et al. 2010). Although Kilpatrick and Stober (2002) found no changes to home range size, the study consisted of a closed suburban white-tailed deer population, and Cooper et al. (2006) only detected no changes in male populations. In Iberian red deer populations where feeding occurred, Pérez-González et al. (2010) observed a change in the distribution and mean harem size in 18 of 19 (94.7%) study sites. In 16 of these study sites, supplemental feeding was the most important factor affecting female distribution. When it occurred, food supplementation almost always determined female distribution and was frequently the most important resource (Pérez-González et al. 2010). Presence of supplemental feed can both delay (Peterson and Messmer 2006) and stop seasonal migration (Lewis and Rongstad 1998) and change home range size (Cooper et al. 2005; Pérez-González et al. 2010). Both Webb et al. (2008) and Cooper et al. (2006) described a reduction in animal home range. Overall, bucks in areas without supplemental feed appeared to have larger home range sizes than bucks in supplemented areas (Cooper et al. 2006). In northern Wisconsin, home ranges of winter-fed deer were similar to those existing on natural forage but winter-fed deer were less likely to migrate to separate summer ranges. Thirty-three of 47 deer monitored migrated without access to supplemental feed compared to 38 of 91 deer when provided with a supplemental food source (Lewis and Rongstad 1998).

In addition to changes in home range and migration, three of eight studies also addressed changes in core concentration area. With access to supplemental feed, the core concentration area of deer consisted of a location which included 50% of all recorded points within an animal's home range (Cooper et al. 2006). Deer core areas also shifted to include the food source and deer that had 2 core areas abandoned the one distant from the feed, particularly during winter (Kilpatrick and Stober 2002). When feed was present, mean distance of core area to feed site was approximately 66.2 m, and was 96.6 m with no feed present (Kilpatrick and Stober 2002). However, Kilpatrick and Stober (2002) also concluded that bait sites established in deer core areas or outside deer home ranges will have little effect on size or spatial arrangements of core area, but might shift core areas of activity within deer home range. Sahlsten et al. (2010), determined that, despite presence of feed, it may be difficult to redistribute moose at the beginning of migration. This is because early in migration, moose were completely indifferent to any attempts to distract them with food.

Discussion

Supplemental Feeding and Diet Selection

Several studies support the hypothesis that supplemental feeding of deer results in increased browsing pressure on the most desirable plants; however, there is no evidence that this selectivity causes a reduction in palatable plants and species richness within plant communities and a corresponding increase in less palatable plant species (Ostfeld and Keesing 2000). Most research to date has been short-term (<3 years), and longer-term studies are needed to determine how changes in deer diet composition resulting from feeding may affect vegetation dynamics.

Although there is evidence (e.g., Murden and Risenhoover 1993) that ungulates focus their browsing activity on a few highly profitable species, the behavioral choice made by deer and their forage choices constantly change as abiotic factors alter the plant community. Some species are selected only under specific conditions, and broad generalizations wildlife managers use to classify plant species as "palatable" and "preferred" should be tempered by the understanding that deer selectivity changes spatially and temporally (Nudds 1980). The dynamics of forage selection make it difficult to conduct studies that take this situation-specific forage selection by deer into account. For example, in advanced stages of plant succession, the decreasing levels of nutrients may reduce nutritional value of forages differentially. Thus, patterns of resource availability during plant succession affect plant defensive systems and, in turn, the relative palatability of plants to herbivores (Davidson 1993).

Deer Responses to Supplementation: Increase in Population Densities

Once supplemental feeding begins, the deer population may increase dramatically because of increased recruitment and survival. Increased deer density is itself a risk factor and a potential impediment to vegetation biodiversity. In our review, only two papers discussed effects of supplemental feeding-induced population increases and the corresponding effects on vegetation (Barnett and Stohlgren 2001, Peterson and Messmer 2006). Peterson and Messmer (2006) found that with access to supplemental feed, mule deer populations increase as a result of the artificially inflated nutrition intake. Increased deer density and subsequent browsing pressure affect vegetation communities because of over-browsing of palatable plants and prevention of the establishment of seedlings (Gundersen et al. 2004, Cooper et al. 2006). Barnett and Stohlgren (2001) found no differences in regeneration of aspen across elk winter range density, however, their results did not follow previous findings from the region (Krebill 1972), and may have been a result of small sample size.

If supplemental feeding is necessary to achieve management objectives, ecologists should identify threshold deer densities at which substantial negative impacts occur to vegetation communities and devise effective strategies to limit deer impacts and sustain ecosystem integrity at the feed site.

Deer Responses to Supplementation: Concentration around Feeding Stations

Behavioral changes which promote concentration of animals around a food source may decrease overall plant diversity on a patch scale (Murden and Risenhoover 1993, Doenier et al. 1997, Lewis and Rongstad 1998, Putman and Staines 2004, Timmons et al. 2010). The pattern of browsing on seedlings around feeders indicates that deer will continue to browse while in the vicinity of the feeder despite having access to supplement (Cooper et al. 2006). These researchers, however, were focusing on patch-level scales of resolution and were not taking into account potential implications for landscape-level vegetation dynamics. Furthermore, social factors among groups of deer restrict immediate access to supplemental food sites such that deer "waiting their turn" at the feeding site continue to use natural browse (Schmitz 1990), and browse depletion in the vicinity of a supplemental food site often exceeds that in adjacent habitat without supplemental food sites (Doenier et al. 1997).

At the landscape level it is possible for supplemental feeding to redistribute deer such that, aside from "sacrifice" areas around feeders, browsing pressure is reduced in other areas of the landscape compared to what would occur if animals were more evenly distributed. This hypothesis requires that management actions are used to maintain a consistent deer density despite the presence of supplemental feed.

Unfortunately the extent of plant community change remains unknown as a result of lack of research on supplemental feeding and plant community dynamics. Many studies we reviewed took place within a relatively short period of time while vegetation changes may require long periods of time (Russell et al. 2001). Long-term studies are needed to examine these effects over multiple animal generations (Nuttle et al. 2011).

Deer Responses to Supplementation: Changes in Deer Migration and Home Range

Based on evidence from the literature, feeding has potential to both hinder and help wildlife managers to preserve traditional migration patterns and maintain populations in balance with the carrying capacity of the habitat. This is because with access to feed, deer migratory patterns and home range use are disrupted and highly variable which can lead to changes in the vegetation community as a result of disproportionate browsing pressure. In turn, this can alter carrying capacity of the habitat in subsequent years if preferred browse species are damaged from prolonged use. Conversely, diversionary supplemental feed has been effectively used by wildlife managers to alter migratory behavior as a means to protect vegetative areas and prevent human-wildlife conflict in some situations (Peterson and Messmer 2007, Sahlsten et al. 2010).

Deer foraging is a dynamic phenomena and foraging deer are kept moving in response to a diffuse food source whose availability in space and time is modified by variation in weather, variation in browse species composition, and variation in deer nutritional needs. If feed rations raise an animal's nutritional plane, deer may remain on the winter range longer (Schmitz 1990, Doenier et al. 1997, Peterson and Messmer 2006). Additionally, establishment of a feeding site within a deer's home range may induce animals to alter their core-use area to coincide with access to the supplemental food (Pérez-González et al. 2010). Changes in deer activity from the presence of supplemental feed can supersede any influence on deer behavior from weather, lunar parameters, and other factors (Henke 1997).

Additionally, winter-feeding can be linked to changes in migratory behavior when conditional migrators fail to migrate from the vicinity of the feeding site and consequently do not teach the migratory behavior to their fawns (Nelson 1998). The damaging effect on the vegetation is then magnified when these animals fail to follow normal migratory patterns away from the area that is unable to support them without the supplement. This is because deer forage preference may quickly reduce the vegetation species and structure via selective browsing (Doenier et al. 1997), particularly on winter ranges with low forage diversity. Additionally, because fed deer tend to spend more time on winter ranges (Peterson and Messmer 2006), increased concentrations of deer for longer periods of time have the potential to impact winter browse through increased foraging pressure once the winter supplement is removed (Doman and Rasmussen 1944, Peterson and Messmer 2006). Thus, the benefits of improvement in deer nutritional level and survival as a result of supplemental feeding tend to be offset by negative impacts on the vegetation (Peterson and Messmer 2006). It may be necessary to identify alternative approaches to improving nutritional quality and survival of deer on winter ranges without the migration-altering effects that supplemental feeding programs can provide. Managers could work to devise strategies to improve nutritional quality and survival of deer without the behavior-altering effects that supplemental feeding programs can provide. An example of this may be periodic relocation of feeding sites.

Management Implications

Feeding wildlife (47% of 7,399 lease operators) is the management technique used most often on leases in Texas, followed by harvest control (32%), planted food plots (22%), brush control (19%), and wildlife census (12%) (Thigpen et al. 1990). Despite this, the body of research on the manner in which supplemental feeding affects the impact of deer on vegetation is not sufficient to address variation in vegetation responses. The only well documented effect of feeding is on vegetation adjacent to feeding stations. Although there is conclusive evidence that supplemental feeding is likely to affect vegetation, potential changes in vegetation, specifically at the community and larger scales, resulting from supplemental feeding are unknown. Changes in vegetation dynamics and composition may occur slowly making long-term studies vitally important, particularly in semiarid environments. Duration of studies in the 16 papers we reviewed was between one and three years. We must make management recommendations that are based on sound science, not based on short-term research projects scattered within one region of the country. A failure to document effects of deer on vegetation may have occurred because study duration was short (Lewis and Rongstad 1998, Nuttle 2011).

Most research of the effect of providing supplemental feed to large herbivores is concentrated in northern temperate environments and limited to domestic livestock rather than native wildlife (Boutin 1989). Additionally, many studies consist only of the effects of providing a supplement to deer herds during winter (Schmitz 1990, Doenier et al. 1997, Cooper et al. 2006, Pérez-González et al. 2010). Based on our review of the literature since 1989, little has changed with regard to our understanding of the long-term effects of year-round supplemental feeding, particularly in snow-free regions. Additional research in a variety of environments is needed to determine how supplemental feeding affects the spatial distribution and foraging behavior of non-captive deer, and the corresponding effects on plant communities. Supplemental feeding may affect deer foraging impacts on vegetation differently in different ecoregions (Timmons et al. 2010). Survey of 334 ranches comprising 2.3 million acres in south Texas indicated the regional economic impact of hunting expenditures was approximately US$326,795, 172 (Dodd 2009). Across south Texas, landowners and lessees that manage for deer spent $1,778,645 ($3.64 per acre) on habitat management, supplemental feeding consisted of $967,225 of this total (Dodd 2009). More research on the effects of supplemental feeding of deer on vegetation is particularly needed in semiarid environments where the practice is widely applied.

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