Goat dietary selections, performance and browsing effects on a brush-invaded oak savanna in southwest Wisconsin over 3 years

Cherrie Nolden

MS Candidate, Agroecology
University of Wisconsin-Madison
canolden@wisc.edu, 608-477-1981

John Harrington, Advisor
Landscape Architecture and Agroecology

Thesis Defense
Agriculture Hall, UW-Madison
Monday July 8, 2019
Multiflora Rose in West Virginia

- West Virginia, multiflora rose, 1986
- Goats reduced brush from 45% to 15% in one season
- Sheep required 3 seasons to do the same
  - Mowing/herbicide improved sheep effectiveness
- Actual goat kill of brush
  - Early season defoliations
  - 5 years, killed 98%
- Management
  - Goats for brush
  - Sheep for forbs
  - Cattle for toppling

(Bryan, 1994)
Brush Management Strategies

• Prescribed Fire
• Mechanical
• Chemical
• Biological
  • Timing
  • Intensity
  • Frequency
  • Duration

Effectiveness at Vegetation Control

– Natural and trained animal food preferences
  • Mimic mother, herdmates
  • Species forage preferences
  • Self-medication
  • Novel food introduction
– Natural and trained behavior
  • Herding, flocking
  • Paddock move anticipation
– Human management
  • Pasture size and location
  • Animal density
  • Duration, Intensity, Frequency
  • Timing
  • Understanding the system, effects of impacts
  • Being observant, adaptable, flexible
Brush Response to Disturbance

- Root bud response
- Single defoliation
- Repeated defoliation
- Apical dominance

Rotational Grazing Concepts

Applied in brush → Rotational Browsing
Can rotational browsing with goats be both an effective restoration tool for reducing a dense brush midstory and meet basic standards for goat meat production?
Research Site

- Yellowstone Lake Wildlife Area, WDNR
- 2008 Tree thinning
- Dense mid-story of closed shrubs

Site Layout

Nolden et al., unpublished data, Yellowstone Lake Wildlife Area, WDNR, Blanchardville, WI
Site Layout

Nolden et al., unpublished data, Yellowstone Lake Wildlife Area, WDNR, Blanchardville, WI

Site Layout

Nolden et al., unpublished data, Yellowstone Lake Wildlife Area, WDNR, Blanchardville, WI
Methods: Experimental Design

- **RCB Design:**
  - 5 Blocks
  - 3 Treatments
  - 0.5 hectares/Trtmt

- **Treatments:**
  - Light browsing (L)
  - Heavy browsing (H)
  - Control (C)

- **Goats:**
  - 6.4 AUE
  - Mix-breed
  - Meat type

![Experimental Design Diagram]

Highlander & Goat Research Sites
Methods: Vegetation Sampling

- Nested Quadrats
- Coverboard

1m² Herb

5m² Brush

2.5m

18 per treatment

Methods: Variables Examined

BRUSH
- Richness
- Density
- Cover
- Height
- Stem Density

HERBACEOUS
- Richness
- Cover

BIOPHYSICAL
- Light penetration
- Soil compaction
- Litter depth

GOATS
- Weight
- Parasitism
- Dietary Selection
### Methods: Hypotheses

#### BRUSH
- Richness
- Density
- Cover
- Height
- Stem Density

**H_{0}: means equal btwn controls, treatments**

#### HERBACEOUS
- Richness
- Cover

**H_{a}: means unequal btwn controls, treatments**

#### BIOPHYSICAL
- Light penetration
- Soil compaction
- Litter depth

#### GOATS
- Weight
- Parasitism
- Dietary Selection

**H_{0}: no change, H_{a}: before ≠ after**

**H_{a}: % eaten=cover**

**H_{a}: % eaten=by herd**

### Methods: Data Analysis

#### BRUSH
- Richness
- Density
- Cover
- Height
- Stem Density

**SAS**

**PROC MIXED, ANOVA,**

**P ≤ 0.05**

**Ranked for normality pdmix800 for letters**

#### HERBACEOUS
- Richness
- Cover

#### BIOPHYSICAL
- Light penetration
- Soil compaction
- Litter depth

#### GOATS
- Weight
- Parasitism
- Dietary Selection

**Kulczyński’s Similarity Index,**

**P ≤ 0.05**
Goat Diet Selections and Performance

- Goat follows
  - Forage type selections
    - 6 d/rotation
    - 6 goats, 15 sec for 5 min
    - 4 times/d
  - 3 private herds
    - Pre & post browsing
      - Weights for ADG
      - Body Condition Scores
      - FAMACHA Scores

Photo: Cherrie Nolden

FAMACHA

Haemonchus contortus – barber pole worm

Images courtesy of Dr. David Thomas, UW-Madison, Sheep Production and Management 430, Spring Semester 2013
Ecological Changes

Photos by Katie Baumann

Brush Cover by Height-Coverboards

Band 5: p=.0369
Band 3: p=.0474

Nolden et al., unpublished data, Yellowstone Lake Wildlife Area, WDNR, Blanchardville, WI
Nolden et al., unpublished data, Yellowstone Lake Wildlife Area, WDNR, Blanchardville, WI

### Brush Cover (% Overall)

- **2011:** p = .7417
- **2014:** p = .0265

### Brush Height (m)

- **2011:** p = .6682
- **2014:** p = .0184

Nolden et al., unpublished data, Yellowstone Lake Wildlife Area, WDNR, Blanchardville, WI
Leaf Litter Depth (cm)

- 2011: p = 0.5652
- 2012: p = 0.0559
- 2014: p = 0.7538

Soil Penetration Depth (cm)

- 2012: p = 0.6854
- 2014: p = 0.7644

Nolden et al., unpublished data, Yellowstone Lake Wildlife Area, WDNR, Blanchardville, WI
Herbaceous % Cover by Treatment

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>Herbaceous Cover (%)</th>
<th>Graminoid Cover (%)</th>
<th>Forb Cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Control</td>
<td>0.0</td>
<td>20.0</td>
<td>40.0</td>
</tr>
<tr>
<td>2014</td>
<td>Control</td>
<td>20.0</td>
<td>40.0</td>
<td>60.0</td>
</tr>
<tr>
<td>2011</td>
<td>Light</td>
<td>40.0</td>
<td>60.0</td>
<td>80.0</td>
</tr>
<tr>
<td>2014</td>
<td>Light</td>
<td>60.0</td>
<td>80.0</td>
<td>100.0</td>
</tr>
<tr>
<td>2011</td>
<td>Heavy</td>
<td>60.0</td>
<td>80.0</td>
<td>100.0</td>
</tr>
<tr>
<td>2014</td>
<td>Heavy</td>
<td>80.0</td>
<td>100.0</td>
<td>120.0</td>
</tr>
</tbody>
</table>

Nolden et al., unpublished data, Yellowstone Lake Wildlife Area, WDNR, Blanchardville, WI

Richness by Treatment (species/m²)

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>Herbaceous Species Count</th>
<th>Graminoid Species Count</th>
<th>Forb Species Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Control</td>
<td>12.0</td>
<td>10.0</td>
<td>8.0</td>
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<td>2011</td>
<td>Light</td>
<td>8.0</td>
<td>6.0</td>
<td>4.0</td>
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<td>2014</td>
<td>Light</td>
<td>6.0</td>
<td>4.0</td>
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<tr>
<td>2011</td>
<td>Heavy</td>
<td>6.0</td>
<td>4.0</td>
<td>2.0</td>
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<tr>
<td>2014</td>
<td>Heavy</td>
<td>4.0</td>
<td>2.0</td>
<td>0.0</td>
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</tbody>
</table>

Nolden et al., unpublished data, Yellowstone Lake Wildlife Area, WDNR, Blanchardville, WI
Nolden et al., unpublished data, Yellowstone Lake Wildlife Area, WDNR, Blanchardville, WI
Availability vs. Goat Selections in WI

2011-2014 Ave Forage Availability

- Woody 49%
- Forbs 38%
- Grass 13%

2011-2013 Ave Goat Forage Selections

- Woody 85%
- Forbs 12%
- Grass 3%

Scottish Highland Cattle

- Grasses 29%
- Woody Spp 36%
- Forbs 35%

Meat Goats

- Grasses 3%
- Forbs 12%
- Woody Spp 85%

Forage Selections in WI Oak Savanna

(Harrington and Kathol, 2009) (Nolden et al., unpublished data, 2019)
Goat Class and Year with Count of Goats per Category

<table>
<thead>
<tr>
<th>Year</th>
<th>Kid</th>
<th>Nursing Doe</th>
<th>Open Doe</th>
<th>Yearling</th>
<th>Wether</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>40</td>
<td>34</td>
<td>40</td>
<td>25</td>
<td>28</td>
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<tr>
<td>2012</td>
<td>20</td>
<td>12</td>
<td>21</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>2013</td>
<td>13</td>
<td>35</td>
<td>28</td>
<td>13</td>
<td>9</td>
</tr>
</tbody>
</table>

Mean ADG in grams per day

- 45-181 g/d is excellent kid growth (Kerr Center, 2012)
- 64 g/d OK Buck Test (Kerr Center, 2012)
- 59 g/d MD Buck Test (W. Maryland University, 2011-2012)
- 91 g/d BAAP 2012 (Nolden, unpublished data)
### Body Condition Score

**Goat BCS (1-5) by class at start and end, and change by year**

<table>
<thead>
<tr>
<th>Class</th>
<th>Year</th>
<th>Start Mean</th>
<th>Start SE</th>
<th>Start Letter</th>
<th>End Mean</th>
<th>End SE</th>
<th>End Letter</th>
<th>Change Mean</th>
<th>Change SE</th>
<th>Change Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kid</td>
<td>2011</td>
<td>3.1 0.08</td>
<td>AB</td>
<td>--</td>
<td>3.1 0.10</td>
<td>AB</td>
<td>--</td>
<td>0.03</td>
<td>0.116</td>
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<td></td>
<td></td>
<td>2012</td>
<td>2.8 0.07</td>
<td>BC</td>
<td>2.9 0.09</td>
<td>BC</td>
<td>--</td>
<td>0.05</td>
<td>0.107</td>
<td>BC</td>
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<tr>
<td></td>
<td>2013</td>
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<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Nursing Doe</td>
<td>2011</td>
<td>3.2 0.10</td>
<td>C</td>
<td>--</td>
<td>2.8 0.13</td>
<td>C</td>
<td>--</td>
<td>-0.55</td>
<td>0.151</td>
<td>D</td>
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<tr>
<td></td>
<td>2012</td>
<td>1.9 0.10</td>
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<td>--</td>
<td>2.7 0.13</td>
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<td>0.86</td>
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<td></td>
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<td>--</td>
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<tr>
<td>Open Doe</td>
<td>2011</td>
<td>3.1 0.08</td>
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<td>--</td>
<td>3.5 0.11</td>
<td>A</td>
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<td>2012</td>
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<td>2.8 0.16</td>
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<td>0.188</td>
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<td>--</td>
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<tr>
<td>Yearling</td>
<td>2011</td>
<td>4.0 0.45</td>
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<td>--</td>
<td>2.0 0.58</td>
<td>ABC</td>
<td>--</td>
<td>-2.00</td>
<td>0.677</td>
<td>CD</td>
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<tr>
<td></td>
<td>2012</td>
<td>2.4 0.07</td>
<td>BC</td>
<td>--</td>
<td>2.9 0.10</td>
<td>BC</td>
<td>--</td>
<td>0.50</td>
<td>0.113</td>
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</tbody>
</table>

1. Starting and ending BCS (1-5) taken by the goat provider annually
2. BCS (Body Condition Score) change calculated on an animal unit basis over the days browsed
3. Different letters indicate significant difference within effect (Start, End or Change) at P ≤ 0.05
4. BCS data were not collected in 2011
5. BCS range of 1-5 is scored as: 1=emaciated, 3=ideal, 5=obese
6. Mixed model ANOVA results for analyses of Start, End and Change

### FAMACHA Score

**Goat FAMACHA score (1-5) at start and end, and change by year**

<table>
<thead>
<tr>
<th>Class</th>
<th>Year</th>
<th>Start Mean</th>
<th>Start SE</th>
<th>Start Letter</th>
<th>End Mean</th>
<th>End SE</th>
<th>End Letter</th>
<th>Change Mean</th>
<th>Change SE</th>
<th>Change Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kid</td>
<td>2011</td>
<td>1.9 0.11</td>
<td>C</td>
<td>--</td>
<td>1.9 0.11</td>
<td>C</td>
<td>--</td>
<td>0.08</td>
<td>0.147</td>
<td>AB</td>
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<tr>
<td></td>
<td>2012</td>
<td>2.2 0.12</td>
<td>C</td>
<td>--</td>
<td>2.6 0.12</td>
<td>B</td>
<td>--</td>
<td>0.41</td>
<td>0.153</td>
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<td>2013</td>
<td>2.9 0.11</td>
<td>AB</td>
<td>--</td>
<td>2.5 0.11</td>
<td>B</td>
<td>--</td>
<td>-0.40</td>
<td>0.141</td>
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<td>Nursing Doe</td>
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<td>2.1 0.14</td>
<td>BC</td>
<td>--</td>
<td>-0.20</td>
<td>0.179</td>
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<td>2012</td>
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<td>2.3 0.15</td>
<td>BC</td>
<td>--</td>
<td>0.30</td>
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<td>3.4 0.15</td>
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<td>3.8 0.15</td>
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<td>2.4 0.12</td>
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<td>2.3 0.13</td>
<td>BC</td>
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<td>-0.14</td>
<td>0.169</td>
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<td>3.4 0.19</td>
<td>A</td>
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<td>0.31</td>
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<td>--</td>
<td>--</td>
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<td>A</td>
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<td>0.31</td>
<td>0.149</td>
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<td>Wether</td>
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<td>BC</td>
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<td>-0.22</td>
<td>0.298</td>
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</tbody>
</table>

1. Starting and ending FAMACHA score (1-5) taken by the goat provider annually
2. FAMACHA score change calculated on an animal unit basis over the days browsed
3. Different letters indicate significant difference within effect (Start, End or Change) at P ≤ 0.05
4. FAMACHA score of 1=excellent, 3=moderately anemic, 5=deathly anemic
5. Mixed model ANOVA results for analyses of Start, End and Change
Sales

<table>
<thead>
<tr>
<th>Slip</th>
<th>Tag</th>
<th>Hdl</th>
<th>Rs. Description</th>
<th>Purchaser</th>
<th>Avg</th>
<th>Weight</th>
<th>Price</th>
<th>Amount</th>
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<tr>
<td>0684</td>
<td>1031</td>
<td>20</td>
<td>0 X-Bred Kid</td>
<td>4-2</td>
<td>57</td>
<td>1145</td>
<td>260.00w</td>
<td>2977.00</td>
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<td>1031</td>
<td>1</td>
<td>0 D-Kid</td>
<td>1600</td>
<td>35</td>
<td>35</td>
<td>250.00w</td>
<td>87.50</td>
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<tr>
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<td>1031</td>
<td>1</td>
<td>0 D-Kid</td>
<td>1600</td>
<td>35</td>
<td>35</td>
<td>240.00w</td>
<td>258.00</td>
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<tr>
<td>0684</td>
<td>1031</td>
<td>1</td>
<td>0 D-Kid</td>
<td>1600</td>
<td>35</td>
<td>35</td>
<td>240.00w</td>
<td>258.00</td>
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<tr>
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<td>1031</td>
<td>1</td>
<td>0 D-Kid</td>
<td>1600</td>
<td>35</td>
<td>35</td>
<td>240.00w</td>
<td>258.00</td>
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<td>6</td>
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<td>115.1</td>
<td>80</td>
<td>480</td>
<td>140.00w</td>
<td>672.00</td>
</tr>
</tbody>
</table>

Income per kid sold:
- 4 goats per wooded acre
- 0.67 2 of 3 are kids to be sold, 1 is the dam
- 2.67 Sale goats produced per acre
- $400 dollars per wooded acre per year income

WI Contract Browsing Fees

- April 15 to November 1
- Hourly rate $25-60
- Delivery charge $100-200/trip
- Head/Day charge $2-3.00

Example
- 15 ac woodland
- 1 week (7 d)
- 200 goats ($2.00)
- 8 deliveries ($150)
- Labor for 5 ac paddocks (3 moves)
  - 5 hr setup, 3 hr move x 2 ($35)

$3,895 charged/wk
$506.35 income/goat
Why Browse Goats?

- Advantages:
  - Free high-quality forage
  - 0.17-0.31 lb ADG w/o grain
  - Improved/NC BCS
  - NC FAMACHA
  - Potential for Fee Browsing
  - Parasite-free land
  - Organic land
  - Easy kidding
  - Natural goat habitat
  - Self-medication
  - Improve the environment
  - Help neighbors manage their land
  - No cropland conflict
  - Precedent
  - Economical, Profitable!

- Disadvantages:
  - Labor
  - Need portable system
  - Distance from farm
  - Discovery time
  - Potential for liability
  - Potential for vandalism
  - Potential for predation
YLWA Summary

- Good impact in 4 days on heavily browsed sites
- No soil compaction
- Significant reduction in brush density and height
- Increase in invasive forbs
- 85% selection of woody species forage
  - Differences between herds in selections
- Goats healthy
  - Overall unchanged body condition score
  - Unchanged FAMACHA score
- Goats gained weight
  - .17-.31 lb/d for kids

Study Limitations

- Conservative approach in design
- Site browsed for only 3 years
  - 5-8 years needed to kill some brush species (Hart, 2006)
- “Heavily” browsed was 90% defoliation
  - 100% defoliation depletes carbohydrate root reserves faster
  - Contract Browsers will remove 100% of brush within 7 feet of the ground; impacts of actual practice would be more informative
- Compaction was difficult to measure – bedrock
- Split plot study design – animal behavior
- Goat performance – added years of parasites
Funding

For the Yellowstone Lake Wildlife Area research:
We appreciate the financial support from:
- Wisconsin Grazing Lands Conservation Initiative (GLCI)
- North Central Region Sustainable Agriculture Research and Education (NCR-SARE) graduate student grant
- Animal Welfare Approved good husbandry grant
- UW-Madison Center for Integrated Agricultural Systems
- UW-Madison Agroecology Program mini grant

Thank you to:
- Bruce Folley, Wisconsin DNR, YLWA Manager
- Carl Fredericks, Grass Mapping Enterprises, LLC
- Goat Suppliers
  - 2011: Driftless Land Stewardship, LLC
  - 2012: Vegetation Solutions, LLC
  - 2013: 1dr Acres Farm
- Peter Krump and Nicholas Keuler, UW-Madison Statistics Consulting
- Keefe Keeley, Becka Dymzarov, Lee Nolden for field assistance
- John Harrington, Advisor
- Steven Ventura and Richard Cates, Committee members

Questions?

canolden@wisc.edu
608-477-1981

Photo by Ken Brunson
References

- Pflazbot, G. 2013. GoatWorld.com
Kulczynski’s Similarity Index

- Diet composition informs selection discrimination relative to plant composition

\[ \text{KSI} = \left( \frac{2c_i}{a_i + b_i} \right) \times 100 \]

- Where
  - \(a_i\) = % basal cover of component \(i\),
  - \(b_i\) = % of component \(i\) detected in goat diet
  - \(c_i\) = the lesser of \(a_i\) or \(b_i\)

- KSI values
  - \(\geq 80\%\) indicated little or no discrimination (i.e., selection patterns were similar to plant availability)
  - Between 21% and 79% indicated moderate discrimination
  - \(\leq 20\%\) indicated either strong preference for or avoidance of individual plant species
  - Preference and avoidance were distinguished from one another by comparing the proportion of goat diets composed of component \(i\) with basal cover of component \(i\) in paddocks

Oosting, 1956; Ferreira et al., 2009; Sowers et al., 2019

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Kulczynski's Similarity Index

<table>
<thead>
<tr>
<th>Item</th>
<th>Botanical composition, % ¹</th>
<th></th>
<th></th>
<th></th>
<th>²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2011</td>
<td>2012</td>
<td>2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dietary botanical selection, % of diet</td>
<td>woody</td>
<td>88.9 (± 2.2) a</td>
<td>81.2 (± 2.2) b</td>
<td>83.8 (± 2.0) b</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td></td>
<td>forb</td>
<td>8.2 (± 1.9) b</td>
<td>14.5 (± 1.9) a</td>
<td>13.5 (± 1.8) a</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td></td>
<td>graminoid</td>
<td>2.9 (± 0.9) a</td>
<td>4.3 (± 1.0) a</td>
<td>2.8 (± 0.9) a</td>
<td>0.0355</td>
</tr>
<tr>
<td>Botanical Availability, % cover</td>
<td>woody</td>
<td>39.2 (± 4.8) c</td>
<td>58.3 (± 4.8) a</td>
<td>45.0 (± 4.8) b</td>
<td>&lt;.0001</td>
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<tr>
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<td>7.1 (± 2.1) c</td>
<td>11.2 (± 2.1) b</td>
<td>49.2 (± 2.1) a</td>
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<tr>
<td></td>
<td>graminoid</td>
<td>2.1 (± 1.1) c</td>
<td>5.8 (± 1.1) b</td>
<td>13.7 (± 1.3) a</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>KSI, % similarity ³</td>
<td>woody</td>
<td>56.4 (± 3.9) c¥</td>
<td>74.6 (± 3.9) a¥</td>
<td>68.5 (± 3.9) b¥</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td></td>
<td>forb</td>
<td>16.5 (± 2.5) b*</td>
<td>33.2 (± 2.6) a¥</td>
<td>34.5 (± 2.3) a¥</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td></td>
<td>graminoid</td>
<td>1.1 (± 1.8) b*</td>
<td>10.1 (± 1.9) a¥</td>
<td>14.1 (± 1.7) a¥</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

¹ Mixed model means and (±SE) associated with comparison of year main-effects means.
² Mixed model ranked P value associated with year F-test.
³ Kulczynski’s Similarity Index (KSI):

- * Strong preference (i.e. KSI ≤ 20, selection frequency > availability)
- ** Strong avoidance (i.e. KSI ≤ 20, availability > selection frequency)
- ¥ Moderate preference (i.e. KSI between 21% and 79%, selection frequency > availability)
- # Moderate avoidance (i.e. KSI between 21% and 79%, availability > selection frequency)