A Futuristic Look at the Use of Grazed Forages in the Western United States

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Abstract

Scenario analysis was used to develop scenarios the grazed forage industry in the western U.S. will most likely face over the next several decades. Five major factors were identified as being most consequential. Scenarios indicated that livestock use of grazing lands will most likely decline while wildlife use will increase.

Introduction

Risks and uncertainty are naturally inherent in agricultural production. To enable producers and government agencies to plan strategically, they need to account for and understand the uncertainties confronting them. An alternative to econometric forecasting that develops an understanding for the causal relationships and factors that contribute to changes and instability is scenario analysis. Scenarios provide a framework for examining possible futures (Wack, Huss). By reducing uncertainties into a set of scenarios, decision makers are provided with information that accounts for change and unknowns. The objective of this study was to develop futuristic scenarios that will aid the strategic decisions of the U.S. grazed forage industry. Grazed forages include annual pasture, seeded perennial pasture, native

pasture, small grain pasture, native

pasture and range, hay aftermath and crop residue.

Methods

As explained by Brauers and Weber, scenario development consists of an analysis phase, description of future states of environmental subsystems and a synthesis phase.

<u>Analysis Phase</u>

Scenario analysis is conducted by combining the opinions of experts. After the entity under investigation has been defined, factors affecting that entity are identified. The selected factors must be comprehensive enough to reflect all relevant concerns about the future, and must be well enough defined so that all experts are dealing with the same assumptions.

<u>Description of Future States</u>

Two or three possible development paths or possible future states of each factor are typically designated by evaluating historical trends, current conditions and expert opinion. These states of nature should be mutually exclusive and technically exhaustive, i.e., other states of nature should have a probability of occurrence so low as to justify their exclusion.

Synthesis Phase

In this stage, interdependencies between factor levels are considered and alternative scenarios generated through synthesis of these different future states. To accomplish this, Brauers and Weber suggest using marginal and joint probabilities, with the joint probabilities estimated via marginal probabilities and compatibility ratings obtained from the expert panel. This serves as the basis to obtain cross-impact probabilities (probability of two factors occurring together) and to conduct the generation of scenarios.

Through survey and personal interviews with the expert panel, the probability of occurrence of possible future states or levels of each factor are first obtained. These called marginal probabilities and are expressed as $p(i)$, $p(j)$, etc., where $p(i)$ is the probability that event i will occur and $p(j)$ is the probability that event j will occur. The possible future states of each factor are exhaustive and mutually exclusive and thus the assigned marginal probabilities of each factor's levels must add up to 100 percent.

To keep the information demanded from respondents as simple as possible, participants are asked to evaluate how compatible two events are, rather than directly estimating their joint probability. These compatibility ratings are expressed on a scale of 1 to 5. A compatibility rating of 5 indicates two possible occurrences are very compatible, and a rating of 1 indicated they are not likely to occur together. Values of 2, 3 and 4 represent increasing compatibility.

To calculate scenario likelihoods or probabilities of occurrence, the compatibility estimates, k_{ij}, of values 1 through 5 are transformed into probabilities. Marginal probabilities of the two events, *i* and *j*, are used to determine the upper and lower bounds of the joint probability $p(i*j)$ according to probability theory axioms, as:

(1) $l_{ij} = max\{0, p(i) + p(j) - 1\} \leq p(i*j) \leq min\{p(i),p(j)\} = u_{ij}$,

where, l_{ij} = joint probability lower limit and u_{ij} = joint probability upper limit.

Compatibility values are then transformed into joint probabilities $p(i*j)$ using the equations:

(2) $p(i*j) = p(i)*p(j) - \{(l_{ij} - p(i)*p(j))*(k_{ij} - 3)/2\}$, and

(3) $p(i*j) = p(i)*p(j) + \{(u_{ij} - p(i)*p(j))*(k_{ij} - 3)/2\}$.

This gives two linear interpolations, one for $1 \leq k \leq 3$ and one for $3 \leq k \leq 5$. The calculated joint probabilities $p(i*j)$ are preliminary in that the probability of each outcome will likely not be equal to the sum of the joint probabilities for this outcome and every other outcome both occurring and not occurring, or

(4) $p(i) = p(i*j) + p(i*{\sim}j)$,

where $p(i*{\sim}j)$ is the joint probability that event *i* will occur and event *j* will not.

To adjust joint probabilities and determine scenario probabilities, a goal programming model (GP) with the objective of minimizing the differences of the initial or preliminary (p) and corrected or final (p′) joint probabilities can be used (Brauers and Weber). Once the corrected joint probabilities $p'(i*j)$ which satisfy the condition of $p(i) = p'(i*j) + p'(i*{\sim}j)$ are obtained, the difference between the initially calculated joint probabilities $p(i*j)$, and the corrected probabilities $p'(i*j)$ can be measured as d^- and d^+. When $p'(i*j) < p(i*j)$, the difference is d^-, and when $p'(i*j) > p(i*j)$, the difference is d^+. If the two joint probabilities are equal, the difference is zero. The GP has the form:

(5) $\min \sum_{ij}(d_{ij}^- + d_{ij}^+) + M*D$, subject to

(6) $y^t * a_i = p(i)$

(7) $y^t * (a_i * a_j) - p'(i * j) = 0$

(8) $\sum y_s = 1$, $s = 1$ to N

(9) $p'(i * j) + (d_{ij}^-) - (d_{ij}^+) = p(i * j)$

(10) $p'(i * j) + p'(i * \sim j) = p(i)$

(11) $D - d_{ij}^+ \geq 0$

$D - d_{ij}^- \geq 0$

(12) $y_s, d_{ij}^-, d_{ij}^+, D \geq 0 \quad i,j = 1,\ldots,N.$

M = a large value, e.g., 10,000; D = the maximum of all individual difference variables; $a_i = 0$ if outcome A is not in the scenario and 1 if outcome A is in the scenario; and y^t = probability of scenario t.

The GP model provides individual scenario probabilities, but because of the degenerate solution problem in linear programming, alternative solutions or scenario probabilities may exist. Brauers and Weber suggest solving the GP to obtain the minimum possible deviation (MIN_{dev}) and then creating a new objective function and one additional constraint for use in a post-optimality analysis. The new objective function is

(13) Min y_s or Max y_s,

and the additional constraint is

(14) $\min \sum_{ij}(d_{ij}^- + d_{ij}^+) + M * D = \text{MIN}_{\text{dev}}$, $s = 1, \ldots, K$.

This model is solved for each of the K scenarios to obtain their minimum and maximum probability of occurrence. The arithmetic mean of the upper and lower bound then defines the probability of each scenario.

The objective of scenario analysis is to develop a small number of representative scenarios that can be used by managers in strategic planning. In this study, scenarios were combined into groups using cluster analysis on the basis of the compatibility between scenarios. Inter-scenario compatibility ratings are developed using the compatibility estimates used to determine joint probabilities between factor levels. The compatibility rating between two scenarios is developed by comparing each factor outcome in one scenario with all factor outcomes in another scenario, summing all compatibility levels, then dividing by the number of factors levels compared. To choose a scenario to represent each cluster, the mean, mode and median of each factor level within each cluster is calculated and the representative factor level for each factor is chosen using these statistics.

Scenario analysis was conducted in this study by combining the assessments of 12 experts in the grazed forage industry throughout the western United States. The region included North and South Dakota, Nebraska, Kansas, Colorado, New Mexico and all states west. Because this analysis was being conducted for the USFS under the guidelines of the Resource Planning Act of 1974, a 50 year planning horizon was required.

Five factors hypothesized to affect the grazed forage industry over the planning period were first identified along with two to three mutually exclusive outcomes for each factor (Table 1). Panel members reviewed the factors and outcomes and made suggestions for revision. Three surveys were then presented to each panel member. The first survey obtained the marginal probabilities of each factor outcome. The second survey was developed to obtain the compatibility levels between each outcome of each factor. To better interpret the evaluations made by the experts, a list of issues that could influence each factor also was developed.

Respondents were asked to indicate the direction of change they believed each issue would take and also rate the influence each issue was expected to have on the use of grazed forages via the factor the issue was associated with.

The five factors and associated outcomes combined for a possible 162 scenarios. Scenarios were discarded if a compatibility rating of 1 existed between any two outcomes or the intra-scenario compatibility rating was less than 3.10. The intra-scenario compatibility of the remaining scenarios was neutral to very likely to occur together.

Results

Individual outcome marginal probabilities highlighted the general trends anticipated in the Western Region over the planning horizon (Table 1). A decrease in the availability of land for grazing, marginal lands being removed from grazing use, and an increase in the utilization of grazing lands by wildlife more than doubled the probabilities of their alternative outcomes. Small probabilities were given to increases in land available for forage production, impacts of regulation subsiding, livestock utilization of grazing lands increasing and wildlife decreasing. Panel members were slightly in favor of significant changes occurring in the development and/or use of forage production technologies.

As a general rule, outcomes that had a high (low) marginal probability had higher (lower) compatibility ratings with other outcomes. For example, the majority of compatibility ratings associated with "wildlife utilization of grazing lands will increase" (marginal probability of 59%) were level 4 (likely to occur together). Conversely, all but one compatibility rating for "wildlife utilization of grazing lands will decrease" (marginal probability of 10%) was level 2 (low likelihood of occurring together).

Compatibility ratings were fairly equally divided between compatibility levels 2, 3, and 4. Unless a near consensus occurred between regional panel members, extreme compatibility ratings (1 and 5) were eliminated by the central tendency method used to develop the regional compatibility matrix. Level 1 compatibility ratings (will not occur together) occurred twice and compatibility ratings of 5 (very likely to occur together) resulted five times. Most of the level 1 and 5 compatibility ratings involved the relationships between available land, government regulations and numbers of livestock. In general, increased regulations imply decreased land available for grazing which in turn implies less livestock grazing activities. An inverse relationship between the utilization of grazing lands by livestock and wildlife was likewise expressed.

The two scenarios developed for the Western Region (Table 2) can be interpreted in terms of the utilization of grazed forages by livestock and wildlife. Scenario #1 (72% probability of occurrence) specifies a decrease in the utilization of grazed forages by livestock and an increase by wildlife. Conversely, the utilization of grazed forages by livestock and wildlife is not designated to change significantly under Scenario #2 (21% probability of occurrence). Independent of the scenario examined, significant changes in the development and/or use of forage production technologies is consistent with the utilization of grazed forage projected. Land availability and environmental concerns are closely associated to the degree of grazed forage utilization anticipated.

For Scenario #1, changes in land use are expected to decrease the amount of land available for grazing. Urban sprawl and suburbanization are anticipated to increase or significantly increase, additional recreational demands on grazing lands are forecast, as are reforestation projects and allocation of lands for non-agricultural conservation use. These events will limit the utilization of grazed forages under this scenario. Nearly all panel members also expect the use of federal lands for livestock grazing to decrease or significantly decrease and to negatively impact the utilization of grazed forages in the Western Region. The major impact will occur on USFS lands, though over half of the respondents expect grazing on BLM allotments to decrease.

The only two issues expected to exhibit a neutral to positive influence on the use of grazed forages are a persistent increase in the use of conservation easements and a promotion of "open" or "green" space. The impact of both issues on the use of grazed forages is not expected to be prominent, and thus for the events in Scenario #2 to be realized, the impact of issues projected to negatively influence land available for grazing will need to be modest.

For the factor Environmental Concerns and Government Policies, respondents assigned the largest marginal probability of occurrence to the event that regulations will increase on a national level, with lands on the margin being taken out of grazing use. This event was not highly compatible with either scenario and less critical environmental circumstances are anticipated. The maintenance of current grazing utilization levels by both wildlife and livestock (Scenario #2) necessitates that after initial minor changes, the impacts of regulation will subside. For Scenario #1, where a decline in utilization of grazing lands by livestock but an increase by wildlife is anticipated, environmental impacts will be significant in localized areas where resource concerns have already emerged. Regulations associated with water issues appear to be the major concern identified by panel members. Wetland and riparian area conservation, Clean Water Act regulations and the competition for water resources between agriculture and residential users should provide the major impacts. Regulations due to the Endangered Species Act and wilderness/preservation programs are also expected to negatively influence the use of grazed forages. Grazing on BLM and USFS allotments will be further impacted by new regulations and monitoring practices. To maintain both current livestock and wildlife grazing levels, a curtailment of these regulations will be important.

The anticipated decline in livestock numbers in Scenario #1 is projected to occur in beef cattle and sheep. Dairy cattle, goat and horse numbers are expected to increase sightly. A modest decline in profit margins of beef producers, increases in fee and non-fee costs of operating on public and private lands, along with increased public concerns for animal health rights will provide added pressure on diminishing livestock numbers. In order for livestock utilization of grazing lands to maintain current levels as depicted in Scenario #2, the time livestock spend on grazed forages must increase. While this is envisioned for beef cattle, most respondents do not feel increases are in order for other livestock species. Another area of anticipated promise is the use of grazing livestock to combat weed infestations.

While panel members are not overly optimistic that significant changes in the development and/or use of forage production technologies would occur, the fact that both scenarios contained this event emphasizes the importance of technological advancements and educational programs in preserving the grazed forage industry. Most benefits to the grazed forage industry are anticipated in the development of grazing management methods and in advances in technology for livestock distribution, monitoring and handling. Somewhat less influential will be the use of biological control methods for brush and weed management. Use of chemical methods, both existing and prospective, are expected to decline, as are fertilization and irrigation of grazing lands.

The future demand for wildlife resources is expected to come more from non-consumptive use and existence value than from hunting, which is projected to decline. Wildlife will equally utilize public and private resources, while an increase in grazing lands purchased or set-aside for wildlife habitat is anticipated. The expected displacement of livestock by wildlife should exhibit a negative influence on the overall use of grazed forages.

Conclusions

The scenarios of the conditions facing the western forage industry represent a combined opinion of a few select individuals deemed to be knowledgeable about the various aspects of the industry. These scenarios are intended to lend insight and understanding to possible future occurrences that may emerge. They are not intended to be single point indicators that are absolute. When viewed as a whole, the scenarios can serve the purpose of allowing exploration as to what may happen; providing a guideline to aid manager understanding and planning insight.

In general, the use of grazed forages in the western United States is expected to decline over the next several decades due mainly to environmental regulations and the loss of grazing resources from urban sprawl, suburbanization and the loss of federal AUMs. Livestock numbers will decrease as a result of these forces and profit margins of livestock producers will maintain or decline from current levels. Technological advancement will play an important part in trying to maintain the grazing forage industry. Wildlife will also be very competitive with livestock for grazing and habitat resources.

Table 1. Marginal Probabilities of Outcomes for Each Factor Influencing the Use of Grazed Forages, Western Region.

Factor/Outcome	Marginal Probability(%)
A. Land Available for Forage Production	
1. Changes in land use will increase the amount of land available for forage production.	12
2. Changes in land use will have little impact on the amount of land available for grazing.	24
3. Changes in land use will decrease the amount of land available for grazing.	64
B. Environmental Concerns and Government Policies	
1. Regulations will increase on a national level, with lands on the margin being taken out of grazing use.	56
2. Nationally, a significant effect will not be seen, but local effects will be significant in areas where resource concerns have already emerged.	35
3. After initial minor changes, the impacts of regulation will subside.	9
C. Livestock Utilization of Grazing Lands	
1. Livestock utilization of grazing lands will increase.	13
2. Livestock utilization of grazing lands will not change significantly.	37
3. Livestock utilization of grazing lands will decrease.	50
D. Wildlife Utilization of Grazing Lands	
1. Wildlife utilization of grazing land will increase.	59
2. Wildlife utilization of grazing lands will not change significantly.	31
3. Wildlife utilization of grazing lands will decrease.	10
E. Technology Changes in Forage Production	
1. There will not be significant changes in the development and/or use of forage production technologies.	41
2. There will be significant changes in the development and/or use of forage production technologies.	59

Table 2. Most Likely Scenarios for the Grazed Forage Industry Considering a 50-Year Planing Horizon, Western Region.

Factor	Scenario #1 Outcomes	Scenario #2 Outcomes
A. Land Available for Forage Production	Changes in land use will decrease the amount of land available for grazing.	Changes in land use will have little impact on the amount of land available for grazing.
B. Environmental Concerns and Government Policies	Nationally, a significant effect will not be seen, but local effects will be significant in areas where resource concerns have already emerged.	After initial minor changes, the impacts of regulation will subside.
C. Livestock Utilization of Grazing Lands	Livestock utilization of grazing lands will decrease.	Livestock utilization of grazing land will not change significantly.
D. Wildlife Utilization of Grazing Lands	Wildlife utilization of grazing lands will increase.	Wildlife utilization of grazing lands will not change significantly.
E. Technology Changes in Forage Production	There will be significant changes in the development and/or use of forage production technology.	There will be significant changes in the development and/or use of forage production technology.
Probability of Occurrence	72%	21%

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