Quality of deferred forage from waterfowl nesting sites on the Canadian prairies

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Jefferson, P. G., Wetter, L. and Wark, B. 1999. **Quality of deferred forage from waterfowl nesting sites on the Canadian prairies**. Can. J. Anim. Sci. **79**: 485–490. The nesting success of waterfowl can be increased by deferred use of perennial forage plant species adjacent to Canadian prairie wetlands for habitat cover. However, the maintenance of plant species diversity and biomass production requires periodic vegetation management such as biomass harvesting. The objective of this study was to determine the quality of forage harvested from these sites as affected by deferral period (years), cutting height, species type (tame vs. native) and province. Biomass was sampled at 16, 12 and 12 sites in Manitoba, Saskatchewan, and Alberta, respectively, representing a range from 2 to 4 yr of deferred use. Plant species were described and samples were clipped at 10 and 20 cm cutting height at 8 or 16 transect points per site in late July or early August 1994. Forage quality was determined as crude protein (CP), in vitro organic matter digestibility (IVOMD), acid detergent fibre (ADF), neutral detergent fibre (NDF), P and Ca content. Deferral period affected quality, but the response varied by province. For example, IVOMD was 90 g kg^{-1} higher at sites with longer deferred use in Saskatchewan, but was similar for Alberta and Manitoba sites. Harvesting at 20 cm height resulted in 24 g kg^{-1} greater IVOMD and 9 g kg^{-1} increased CP averaged across all three provinces. Forage from tame species sites exhibited 70 g kg^{-1} higher IVOMD, 49 g kg^{-1} greater CP, 0.3 g kg^{-1} more P and 4.6 g kg^{-1} more Ca content than that of native species sites in Alberta but there was no difference between vegetation types at sites in the other provinces. These forage sources will produce medium quality hay for beef cattle production. Deferring native species sites for 2 yr will produce highest biomass yields with the highest cellulosic content for potential bioethanol conversion.

Key words: Conservation, biomass, forage quality, NDF, ADF, protein, cellulose, hemicellulose, P, Ca

Jefferson, P. G., Wetter, L. et Wark, B. 1999. **Effets du report de l'utilisation des cultures fourragères implantées dans les aires de nidification de la sauvagine dans les prairies canadiennes sur la qualité du fourrage pour les bovins**. Can. J. Anim. Sci. **79**: 485–490. Il est possible d'améliorer les conditions de nidification de la sauvagine dans la prairie canadienne en retardant l'exploitation des cultures fourragères perennes installées aux abords des zones humides pour protéger l'habitat des oiseaux. Toutefois, le maintien de la diversité floristique et de la productivité en biomasse requiert certaines interventions périodiques, notamment l'enlèvement de cette biomasse. L'objet de nos recherches était de déterminer la qualité pour les bovins des fourrages récoltés à ces emplacements selon la durées en année du report d'utilisation, la hauteur de fauche, le type d'espèce, cultivée ou indigène et la province en cause. Les prélèvements de biomasse étaient faits, respectivement, à 16, 12 et 12 emplacements au Manitoba, en Saskatchewan et en Alberta, couvrant un écart de durée de report d'utilisation de 2 à 4 ans. Après identification des espèces fourragères, les échantillons étaient fauchés en fin juillet-début août 1994, à 10 et 20 cm de hauteur à 8 ou 16 points de transect par emplacement. La qualité fourragère était déterminée d'après la teneur en protéine brute (PB), la digestibilité in vitro de la matière sèche (DIVMS), la teneur en lignocellulose (FDA), en fibre au détergent neutre (FDN), en P et en Ca. La durée du report d'utilisation jouait sur la qualité, mais plus ou moins fortement selon la province. Ainsi en Saskatchewan la DIVMS était de 90 g kg^{-1} plus forte aux emplacements marqués par une durée de report plus longue, mais de telles différences n'étaient pas observées en Alberta ni au Manitoba. La fauche à la hauteur de 20 cm résultait en un gain de 24 g kg^{-1} pour la DIVMS et de 9 g kg^{-1} pour la teneur en PB, toutes provinces confondues. En outre, en Alberta le fourrage provenant d'espèces cultivées manifestait un gain de 70 g kg^{-1} pour la DIVMS, de 49 g kg^{-1} pour la teneur en PB et, respectivement, de 0,3 et 4,6 g kg^{-1} pour les teneurs en P et en Ca sur les fourrages provenant de prairies naturelles. Ces différences entre type floristique ne se retrouvaient pas dans les deux autres provinces. Le foin provenant de ces endroits s'est révélé de qualité moyenne pour l'alimentation des bovins à viande. C'est le report jusqu'à 2 ans de l'exploitation des herbages naturels qui fournissait les rendements les plus élevés de biomasse et la teneur en cellulose la plus forte, d'où leur intérêt pour la production éventuelle de bioéthanol.

Mots clés: Conservation, biomasse, qualité des fourrages, FDN, lignocellulose, province, cellulose, hémicellulose, P, Ca

The reproductive success of ground-nesting waterfowl can be increased by establishing perennial grass and legume forage species on land adjacent to sloughs, ponds, and water courses on the Northern Great Plains in Canada that has been recently cropped with annuals (Wark et al. 1995). The upright vegetative cover provided by deferred grazing or haying of one or more seasons' growth results in a protective habitat for waterfowl nests and reduces egg predation. Deferment has been defined as the postponement or delay of grazing to achieve a management objective (Forage and Grazing Terminology Committee 1992). Ducks Unlimited

Abbreviations: **ADF**, acid detergent fibre; **DNC**, dense nest cover; **CP**, crude protein; **IVOMD**, in vitro organic matter digestibility; **NDF**, neutral detergent fibre; **OM**, organic matter

Canada, a private conservation agency, has designated such sites as “Dense Nesting Cover” (DNC) and the primary objective requires deferred forage utilization by other consumers such as cattle. To maintain plant biodiversity and biomass production however, rejuvenation management of the plant community is required. Harvesting biomass where grazing has been deferred for two or more growing seasons can be as effective as controlled burns to maintain the plant community. The periodicity of rejuvenation treatment depends on site factors such as plant vigour, litter accumulation, and plant species (Wark et al. 1995). Haying minimizes costs to the management agency compared with fire rejuvenation due to the cost of fire safety and containment.

Forage biomass harvested from such sites could be used by local beef producers as winter feed for pregnant beef cows in cow/calf operations. These producers are experienced in the use of opportunity forages such as “slough hay”, chaff from annual crops and cereal crop straw to reduce the cost of winter feed. However, the harvest date required to avoid damaging eggs or young birds with machinery is after 15 July (Wark et al. 1995), well after the harvest date for optimum forage quality. July and August harvest dates may favour native forage species compared with introduced or “tame” forage species for these sites. Forage quality generally declines as the proportion of senescent or dead plant tissue and leaching of soluble nutrients and minerals increases with the length of the deferral period (Stoddart et al. 1975). To effectively rejuvenate sites with hay harvesting, litter removal and low cutting height are recommended (Wark et al. 1995). However, higher cutting height can increase forage quality as litter and lower plant parts may be older and more lignified than the upper plant parts (Smith 1972).

An alternative use for forage biomass from DNC sites in the future could be as ligno-cellulosic feedstock for bioethanol conversion. Cellulose and hemicellose from biomass can be reduced to constituent sugars and fermented to produce ethanol for petroleum fuel replacement (Wyman 1997). The CO_2 released from combustion of bioethanol represents carbon previously removed from the atmosphere by photosynthesis while petroleum fuel combustion releases additional CO_2 into the atmosphere. Thus, bioethanol from ligno-cellulosic feedstocks may help industrialized countries meet their commitments to the reduction of greenhouse gas emissions. While commercial biofuel plants do not presently exist, there is continuing research and development efforts by both government and private industry (Belkacemi et al. 1998). Recent research reports indicate that ethanol yield from ligno-cellulosic feedstocks could be as high as 90% of theoretical (Nguyen et al 1999). The potential “quality” criteria for this market are cellulosic properties and biomass yield. Forage harvested from DNC sites may be better suited to this industrial application than as livestock feed.

The objective of this study was to determine the forage quality and celllulosic properties of perennial forage biomass from DNC sites as affected by province, species type (tame vs. native), deferral period and harvesting height.

MATERIALS AND METHODS

Forty sites were selected from DNC seedings of Ducks Unlimited Canada in the three prairie provinces, Alberta, Manitoba and Saskatchewan, based on original seed mixture (tame vs. native), and deferral period (2, 3 or 4 yr). Forage from a site deferred for 2 yr consisted of current growing season growth plus that of the previous year, 3-yr deferred forage consisted of current growth plus that of the previous 2 yr and so on. Site locations are listed by latitude and longitude in Table 1 and were generally located near Brandon, Manitoba, Yorkton, Saskatchewan and Edmonton, Alberta. Sampling dates ranged from 18 to 28 July 1994 in Alberta, from 14 to 25 July 1994 in Manitoba and from 25 to 27 July 1994 in Saskatchewan.

At each site a transect was established across the area to be sampled. Eight, 16 or 18 sampling points along the transect were established at randomized distances along the transect. Most sites (32) had 16 samples, four sites had 8 samples, three sites had 18 samples and one had 10 samples. A Daubenmire frame (Cook and Stubbendieck 1986) was placed in the centre of 1-m^2 at each point. Plant species present, stem counts of each species and seed head counts for each species were recorded. Based on these counts, one to three dominant species were identified for each site. All plant material was harvested from within the 1-m^2 frame at a 10-cm cutting height. An adjacent 1-m^2 frame was harvested at a 20-cm cutting height. Plant material was dried at ambient temperature in paper bags and then shipped to Swift Current for processing.

All samples were dried in a forced-air oven at 60°C after arrival at the Semiarid Prairie Agricultural Research Centre at Swift Current, Saskatchewan. The dry weight of the sample was recorded and used to calculate forage biomass yield on a dry matter basis. The samples were ground in a Wiley mill to pass through a 1-mm screen, labelled and placed in glass jars.

In vitro organic matter digestibility and ash content (Tilley and Terry 1963) as modified by Troelsen and Hanel (1966), ADF and NDF (Goering and Van Soest 1970), and cellulose content (Crampton and Maynard 1938) were determined for each sample. Fistulated sheep used for the collection of rumen fluid were fed a standard bromegrass/alfalfa forage diet and cared for in accordance with the Canadian Council on Animal Care guidelines (CCAC 1993). Hemicellulose was calculated from the difference between NDF and ADF (Van Soest 1982). Nitrogen content was determined (Association of Official Analytical Chemists 1984) and multiplied by 6.25 for crude protein content. Phosphorous content was colorimetrically determined after sample digest with sulphuric acid (Varley 1966). Calcium content was determined by atomic absorption spectroscopy (Hitachi 1987).

The model for statistical analysis was a nested design (Steel and Torrie 1980) with sites nested within provinces and samples within sites. Analysis of variance (ANOVA) was calculated by PROC GLM in SAS (SAS Institute, Inc. 1985). Similar designs were followed for ANOVA of age, vegetation type and harvesting height effects. Standard error of the mean was calculated whenever the F test of the ANOVA table was significant at $a = 0.05$. Linear regression

Table 1. Latitude, longitude, sample size per site (*n*), biomass and dominant plant species of dense nesting cover sites by province, type of vegetation, and deferral period

Province	Site Name	N Lat. ° ′ ″	W Long. ° ′ ″	Type[z]	Deferral period years	*n*	Biomass (kg ha^{-1}) Mean	SE	Dominant species
Alberta	A. Johnson	53 1 2	111 11 53	N	2	16	2310	380	*Agropyron elongatum/Sonchus arvensis*
	B & E Acres	52 0 28	113 31 19	N	2	16	4460	500	*Agropyron trachycaulum/Agropyron dasystachyum/Stipa viridula*
	Linstrand	53 9 8	112 44 20	N	2	16	2580	380	*A. dasystachyum/A. elongatum*
	Martin	53 10 32	111 28 0	N	2	16	3950	660	*A. trachycaulum/Cirsium arvense*
	Bullington	52 15 59	112 44 27	N	3	16	2680	265	*A. trachycaulum/S. viridula*
	Whiteside	52 10 4	112 36 19	N	3	16	3650	440	*A. trachycaulum/S. viridula*
	A. Johnson	53 1 2	111 11 53	T	2	16	6440	400	*Medicago sativa/Bromus riparius*
	Whiteside	52 10 4	112 36 19	T	2	16	4960	500	*M. sativa*
	J.L. Barss	53 4 48	111 12 0	T	3	16	5190	410	*A. elongatum/M. sativa*
	Gilbert	52 26 38	112 43 16	T	3	16	3480	220	*Bromus inermis/M. sativa*
	Graham	53 46 35	111 52 48	T	4	16	5920	380	*B. inermis/M. sativa*
	Sena Walker	52 31 2	112 37 31	T	4	18	3100	260	*M. sativa*
Saskatchewan	Bolton	51 15 9	103 47 26	N	2	18	3560	290	*A. dasystachyum/Agropyron smithii/S. viridula*
	Yosinowski	51 21 13	104 1 45	N	2	16	3600	200	*A. dasystachyum /A. trachycaulum/S. viridula*
	Collingwood	51 30 35	103 58 11	N	3	16	3850	370	*M. sativa/A. dasystachyum*
	Faye	51 13 15	103 46 11	N	3	16	4200	350	*Agropyron intermedium/M. sativa/S. viridula*
	Nichol	51 32 46	103 50 20	N	3	16	3420	440	*A. smithii/M. sativa*
	Hyrnyk	51 59 11	103 38 34	N	4	16	1400	190	*S. viridula/M. sativa*
	Bencze	51 19 11	103 56 48	T	2	16	5880	480	*A. elongatum*
	Hehn	51 24 42	104 20 39	T	2	16	3930	400	*A. intermedium/A. trachycaulum/M. sativa*
	Breti	51 20 53	104 13 44	T	3	16	4270	330	*M. sativa*
	J. Kuhar	51 22 1	104 14 29	T	3	16	4230	240	*M. sativa*
	C. Start	51 20 48	103 51 4	T	4	16	2680	420	*A. intermedium/A. trachycaulum*
	Stephanson	51 53 20	103 51 33	T	4	16	2170	350	*A. intermedium/A. elongatum*
Manitoba	Fort Whyte	49 55 12	97 7 12	N	1	8	2350	150	–[y]
	Eve Werier	49 51 19	97 14 45	N	2	8	9100	640	–
	Myers	49 24 2	99 30 11	N	2	10	12510	700	–
	Hoseas1	49 25 45	99 18 51	N	3	16	5610	460	*A. dasystachyum/Andropogon gerardi/S. viridula*
	Hoseas2	49 25 45	99 18 51	N	3	16	5190	470	–
	Kolesar	50 16 49	99 47 44	N	3	16	4520	290	*S. viridula /A. dasystachyum*
	Cochran	50 24 2	96 55 53	N	4	18	5170	490	*A. dasystachyum*
	Turner	49 12 39	99 49 0	N	4	16	4560	250	*S. viridula/A. smithii /A. trachycaulum*
	Doerksen	49 49 35	100 16 49	N	5	8	1790	250	*A. smithii/A. dasystachyum/S. viridula*
	Reynolds	49 10 20	99 27 34	N	5	8	2470	350	*S. viridula*
	Clements	49 13 57	99 38 49	T	2	16	7740	340	*A. elongatum /Agropyron tricophorum*
	Johnson	50 8 51	99 53 39	T	2	16	5370	210	*A. intermedium/M. sativa*
	Goodman	49 25 44	99 20 16	T	3	16	13220	420	*A. intermedium/M. sativa*
	Scott	50 8 14	99 48 41	T	3	16	7200	300	*A. intermedium/M. sativa*
	Karzmerik	50 11 6	99 55 43	T	4	16	6600	620	*A. intermedium*
	Stanick	50 5 55	99 56 7	T	4	16	9420	450	*A. intermedium/A. trachycaulum/M. sativa*

[z]N, native species site; T, tame species site.
[y]Data not recorded.

Table 2. Biomass, forage quality, and cellulosic properties of dense nesting cover sites by province and vegetation type

	Alberta			Saskatchewan			Manitoba		
	Tame	Native	SE	Tame	Native	SE	Tame	Native	SE
Biomass (kg ha^{-1})	4300	2920	413	3450	2980	–	7370	4770	–
Crude protein (g kg^{-1})	104	55	6	96	100	–	77	57	–
IVOMD (g kg^{-1})	541	471	10	523	502	–	476	406	12
NDF (g kg^{-1})	571	691	14	593	600	–	658	694	–
ADF (g kg^{-1})	387	418	–^{z}	375	388	–	426	427	–
Phosphorus (g kg^{-1})	1.5	1.2	0.2	1.3	1.3	–	1.4	1.1	–
Calcium (g kg^{-1})	7.0	2.4	0.5	7.2	6.8	–	5.0	2.5	0.6
Ash (g kg^{-1})	69	60	–^{z}	99	100	–	86	85	–
Cellulose (g kg^{-1})	357	388	–	353	346	–	387	390	–
Hemicellulose (g kg^{-1})	184	273	12	213	218	–	232	267	6
n	98	96		96	98		96	124	

^{z}*F* test was not significant.

Table 3. Biomass, forage quality, and cellulosic properties of dense nesting cover sites by province and harvesting height

	Alberta			Saskatchewan			Manitoba		
	10 cm	20 cm	SE	10 cm	20 cm	SE	10 cm	20 cm	SE
Biomass (kg ha^{-1})	4550	3550	148	4340	2840	107	7120	6100	135
Crude protein (g kg^{-1})	76	84	2	91	105	3	63	69	2
IVOMD (g kg^{-1})	499	514	4	491	534	5	429	444	3
NDF (g kg^{-1})	637	623	–^{z}	613	580	6	682	675	–
ADF (g kg^{-1})	405	399	–	393	370	4	431	423	2
Phosphorus (g kg^{-1})	1.3	1.4	–	1.2	1.4	0.04	1.2	1.2	–
Calcium (g kg^{-1})	4.5	5.0	–	6.6	7.5	–	3.4	3.7	–
Ash (g kg^{-1})	64	64	–	95	95	–	85	86	–
Cellulose (g kg^{-1})	376	369	–	357	342	2	389	388	–
Hemicellulose (g kg^{-1})	232	224	–	220	210	–	251	252	–
n	97	97		97	97		110	110	

^{z}*F* test was not significant.

was used to examine relationships among variables and calculated with JMP (SAS Institute, Inc. 1995).

RESULTS

Biomass production varied among provinces and sites within provinces (Table 1). The widest range of biomass yields, from 1790 to 13220 kg ha^{-1}, were observed for sites in Manitoba. Similar low biomass yield sites were observed in Alberta and Saskatchewan, but the highest yield sites in those provinces were 50% of the highest yield site in Manitoba. This reflects the variation in yield potential as affected by climate, soils and other edaphic factors that are beyond the scope of this study. There were more species identified at the Alberta and Saskatchewan sites than in Manitoba (data not shown) but this may reflect the bias of different observers in each province as well as plant diversity. The dominant species observed for each site included grasses, alfalfa and some weeds. The presence of alfalfa, a tame species, in some native sites in Saskatchewan was surprising and may reflect weedy plants of this species from previous seedings. The alfalfa in native sites in Saskatchewan did not appear to affect yield potential since the lowest biomass yield site in the study, the Hyrnyk site, also contained alfalfa.

Each provincial data set was analyzed separately because all variables differed among the provinces. The vegetation type affected biomass and forage quality differently among the three provinces (Table 2). In Alberta, tame species sites exhibited greater biomass production, higher digestibility, crude protein, P and Ca content and lower NDF than native species sites. However, in Saskatchewan, there was no difference between vegetation types for biomass or forage quality parameters. In Manitoba, forage from tame species sites had higher digestibility than that from native sites but all other quality variables were not different. It should be noted that even the highest P content values observed were not adequate to meet the P requirement of non-lactating, pregnant beef cows in the last trimester of gestation (National Research Council 1996).

The cellulosic properties of forage from native and tame species DNC sites did not differ with the exception of hemicellulose in Alberta and Manitoba (Table 2). Native species sites exhibited higher hemicellulose content than tame species sites in those two provinces. The forage from different vegetation type sites did not differ in Saskatchewan. The cellulose contents reported are similar to those from monoculture native grasses grown at six locations in the prairie provinces of Canada (Jefferson et al. 1997). However, the hemicellulose contents are less in this study than as reported by Jefferson et al. (1997).

Increased harvesting height reduced biomass but resulted in a consistent improvement in crude protein content and

Table 4. Biomass, forage quality and cellulosic properties of dense nesting cover sites by province and deferral period

Province	Alberta				Saskatchewan				Manitoba			
Period (y)	2	3	4	SE	2	3	4	SE	2	3	4	SE
Biomass (kg ha^{-1})	4480	3460	3640	–[z]	4220	3990	2080	387	8150	7150	6400	–
Crude protein (g kg^{-1})	72	81	98	–	58	113	128	9	74	62	62	–
IVOMD (g kg^{-1})	497	502	541	–	458	536	548	17	445	422	431	–
NDF (g kg^{-1})	651	638	565	–	665	576	537	22	683	677	686	–
ADF (g kg^{-1})	424	393	371	–	404	378	356	10	426	433	442	–
Phosphorus (g kg^{-1})	1.3	1.4	1.3	–	0.8	1.4	1.8	0.1	1.5	1.1	1.0	0.1
Calcium (g kg^{-1})	4.0	4.4	7.4	–	3.7	8.7	8.8	1.7	3.8	3.7	3.5	–
Ash (g kg^{-1})	63	64	68	–	87	90	113	3	79	90	81	–
Cellulose (g kg^{-1})	397	364	335	–	371	345	326	7	382	397	401	–
Hemi cellulose (g kg^{-1})	226	244	194	–	261	197	181	18	257	244	244	–
n	80	80	34		66	80	48		50	80	66	

[z] *F* test was not significant.

forage digestibility and inconsistent effects on fibre and mineral characteristics (Table 3). Higher harvest height produced higher P content and lower ADF and NDF content at Saskatchewan sites but not at Alberta sites. At the Manitoba site, higher harvest height decreased ADF but had no effect on NDF, P or Ca.

Cellulosic properties were not affected by harvesting height with the exception of cellulose content at the Saskatchewan sites (Table 3). While increased harvest height may produce forage of higher quality for beef cattle, it would reduce the yield of biomass in a bioethanol feedstock harvesting system with little or no advantage for cellulosic characteristics.

The effect of deferral period varied among provinces with no effect in Alberta and Manitoba but significant effects on all variables in Saskatchewan (Table 4). Biomass, NDF, ADF, cellulose and hemicellulose content decreased while crude protein, IVOMD, P, Ca, and ash content increased as deferral period increased. Phosphorous content decreased with deferral period in Manitoba. These results were contrary to our hypothesis that deferred use of the forage would result in lower forage quality. Weathering of deferred forage has been reported to increase digestibility (Stoddart et al. 1975) but decrease CP, P and Ca contents. Other changes to the deferred forage, such as litter decomposition and nutrient recycling in the soil may be more important than weathering of standing biomass. More detailed studies will be needed to identify such factors. Generally, the differences in forage quality ranked $4 \geq 3 > 2$ yr of deferral for Saskatchewan sites. Based on the Saskatchewan results, a 2-yr deferral period would maximize biomass yield and cellulosic content for bioethanol feedstock harvest while 3- or 4-yr deferral would result in medium quality hay for beef cows. Additional P and Ca mineral supplements would be required for beef cow rations based on this hay, however.

About 85% of the variation in cellulose content of the forages sampled in this study was accounted for by the variation in ADF (data not shown). The degree of this relationship varied with the deferral period with r^2 values of 0.77; n = 181, 0.84; n = 224, and 0.92; n = 131 for 2, 3 and 4 yr, respectively. The residue of the ADF procedure contains largely cellulose and lignin (Van Soest 1982) so these correlations should be expected. Since ADF is commonly used to predict forage quality for ruminant animal consumption, its utility for predicting cellulose content in biofuel production will be useful.

DISCUSSION

Differences among the provinces for biomass production, forage quality and cellulosic characteristics were observed in this survey. The choice of plant species and mixtures for DNC revegetation has varied between provinces due to climatic differences, seed availability, and site characteristics. Alberta sites exhibited different results from those in Manitoba and Saskatchewan. Manitoba sites had more warm-season (C4) grass species present despite the dominance of cool-season (C3) species. Saskatchewan sites, both tame and native had more alfalfa than Alberta and Manitoba sites. While it is impossible to draw specific conclusions about the impacts of these differences, we speculate that they did contribute to the observed differences in forage biomass, quality and cellulosic characteristics.

If biomass harvesting is conducted at 4-yr intervals to rejuvenate vegetation on DNC sites, then tame forage plant species will produce a hay that can be utilized for overwintering beef cows. The quality of native forage species may be lower than that of tame species. Since forage quality generally improved with older deferred forage, wildlife managers can delay forage harvesting for 3-yr without reducing the quality of the hay produced compared with 2 yr of deferral. Increased cutting height did improve quality, but reduced biomass yield. Primary producers generally value forage yield more than forage quality and thus will likely choose to harvest at 10 cm height. These forage sources will produce medium-quality hay for beef cattle production.

If a bioethanol industry is developed utilizing ligno-cellulosic feedstocks, native species biomass would likely be preferred by the industry over tame species due to their higher hemicellulose content. The primary producer, however, will likely prefer to grow tame species due to the higher biomass yield than native species. Thus, price incentives may be required to obtain feedstocks with higher cellulosic properties. A rejuvenation interval of 2 yr would be preferred to longer intervals in order to maximize biomass yield and cellulosic characteristics but minimize ash content.

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