Comparison of haymaking strategies for cow-calf systems in the Salado Region of Argentina using a simulation model. 1. Effect of herbage mass at cutting and cow stocking rate under a rigid system of management

A. J. Romera*,†, S. T. Morris*, J. Hodgson*, W. D. Stirling* and S. J. R. Woodward‡
*College of Sciences, Massey University, Palmerston North, New Zealand, †INTA, Balcarce, Argentina, and ‡Woodward Research Limited, Hamilton, New Zealand

Abstract
A simulation model was used to compare the long-term performance of cow-calf farm systems under different haymaking strategies on a 100-ha farm. In the simulation, farm management was based on that which had been developed on Reserva 6, an experimental cow-calf farm established in 1966 at Instituto Nacional de Tecnología Agropecuaria-Balcarce Experimental Station, Argentina, where different technologies, including haymaking, have been adapted and applied in order to increase productivity of cow-calf systems in the Salado Region of Argentina. The management of the system is based on a restricted mating season (2 months), early weaning (5–7 months of age) and forage conservation. The simulations showed that the effect of using hay with respect to the strategy without hay, in terms of calf liveweight (LW) production per hectare, was greatest at the cow numbers that maximized production (290–320 cows) with a proportionate increase of 0.25. On the other hand, the advantage of using hay was smallest when the herbage mass at cutting for hay was 6 t dry matter (DM) ha⁻¹, particularly when more than 0.50 of the farm area was allocated to haymaking. The differences among the haymaking policies increased with cow numbers, especially at high herbage masses at cutting for hay. The analysis also suggested that the LW production per hectare of cow-calf farms would be maximized by harvesting 0.40–0.50 of the total farm area and aiming to cut hay at a herbage mass of 4 t DM ha⁻¹ and with medium quality.

Keywords: cow-calf systems, computer model, long-term simulation, haymaking policy

Introduction
The Salado Region (or Pampeana Depression) of Buenos Aires Province, Argentina, is an area of approximately 9 m ha⁻¹ (Soriano, 1992). The region has soil limitations for growing crops, and about 0.90 of the land is dedicated to cow-calf production (Carrillo and Shiersmann, 1992; Carrillo et al., 1998; Rearte, 1998).

In 1966 an experimental cow-calf farm was established at the Instituto Nacional de Tecnología Agropecuaria (INTA)-Balcarce Experimental Station where different technologies could be adapted and applied in order to increase the productivity and stability of systems in the area. Primarily, the objective of this farm was to estimate the production potential of the cow-calf systems of the Salado Region by optimally using the technology available to commercial farmers in the area (Carrillo et al., 1998). The system is known as ‘Reserva 6’ and is still in operation, consistently producing much more than the average farm (270 vs. 60–70 kg LW ha⁻¹ year⁻¹) through the use of cultivated pastures, subdivision, regular fertilizer application, planned health control, a restricted mating season (2 months), early weaning (5–7 months of age) and forage conservation.

The system follows a strict haymaking programme, closing paddocks at the beginning of spring (normally early October) after one spring grazing. Every year, 0.30 of the area is devoted to making low-quality hay (DM digestibility of 0.45) by cutting at high herbage masses, most of which is destined to provide maintenance feed for pregnant adult cows in the following winter. Cows are kept on a small paddock from weaning (March) to calving (August–September), receiving 6–9 kg DM of hay day⁻¹ and losing about 0.10 of their initial LW over...
this period. After calving, cows and calves are moved to paddocks that have not been grazed since early autumn.

The objective of this study was to compare, at a systems level, the long-term performance of a wide range of hay quantity-quality combinations using Reserva 6 as a base system. Comparing different haymaking strategies using a classical experimental approach of testing several combinations in the field would not be feasible, because it would require running several farmlets for several years, so the question was addressed through a simulation study.

Materials and methods
A cow-calf farm model was used for the simulations as described in detail by Romera et al. (2004). The biological components of the model were simulated using legacy models (Neil et al., 1997), described by Freer et al. (1997) for the cattle, McCall and Bishop-Hurley (2003) for the pastures and Allen et al. (1998) for the soil–water balance. The simulation time-step was 1 day.

The pasture model was climatically driven (by incident solar radiation, air temperature and soil water content) and actual climatic data from Balcarce were used to assess the long-term differences between alternative management strategies. The herbage accumulation predicted by the pasture model was compared with several years of actual data from herbage-cutting studies carried out at the INTA, Balcarce Experimental Station, and the agreement between observed and predicted data was considered acceptable (Figure 1).

A residual herbage mass of 600 kg dry matter (DM) ha⁻¹ after cutting hay was assumed. Field DM losses at harvesting were considered to be 0.20, feeding losses 0.05 and storage losses 0.01 per month (Barry et al., 1980). The DM digestibility of the hay was reduced by 0.04 U from the mean DM digestibility of the sward at cutting. In order to focus on strategic issues, as opposed to day-to-day operational decisions, in the simulations it was assumed that cutting hay was always possible, regardless of weather conditions.

Herd management
The management of the farm is represented by forty-four decision rules entered by the user. The mating period was October–November. Weaning was planned for 1 March but could take place at any time after 1 February if the body condition score of the cows was lower than 1 (equivalent to 5 on the common 1–9 scale, Freer et al., 1997). Most of the cattle sales occurred in autumn: weaned calves not retained as replacements, non-pregnant cows, and cows that had lost their calves.

Figure 1 Observed vs. simulated herbage dry matter (DM) accumulation for different periods. The field data were obtained from cutting studies following the Anslow and Green (1967) method at the Research Station of INTA Balcarce, Argentina (37°58’S) [Orbea and Villar, 1972 (●); Fernández Greco et al., 1996 (○); Fernández Greco et al., 1997 (▼); Piaggio et al., 1998 (■); Fernández Greco et al., 1998 (□)]. In all cases, the observed values correspond to agropiro (Thinopyrum ponticum) swards fertilized with phosphorus only.

Cows could be assigned to three herds, with two points in time when cows were regrouped, i.e. weaning (in March, coinciding with pregnancy diagnosis) and calving (August–September). At weaning the new replacement heifers entered herd 1, the second-year heifers (in calf for the first time) entered herd 2 and the mature cows (also in calf) entered herd 3. Note that the start of herd 3 could be delayed until the available hay was enough to provide feed (at least 8 kg DM of hay cow⁻¹ day⁻¹) until the end of calving, in which case the cows remain in herd 2. Immediately after calving, cows in herd 3 were moved to herd 2 and herd 3 disappeared until the following March.

Herd 1 and 2 grazed rotationally on two groups of paddocks. Ten paddocks were initially allocated to herd 1 and 29 to herd 2, but these numbers could change dynamically during the simulation through management rules. Once calving started, cows in herd 2 were offered hay ad libitum until the end of the calving season or until all hay was consumed. Cows in herd 3 were fed hay only (8 kg DM of hay cow⁻¹ day⁻¹) as only one paddock was allocated for use by herd 3.

Simulation study
The simulations described are based on a 100-ha cow-calf farm with forty paddocks of equal size. Two
management variables related to the haymaking policy of the farm were varied in the simulations: the area closed for haymaking in spring (AREA: ha) and the target herbage mass at which hay is harvested (MASS: t DM ha\(^{-1}\)). If the target herbage mass for cutting is not reached, the closed paddocks are cut at a final cutting date, in which case the actual cutting herbage mass could be lower than the target. Paddocks are only cut once in a season and then released for grazing.

The different haymaking policies were simulated across a wide range of target cow numbers (SR: total number of cows on the 100 ha farm after the autumn sales). Note that the actual cow numbers may be lower than the target, as ‘emergency’ cattle sales might take place in years where there is very low mean herbage mass on the farm or low cow body condition.

The three factors were combined factorially in 140 combinations (5 \(\times\) 4 \(\times\) 7 levels of AREA, MASS and SR respectively).

Table 1 shows details of the treatments simulated. As a control treatment, a strategy without hay (NoHay) was included and tested for the same range of cow numbers (therefore adding seven more combinations).

Twenty artificial sets of 50 years of daily weather data were generated by selecting years at random from an actual series of data recorded at the Balcarce Research Station of INTA (37°58’S), close to Reserva 6, from 1970 to 2000. All the 147 strategies were simulated using the same twenty series of 50 years of weather data, reinitializing the model each time, which gave a total of 2940 simulations. The intention was not to simulate outputs in the following year, so annual outputs take the form of an auto-correlated time series. However the design ensures that the separate 50-year series of data are independent, simplifying statistical analysis. The means and coefficients of variation (CV) for different performance indicators were statistically compared by considering each of the twenty simulations of 50 years to be an independent replicate. The GLM procedure of SAS (1999) was used, the statistical model being:

\[
y_{ijkl} = \mu + \text{SR}_i + \text{AREA}_j + \text{MASS}_k + (\text{SR AREA})_{ij} + (\text{SR MASS})_{ik} + (\text{AREA MASS})_{jk} + (\text{SR AREA MASS})_{ij} + \text{R}_l + e_{ijkl}
\]

where \(y_{ijkl} = ijkl\)-th observation (the mean or CV of some output variable over the \(ijkl\)-th 50-year simulation run), \(\mu\) = general mean, \(\text{SR}_i\) = \(i\)-th cow number target, \(\text{AREA}_j\) = \(j\)-th area policy (i.e. area in hectares closed for haymaking), \(\text{MASS}_k\) = \(k\)-th target cutting herbage mass policy (i.e. mass at which cutting is decided), \(\text{R}_l\) = \(l\)-th replicate (i.e. 50-year weather sequence effect), \(e_{ijkl}\) = error corresponding to the \(ijkl\)-th observation.

**Results**

The quantity and quality of the hay produced differed between strategies (Table 2). Cutting at a greater herbage mass produced more hay but with a lower digestibility. The range in total hay produced was almost sixfold between minimum and maximum.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area closed for haymaking: AREA (ha)</td>
<td>20/30/40/50/60</td>
</tr>
<tr>
<td>Target herbage mass for cutting: MASS (t DM ha(^{-1}))</td>
<td>3 (1 January)/4/5 (20 January)/6 (1 March)†</td>
</tr>
</tbody>
</table>

*Dates in parenthesis indicate the date when hay is made regardless of the herbage mass in the closed paddocks.

†Policy approximately applied in the experimental farm of INTA, Balcarce, Argentina.

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Not all the hay produced was actually consumed, depending on the amount of hay harvested relative to cow numbers (Figure 2). When hay was made at a low herbage mass (3 or 4 t DM ha$^{-1}$), it was mostly consumed, even at the maximum value of area harvested. This was not the case when hay was cut at a high herbage mass (5 or 6 t DM ha$^{-1}$).

The impact of the haymaking policy on the nutrition of the cattle is illustrated in Figure 3, which shows the LW of the cows at calving and at weaning. The strategies with low-quality hay resulted in lower cow LW at calving. The difference was slightly smaller by weaning but still significant. The LW of cows fed hay was consistently lower than when no hay was fed.

### Table 2

<table>
<thead>
<tr>
<th>Area harvested (ha)</th>
<th>Target cutting herbage mass policy (t DM ha$^{-1}$)</th>
<th>Hay produced</th>
<th>Digestibility of dry matter (DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>39.2 (1.1)$^a$</td>
<td>54.4 (2.8)$^b$</td>
<td>68.2 (7.3)$^c$</td>
</tr>
<tr>
<td>30</td>
<td>58.8 (2.0)$^a$</td>
<td>81.5 (4.5)$^b$</td>
<td>102.4 (10.7)$^c$</td>
</tr>
<tr>
<td>40</td>
<td>78.7 (2.8)$^a$</td>
<td>108.6 (6.2)$^b$</td>
<td>136.2 (14.9)$^c$</td>
</tr>
<tr>
<td>50</td>
<td>98.8 (4.7)$^a$</td>
<td>135.5 (8.5)$^b$</td>
<td>169.6 (19.1)$^c$</td>
</tr>
<tr>
<td>60</td>
<td>119.0 (6.7)$^a$</td>
<td>161.7 (11.1)$^b$</td>
<td>201.8 (24.0)$^c$</td>
</tr>
</tbody>
</table>

Hay digestibility 0.530 (0.004)$^a$ 0.499 (0.008)$^b$ 0.481 (0.015)$^c$ 0.468 (0.018)$^d$

Values in parenthesis are standard deviations. Means in the same row followed by different letters are significantly different ($P < 0.05$), t pair-wise test.

### Figure 2

Proportion of the hay produced and actually used in the following winter for each target number of cows, area harvested (—●—, 20 ha year$^{-1}$; ———O——, 30 ha year$^{-1}$; ———▼——, 40 ha year$^{-1}$; ———▲——, 50 ha year$^{-1}$; and ———■——, 60 ha year$^{-1}$) and target herbage cutting mass at haymaking where (a) 3 t DM ha$^{-1}$, (b) 4 t DM ha$^{-1}$, (c) 5 DM t ha$^{-1}$ and (d) 6 t DM ha$^{-1}$). Maximum is never 1.00 because of storage losses.
fed, the difference increasing progressively with increase in herbage mass at harvesting and area harvested.

The three main effects of AREA, MASS and SR and their interactions were all significant (P < 0.001) for the total amount of LW sold from the farm (kg LW ha\(^{-1}\) year\(^{-1}\)) and for the amount of calf LW sold (kg LW ha\(^{-1}\) year\(^{-1}\)). However, target cow number was the most important source of variation in both cases, explaining more than 0.60 of the total variation. Replicate (i.e. 50-year weather sequence) was the second most important explanatory variable.

To illustrate these results, Figure 4 shows the combined effect of the variables AREA and MASS on calf LW sold for the different cow numbers. The contour map representations at the top of Figure 4 show that the ‘favourable region’ (lightest shading) moves downwards on the area harvested axis as cutting herbage mass increases. That is, the higher the cutting herbage mass, the lower the optimum area for haymaking (approximately 46, 39, 34 and 22 ha for 3, 4, 5 and 6 t DM ha\(^{-1}\) respectively). The lower panel of Figure 4 shows how each strategy (including NoHay) reacts to the increase in cow numbers. The effect of using hay tended to be maximum (proportionately up to about 0.25 increase in calf LW sold) at the cow numbers (290–320 cows) that maximized production. Figure 4 also indicates that the benefit of using hay was less clear at the highest cutting herbage mass policy, and even disappeared when more than 50 ha were allocated to

Figure 3  Liveweight (LW) of cows after calving (— —, — —) and at weaning (— —) for each haymaking policy (denoted on the x-axes by AREA–MASS), where AREA is the area closed for haymaking (20–60 ha) and MASS is the target herbage mass at cutting (3–6 t DM ha\(^{-1}\)). Vertical lines indicate standard deviations (SD) obtained as the average of the SD from each of the twenty simulation runs (see text for details).

Figure 4  Response of calf liveweight (LW) sold to the target number of cows for each level of area closed for haymaking (——, 20 ha year\(^{-1}\); — —, 30 ha year\(^{-1}\); — —, 40 ha year\(^{-1}\); — —, 50 ha year\(^{-1}\); — —, 60 ha year\(^{-1}\); and — —, NoHay). Cutting mass policy (target herbage mass at haymaking) were: (a) 3 t DM ha\(^{-1}\), (b) 4 t DM ha\(^{-1}\), (c) 5 t DM ha\(^{-1}\) and (d) 6 t DM ha\(^{-1}\). ‘x’ in contour graphs indicates the approximate location of the maximum points.
haymaking. The difference among the haymaking policies increased with cow numbers, especially at high cutting herbage masses. The figures indicate that the greatest benefit was gained by making hay at low to medium herbage masses and cutting about 40–50 ha.

The effect of the strategies on the variability of the system outputs was also explored using ANOVA on the CV for calf LW sold. Replicate (different weather patterns), the main effects and their interactions were all significant. Again, target cow number explained more of the differences in the CV than other factors, with the CV increasing with the cow number (Figure 5). There appears to be an optimum (i.e. lowest CV) at AREA = 40 ha and MASS = 4–5 t DM ha\(^{-1}\) (Figure 5), and cutting more than 50 ha increases the variability without any benefit in the mean calf LW production (Figure 5). The NoHay strategy showed the highest variability across the range of cow numbers (bold dots in Figure 5).

In summary, Figure 4 shows the expected curvilinear response in average calf LW production, with a maximum at approximately 290 cows, and Figure 5 indicates the increase in the variability of the system output as cow numbers increase.

One of the reasons for the lower calf LW sold from the NoHay strategy is the lower proportion of years where the heifers reach adequate LW for first mating at 15 months of age (data not shown). On average across all target cow numbers, early mating of heifers was only possible in 24.6 (3.2) years out of 50 (i.e. 0.49 of the years) for the NoHay strategy, while in the best strategy (AREA = 40 ha, MASS = 4 t DM ha\(^{-1}\)) it was possible in 43.1 (4.1) years (i.e. 0.86 of the years).

A low proportion of years with heifers meeting the desired LW at mating was also noted in the haymaking policy cutting at the lowest mass (i.e. at 3 t DM ha\(^{-1}\)), and this was especially evident at low cow numbers. It was hypothesized that this was partially the result of an important pasture clean-up effect produced by making hay, but only if the pastures were not mowed too early in spring. To test this, one of the most productive haymaking strategies (AREA = 50 ha, MASS = 4 t DM ha\(^{-1}\)) was simulated as before, but without feeding the hay back to the animals. In terms of heifer feeding, this combination performed as well as the equivalent normal hay-using strategy. In relation to this, the heavier cow LW with NoHay strategy reflects a diversion of forage from heifers to cows (Figure 3).

Another of the characteristics of the less productive and less stable strategies (especially 60-5, 60-6 and NoHay), was their relative inability to sustain high cow numbers, because of recurrent ‘emergency sales’. This is shown in Figure 6 where the relationship between target cow numbers (SR) and the actual cow number for each strategy is given.

**Discussion**

Bishop-Hurley and Nuthall (1994) noted that most of the research into forage conservation and supple-

![Figure 5](image-url)
mentation has been concerned with the effect of supplementation on individual animal production and performance, rather than on the integration of conservation into management systems. The objective of this study was to explore the effects of different haymaking policies at a strategic level by modelling a cow-calf farm. The results presented by Blaxter and Wilson (1963), relating to the optimal time to cut hay, indicated that a single recommendation could not be made. According to those authors, choice must depend on the type of animal production envisaged. In the case of ‘Reserva 6’, the hay is intended to maintain dry cows, a very flexible category of animals able to cope with the broadest range of feed qualities. The conclusions drawn from this study should be considered in such a context.

Choosing between alternative haymaking strategies represents a multi-criteria problem, which in general cannot be solved by maximizing any single variable. The cost of haymaking, labour availability and many other variables are dependent on a particular farmer’s situation and goals (Valentine et al., 1993). In line with the approach proposed by Cacho et al. (1999), instead of

Figure 6 Relationship between target and actual number of cows for each combination of area closed for haymaking (, 20 ha year⁻¹; , 30 ha year⁻¹; , 40 ha year⁻¹; , 50 ha year⁻¹; , 60 ha year⁻¹; , NoHay; and , 1:1 line) and target herbage cutting mass at haymaking [where (a) 3 t DM ha⁻¹, (b) 4 t DM ha⁻¹, (c) 5 t DM ha⁻¹ and (d) 6 t DM ha⁻¹].

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management recommendations, studies of this type provide information about system response patterns that decision-makers can use according to their particular needs. An exploratory economic risk analysis is presented in the third paper of the series (Romera et al., 2005b). The pasture model was originally calibrated and tested by its authors using grazed pasture data in New Zealand (McCall and Bishop-Hurley, 2003) but preliminary tests against Argentinean data permit reasonable confidence that it represents the response of actual pastures to different climatic conditions (i.e. variation between years). It should be noted, however, that the available Argentinean data came from controlled short-term (3–5 months) cutting studies and the results might not represent the production (and seasonal patterns) of pastures under grazing in the long term (Otr et al., 1988). When compared with Reserva 6 at a similar stocking rate (i.e. 1.7 cows ha\(^{-1}\)) and haymaking policy (0.30 of the area allocated to haymaking and cutting at 6 t DM ha\(^{-1}\)), the simulated LW production showed good agreement with the data reported by Carrillo et al. (1998) for the period 1966–1995 [271 (40) vs. 272 (31) kg LW ha\(^{-1}\) year\(^{-1}\) for real and simulated data respectively]. However, the simulated system was able to sustain higher stocking rates than have been obtained in real situations so far. The actual productivity of pastures under grazing is unknown. Hence, in order to gain more confidence in the comparison between strategies, a range of stocking rates was used. The assumption behind this was that, in terms of comparisons between strategies, a range of stocking rates would have more or less a similar effect as a range of pasture productivity. A strategy that performs better than the rest across a wide range of stocking rates in the model would have a good chance of performing well in the field. Therefore, the results produced by the model are not to be considered in absolute terms; rather the interest is in the relative behaviour of the different strategies in which it is possible to have much greater confidence (Fu, 2002).

Both the mean and variance of outputs from a management policy can be important criteria in decision-making (Pleasants et al., 1995). Pasture conservation has been proposed as an option to make systems more resistant to drought (McMillan, 1989). In the present study, the strategy that did not use hay was consistently less productive and less stable than most of the combinations using hay. Cow numbers affected the relative behaviour of the different strategies, both in average production and variability. The benefits of haymaking were more important at the intermediate cow numbers tested. In Romera et al. (2004), the variability of the system was significantly reduced by using hay, but the increase in average production per hectare was moderate. This low impact can now be explained by the fact that, in that experiment, only the lowest level of stocking rate was used. The advantages of the haymaking strategies could be partially explained by the effect of haymaking on increasing the proportion of years when heifers reached the target LW for mating at 15 months of age.

The merits of using hay in pastoral systems are not universal. Taylor and Scales (1985) found no beneficial effect of using hay in terms of carcass weight gain per hectare in a series of farmlet studies, but those studies used young growing cattle and the farmlets were irrigated. Scattini (1984), working with tropical grass pastures, found small benefits from making and feeding hay but again the experiments only included weaned steers and heifers grazing in winter and spring (May–November). In general, hay is not a particularly appropriate food for finishing stock. In such cases the main advantage would only come from the pasture-conditioning effect of haymaking (topping) by removing accumulated dead material in summer (Scattini, 1984). In contrast, breeding beef cows are well suited to eating low-quality roughages during periods of feed restriction (McCall, 1994; Pleasants et al., 1994). In a 3-year farmlet study, Thomson et al. (1989) found little benefit of pasture conservation in dairy systems, though only 0.17–0.33 of the area was conserved. The possible benefits of hay are highly dependent on the type of farming system being considered (e.g. finishing vs. cow-calf farms). An important part of the advantage of making hay lies in the reduction of system variability. Therefore, the advantage will be the larger the more inconsistent the climate of the region and, in general, long-term studies are required to capture effects of this type. In summary, the benefits of making and using hay will depend on the particular type of operation, the environmental conditions of the area under study (and to a certain extent on the length of the study period) and on the way haymaking is managed (i.e. the decisions of closing and mowing paddocks).

The simulated results obtained here indicate that dedicating 0.40–0.50 of the total area of the farm to haymaking, and cutting at a herbage mass of approximately 4 t DM ha\(^{-1}\) and producing a medium-quality hay, would allow high stocking rates to be sustained and, therefore, yield a more productive system. However, assigning too much area to haymaking, especially when the hay was made at a high herbage mass, produced the worst performance among the haymaking policies across the range of stocking rates. The most extreme haymaking strategies did not perform better than the strategy without hay, especially at high cow numbers, and clearly cutting 0.60 of the area would be too much, as detrimental effects (i.e. lower productivity and greater variability) started to appear in relation to more moderate strategies.
The effect of cutting at too high a herbage mass is noteworthy. Apart from its direct effect on the amount of hay produced, it also reduced animal intake capacity via hay quality. The effect on the LW of cows (Figure 3) indicates that this is likely to be due to the lower quality of the hay, although the longer period of time when the paddocks remain closed (while waiting for the herbage mass to accumulate) can also be part of the explanation. Another possibility could be that cutting hay late does not leave enough time for pasture to re-grow before winter. When hay is made early (3–4 t DM ha\(^{-1}\)), it is possible to harvest up to 0.40–0.50 of the whole area of the farm and sustain very high cow numbers. Cutting at a low herbage mass (therefore early in the spring), on the other hand, reduces the possibilities of using haymaking as a pasture topping tool, which is an additional, but important, benefit. Therefore, with this scheme of closing a fixed area at a more or less fixed date, the optimum combination seems to be cutting at medium herbage mass and a rather large proportion of the farm (around 0.40–0.50).

Among the strategies compared in the present study, the one that is most similar to the haymaking policy applied in the Experimental Farm of INTA, Balcarce, is the combination of 30 ha, being cut at a herbage mass of 6 t DM ha\(^{-1}\). According to the results obtained in the present study, this combination was in the mid-low part of the range, both in expected production and stability. The results suggest that the policy followed in Reserva 6 of allocating 0.30 of the farm to haymaking is not excessive and suggest that productivity could be increased by making hay at lower herbage mass, improving the quality of the hay produced.

Harvesting excessive amounts of hay by cutting at high herbage masses (and producing low quality hay) and harvesting more than 0.50 of the area does not seem to be a useful alternative. However, making more hay than required for immediate needs could be beneficial if a more flexible haymaking policy were adopted, allowing the production of higher quantities of good quality hay, perhaps leading to more productivity and stability. In this case, hay surpluses could be carried into the next year and used as a buffer for the system, or be traded if the market conditions allowed. A more flexible strategy that takes into account simple pasture budgeting to decide the dates of closing and harvesting of pastures is the subject of the second paper of the series (Romera et al., 2005a).

Acknowledgments

This study was possible thanks to a Postgraduate Scholarship awarded to the senior author by the New Zealand Agency for International Development (NZAID), and the support of the Instituto Nacional de Tecnología Agropecuaria (INTA) of Argentina.

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