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LIVESTOCK-CROP INTERACTIONS

THE DECISION TO HARVEST OR TO GRAZE MATURE GRAIN CROPS

Thomas L. Nordblom

International Center for Agricultural Research in the Dry Areas
ICARDA

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Thomas L. Nordblom

FARMING SYSTEMS PROGRAM
ICARDA
P. O. Box 5466, Aleppo, Syria

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SUMMARY

Farmers in the driest areas of the ICARDA region frequently face the question of whether to harvest or to graze mature grain crops, particularly barley. Farmers persist in cultivating barley under poor and highly variable growing conditions and often graze rather than harvest their plots. It can be shown that a grazed crop is not a failure.

The process by which farmers decide to harvest rather than graze barley plots is described with the use of harvest-time budgets. Anticipated harvest costs, harvested straw and grain values and direct grazing values, are all expressed as functions of grain yield in an analytical framework to introduce the idea of "grazing thresholds": grain yield levels below which direct grazing of the crop is most profitable and above which harvesting is most profitable.

At yield levels below a grazing threshold, the direct grazing value forms the upper revenue boundary for the crop. At the yields above the threshold, the net harvest benefits (straw plus grain values minus harvest costs) form the upper revenue boundary. Straw and grazing values differ among cultivars, as do the frequency distributions of grain yield over time. Therefore, cultivars should be compared on the basis of their upper revenue boundaries and their yield distributions.

In the drier areas, where crop residue and direct grazing values account for a large proportion of the crop values, farmers will continue to evaluate cultivars with respect to both mature forage and grain production characteristics. It is unlikely that breeders selecting for grain yield alone and ignoring mature forage aspects will meet the goal of developing cultivars which are superior according to farmers' criteria.

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INTRODUCTION

Barley is the predominant cereal crop in the drier areas (200 to 350 mm annual precip.) of the ICARDA region. Climatic conditions vary tremendously in these areas and during dry years grain yields can be so low as to be of little value. The role that barley plays in an integrated crop-livestock system goes far beyond grain production; it is also far more complex. Straw may equal the economic value of the grain in some years and the stubble of harvested areas is usually grazed. As an alternative to harvesting a poor crop, the barley producer may choose to allow animals to graze the standing crop, since there can be a significant economic return for doing so. Both of these practices are commonly observed in the ICARDA region.

Farmers in the drier areas are frequently faced with a choice: to harvest or graze a mature barley crop. Yet we know very little about how farmers make this choice -- what is the decision process for farmers making such a decision, and what are the main determinants of the choice? We have given little attention to this issue at ICARDA when allocating our research effort to barley production -- what are the implications of the dual roles of barley production for our research? This paper attempts to answer these questions.

The major focus of the paper is on the decision to graze a barley crop as an alternative to harvesting it. A framework is developed to understand this decision process, and is used to explain (1) how grazing a standing crop can be more profitable than harvesting it, (2) when and where the grazing option is likely to be more attractive and (3) what the implications are for a barley breeding program.

In the next section of the paper the prevalence of barley grazing in Syria is described. Then a budgeting process is presented which describes the factors and relationships a farmer considers when he decides to harvest or graze a particular plot; hypothetical budgets are constructed. This is followed by a more general formulation of the decision process which allows us to define a grazing threshold, i.e., the anticipated grain yield at which the farmer is indifferent between grazing or harvesting. The model allows measuring the contribution of forage aspects to the total crop value, whether grazed or harvested. This leads to a discusssion of breeding objectives to find cultivars that will be acceptable to farmers and quickly adopted.

Other research which complements this paper, has covered the grazing of immature barley stands followed by regrowth and grain harvest (Nordblom, 1983), grazing of lentils (Nordblom and Halimeh, 1982) and grazing of wheat (Jose, 1974). The analysis developed in this paper for mature stage grazing of barley can be generalized to apply to wheat and lentils as well.

1. GRAZING OF MATURE BARLEY IN SYRIA

As in most areas of the world where cereals are grown, crop residues play an important role in animal nutrition in Syria.[1/] The grazing of mature crops and crop residues is the major link between the arable areas and the Syrian steppe (Martin, 1981, p. 24). Whether the crop is grazed in the field or harvested and separated into grain and straw, most of the above ground bio-mass is consumed by sheep. Thus, a high average grain yield is neither the only, nor even the most important, criterion by which the farmer chooses a barley cultivar.

Grazing of mature barley is a common practice in Syria. In a recent sample of barley growers in Syria more than half the 155 farmers interviewed reported grazing rather than harvesting their crops in 1981. All but a few of the farmers interviewed expressed intentions to graze rather than harvest in 1982, a generally poorer growing season (Somel, 1982a).

In an earlier ICARDA study, farmers from the village of Hawaz, in the driest farming area (zone 4) of Aleppo Province, were interviewed over three consecutive years. Data on their barley crops are summarized in Table 1. The second year of the study was very dry and the farmers reported harvesting only 25 percent of their barley plots; sheep grazed the rest. Unusually good growing conditions occurred in the next year and all plots were harvested. A strong positive association between the mean yield of harvested plots and percent of plots harvested is evident in Table 1. No estimates of the grain yield potential of the grazed plots are available.

1/ See Anderson, 1978; Carey, 1982; Capper, 1982; and Srivastava and Varughese, 1979.

Table 1. Barley harvest summary: three years in Hawaz.

Year	% of plots grazed and not harvested	Grain yields of harvested plots: Mean (kg/ha)	S.D. (kg/ha)	C.V. (%)
1978	8	336	124	37
1979	75	170	66	39
1980	0	681	439	64

Source: Unpublished Village Study Data, Farming Systems Program, ICARDA, Aleppo, Syria.

Visual observations by the author in 1982 confirmed several farmers' statements that most barley fields in the Hawaz area would again be grazed. The crop was generally too short to be harvested by combine without serious loss of grain. Farmers' estimates of potential yields from plots that were to be grazed varied over the range of 200 to 400 kg of grain per hectare. Some said they would harvest small plots by hand to provide winter feed, rather than purchase straw later in the year.

That farmers persist in growing barley under such variable conditions, supports the idea that a grazed crop is not necessarily a failure. We may presume that the economic benefits of grazing a mature crop frequently exceed the net harvest benefits (value of grain and residue minus harvest costs), due to the high demand by livestock for forage.

A barley crop which is grazed rather than harvested provides valuable nutrition for sheep, especially when other sources of forage are scarce. If the sheep belong to the barley farmer no cash income is generated directly by grazing but the costs of alternative feeds are avoided. The farmer who allows his sheep to graze his own barley crop loses the opportunity to sell the crop to another sheep-owner for grazing. This "opportunity cost" is that which the farmer could count against his sheep operation and which he should credit his barley operation. Presumably, if the crop were worth less than this for his own sheep he would sell it for grazing.

The above points lead to a discussion of the budgeting process by which farmers decide whether to harvest a particular field (or part of a field) or allow it to be grazed.

2. BUDGETING AT HARVEST TIME

As the time of harvest approaches, farmers anticipate their options and calculate the costs and returns of each option. In good years, demand for grazing forage will be largely satisfied by weeds and natural rangeland, and supplies of crop residues will be high; the value of the grain yield will exceed harvest costs by a comfortable margin and there is little doubt that farmers will choose to harvest the crop.

The discussion below will concentrate on the poorer conditions under which a farmer must consider whether his gains from harvesting will exceed those from direct grazing of the crop (Somel, 1982b). Poor crop conditions are often associated with poor growth of native pasture and, therefore, high demand for mature crop grazing.

The calculations a farmer makes at harvest time depend on the current information he has regarding harvesting costs, grain prices and the demand for grazing. The farmer tries to estimate the potential yield of his crop and may also receive offers from sheep owners who wish to purchase grazing rights.

A hypothetical illustration can be given of a farmer with a long narrow field which runs from the shallow soils of a hillside to deep fertile soils on flat ground. On the basis of soil depth, slope and general productivity, the farmer considers this field to have three distinct plots, A, B, and C. All three plots were sown with barley in this particular year and produced crop stands with visibly different yield potentials. After carefully examining the crop stands the farmer estimates that, if harvested for grain, his hillside plot A would yield 200 kg per hectare, plot B 400 kg and the deep soil of plot C, 600 kg per hectare. Due to poor growing conditions, these yields are below the expected long-term averages of the three plots.

We assume that hand harvest is the only method available to the farmer. He knows that the costs of harvesting, transport, threshing, winnowing and bagging increase with grain yields, but not as much as the increase in grain and residue values. The price he could get by selling the crop for direct grazing is lowest for plot A and highest for plot C, in accordance with quantity and quality of forage. A summary of the farmers' estimates and choices is given in Table 2.

Given the alternatives listed in Table 2, the farmer would clearly choose to sell the crop in plot A for grazing and to harvest plot C. The farmer would be just as well off if plot B were grazed or harvested, thus he is indifferent about the choice. The three budgets assume the grain price to be SL 0.75/kg. If the price of grain were SL 1.0/kg plot B would then be worth harvesting while Plot A would still be grazed.

Table 2. Hypothetical harvest-time budgets for three barley plots owned by one farmer.

		Plot A		Plot B		Plot C	
Anticipated grain yield if harvested:		200 kg/ha		400 kg/ha		600 kg/ha	
Choice:		Harvest	Graze	Harvest	Graze	Harvest	Graze
Expected revenues:							
grain value[1/]	(SL/ha)	+150	-	+300	-	+450	-
harvest residue value[2/]	(SL/ha)	+100	-	+150	-	+200	-
direct grazing value	(SL/ha)	-	+150	-	+250	-	+350
Expected harvest costs	(SL/ha)	-175	-	-200	-	-225	-
Net benefit	(SL/ha)	+75	+150	+250	+250	+425	+350
Best choice		Graze		Indifferent		Harvest	

1/ Price of barley grain assumed to be SL 0.75/kg.

2/ Includes both the harvested straw and the post-harvest residues left in the field.

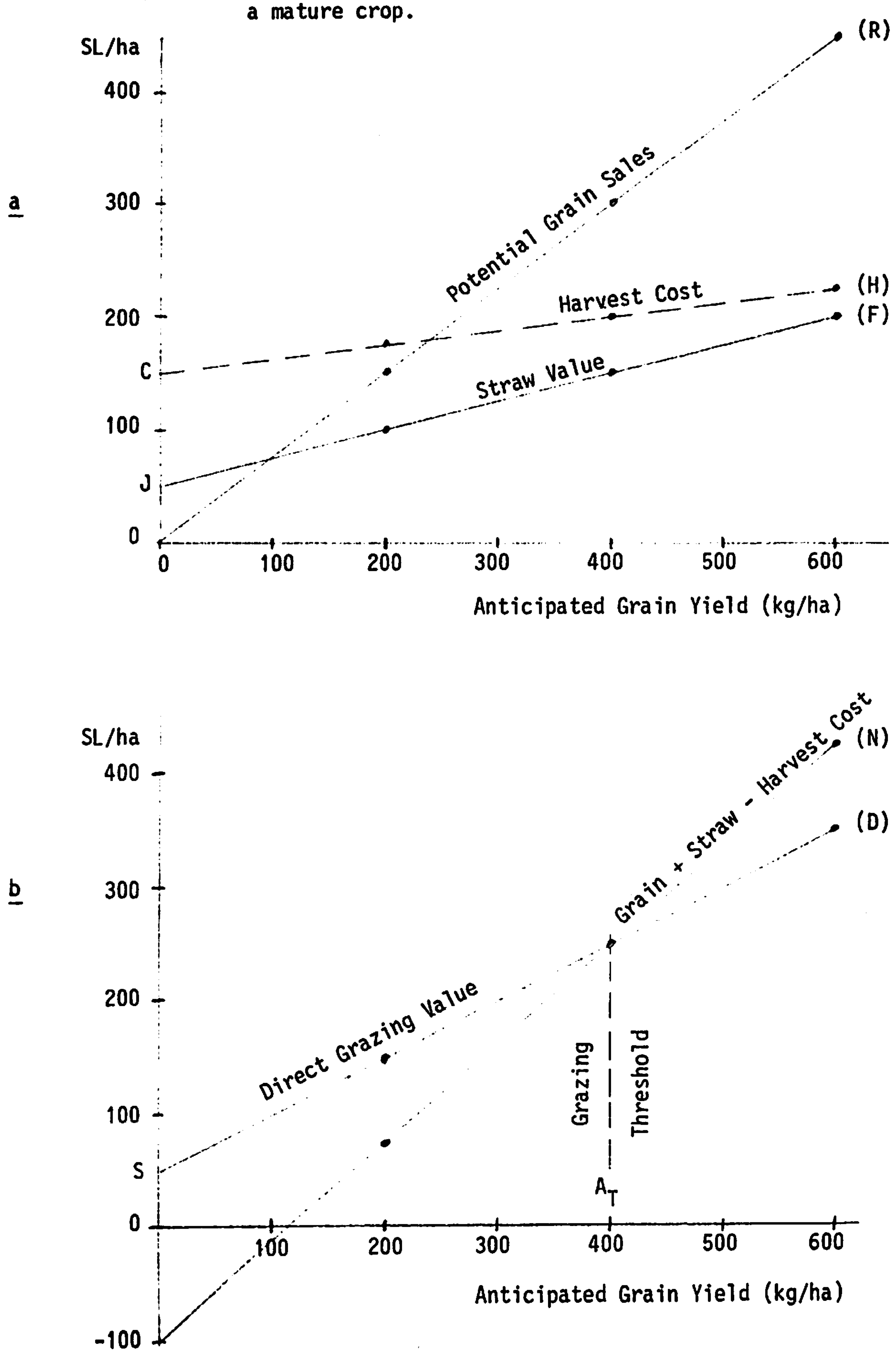
Farmers in even the driest areas point out that a standing crop can have considerable economic value for grazing, and the costs of harvest are avoided if the crop is grazed. Thus, farmers have long been making full use of an effective risk-minimizing technique: that is, to delay the decision on incurring some production costs until the outcome is more certain (Roe and Nygaard, 1980, p. 15). Harvest costs are only incurred at the last moment, and the farmer has the option to avoid them if the outcome from grazing appears more favorable.

3. THE GRAZING THRESHOLD

The hypothetical budgets in Table 2 can be used in developing a general model of harvest versus graze decisions. This provides a new way to evaluate the role of mature barley forage when comparing barley cultivars. Grain values, straw (post harvest residue) values, and harvest costs from Table 2 are plotted in Figure 1-a. To simplify the discussion, it is assumed that these costs and values lie on straight lines (i.e., they are linear functions of anticipated grain yield).

The net benefits of harvest (grain plus straw value minus harvest costs) are plotted in Figure 1-b, as are the direct grazing values. The point where the two lines cross (at 400 kg/ha) is the grazing threshold. At yields anticipated to be less than this, the farmer will find the grazing value of the crop to be higher than the net benefit of harvest. At anticipated yields above the threshold, the farmer will find that the net benefits of harvesting are greater than the direct grazing values.

Figure 1. Costs and revenues for grazing or harvesting a mature crop.



A significant point is that the crop will yield positive revenues even at the lowest yield potentials, with the farmer always choosing his best option: grazing or harvest. Moving from low to high yield levels there is a boundary below which the farmer will not expect his revenues to fall. Above the grazing threshold this boundary is defined by the net harvest benefit line; below the threshold it is defined by the direct grazing line. The concept of a revenue boundary can be used to compare cultivars having different grain and mature forage quality and production characteristics. This subject will be treated after a discussion of the variability of grazing thresholds across locations, under different price and cost conditions, and over time.

The straight cost and revenue lines of Figure 1 can be expressed conveniently as linear functions of anticipated grain yield (A). These functions are listed in Table 3, along with the parameter values associated with the lines drawn in Figure 1. The algebraic formula for the grazing threshold is solved using these parameter values.

In the earlier example, it was shown that the farmer would prefer to harvest rather than graze plot B if the price of barley grain were SL 1.0/kg instead of SL 0.75/kg, and that plot A would still be grazed. The grazing threshold function given in Table 3 allows us to calculate the effects of changes in any or all of the prices and costs involved.

With the grazing threshold function we are in a position to theoretically pinpoint the yield level at which the farmer would be indifferent between grazing and harvesting, given a higher grain price. Leaving all other parameters unchanged for our hypothetical farmer, the higher grain price of SL 1.0/kg points to a new grazing threshold of 240 kg/ha.

Table 3. Cost and revenue functions, and the grazing threshold.

Line in Figure 1	Function	Parameter		Parameter Value[1/] (SL)
Grain sales	R = PA[2/]	Grain price	P	0.75
Straw value	F = J+BA	Intercept	J	50.00
		Slope	B	.25
Harvest cost	H = C+GA	Intercept	C	150.00
		Slope	G	.125
Direct grazing value	D = S+UA	Intercept	S	50.00
		Slope	U	.50
Net harvest benefit	N = R+F-H = J-C+(P+B-G)A			

The grazing threshold is the anticipated yield level at which direct grazing value equals net harvest benefit (i.e., where D=N)

$$\text{The grazing threshold} = \frac{C+S-J}{P+B-U-G} = \frac{(150 + 50 - 50)}{(.75 + .25 - .50 - .125)} = 400 \text{ kg/ha} = A_T$$

1/ Values which will give the plots of Figure 1.

2/ A = Anticipated grain yield if harvested (kg/ha).

Table 4. Calculated grazing threshold grain yield levels (A_T in kg/ha) under different price and cost assumptions. 1/

Harvest costs H = C+GA		U = .5 P=.75	U = .5 P=1.0	U = .5 P=1.25	U = .625 P=.75	U = .625 P=1.0	U = .625 P=1.25
G=.15	C=150	429	250	176	667	316	207
	C=100	286	167	118	444	211	138
	C= 50	143	83	59	222	105	69
G=.10	C=150	375	231	167	545	286	194
	C=100	250	154	111	364	190	129
	C= 50	125	77	56	182	95	65

U = Additional direct grazing value per kg of grain in the standing crop (SL/kg).

P = Price per kg of harvested grain (SL/kg).

C = The minimum harvest cost, at zero grain yield (SL/ha).

G = The additional harvest cost per kg of grain in the standing crop (SL/kg).

1/ Assuming the minimum grazing and harvest residue values, S and J respectively, are equal and that the total value of the crop residue increases by B = SL 0.25 per kg of grain harvested.

In some of the driest barley growing areas, grazing thresholds may be near the local average grain yield levels. That is, in about half of the years, farmers in these areas find that grazing is their best option. In the higher rainfall areas barley may only rarely be grazed rather than harvested. These observations lead to questions about the relative contributions of the forage properties of mature barley in different locations, and about how new cultivars are likely to be evaluated by farmers (Srivastava and Varughese, 1979, p. 145).

4. FORAGE CONTRIBUTIONS TO TOTAL CROP VALUE

Livestock account for a smaller share of farm income in the higher than in the lower rainfall zones. Crops are more profitable in the higher rainfall zones and it is possible to find more livestock per hectare than in the driest farming areas. However, in the drier farming areas, livestock are a main source of income, with much of the local barley crop marketed through animal products. In fact, average barley yields in the driest areas are so low that there would be little interest in growing barley without the local demand by livestock for grazing and crop residues.

The forage contribution of barley can be illustrated with another graphic example. A traditional barley cultivar exhibits much lower yields in the drier (zone 4) farming area around Khanasser than in the higher rainfall (zone 3) area around Breda. A hypothetical grain yield frequency distribution has been drawn for each location in Figure 2-c. The lower half of the Breda yield distribution overlaps most of Khanasser's yield distribution. While low yield levels are possible at Breda, they are much less frequent than at Khanasser.

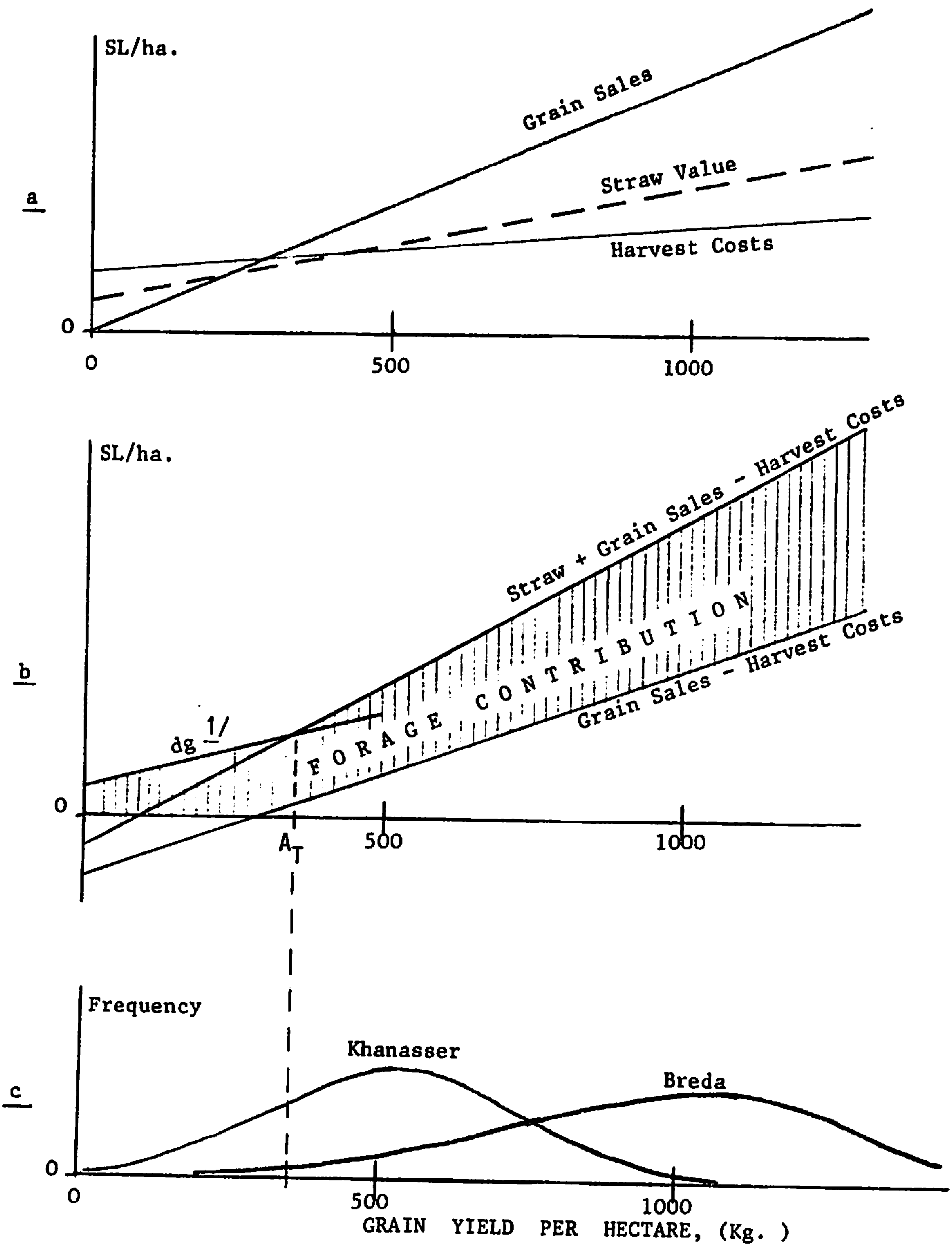
To simplify the economic comparisons, it is assumed that the same cost, price and direct grazing value relationships hold for both locations, and that these relationships hold over many years. These assumptions allow us to use the graphical representation of forage contributions at each yield level (shaded area in Figure 2-b) in association with the long run yield probabilities for each location (Figure 2-c).

The direct grazing values at the lower yield levels are shown as the line labeled dg in Figure 2-b. The yield level A_T, at which the direct grazing value equals the net harvest benefit, is the grazing threshold. A farmer in either location would choose the grazing option at yields lower than A_T, and the harvest option at all higher yields. According to the yield frequency distributions in Figure 2-c, barley crops in Khanasser would be grazed rather than harvested in about one year in the three or four, but only about one year in 20 at Breda. An important aspect to notice in Figure 2-b is the positive grazing value of the crop at even the lowest yield levels; given the demands for forage there may never be a complete crop failure.

At the mean grain yield level for Khanasser, the straw value increases the net harvest benefit by nearly 200 percent. Grain yields are so low in the Khanasser area that there would be little interest in barley cultivation without the demand for straw and forage by livestock. Even at Breda, where average grain yields are nearly double those at Khanasser, crop residues appear to roughly double the net harvest benefits over the grain harvest value alone.

The above comparisons illustrate the large contribution of livestock forage demand to the total value of barley crops, and how this value changes across locations. We now have the basis for a discussion relating to plant breeding criteria.

Figure 2. Forage contributions to total barley crop value.



1/ dg = direct grazing value as a function of anticipated grain yield potential.

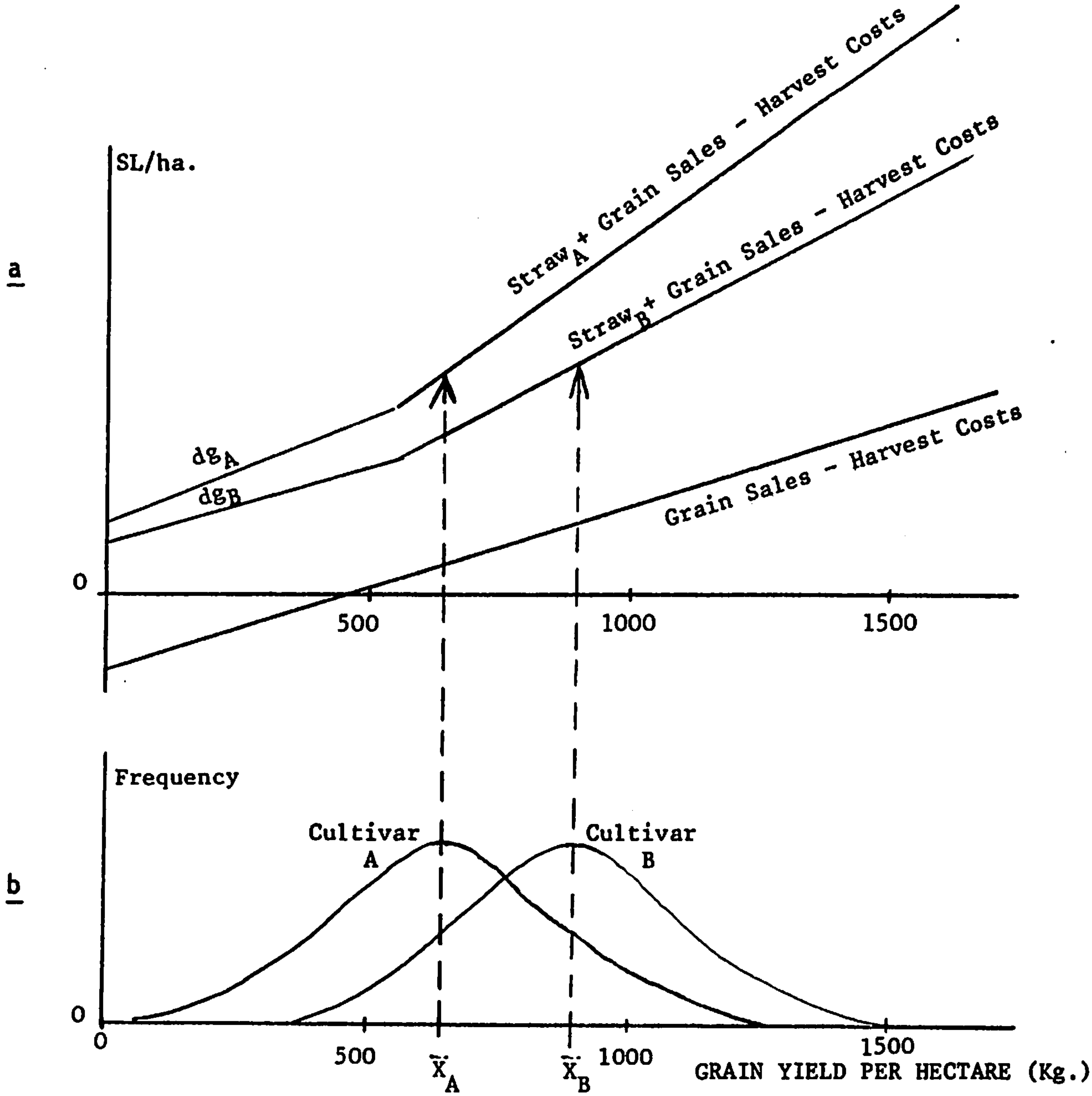
5. IMPLICATIONS FOR PLANT BREEDING

Clearly, the overall grain yield distributions of different cultivars, at a given location, are the basis for grain yield comparisons. But, as we have seen, grain yield alone is only one concern of the farmer; the upper revenue boundary at each grain yield level may be different for different cultivars, providing an important basis for comparison.

Consider the case where two cultivars (A and B) at a given location, exhibit different grain yield distributions (as in Figure 3-b) and different forage qualities and yields (as in Figure 3-a). Farmers may be indifferent between cultivars A and B. This example is given to illustrate the trade-offs a farmer faces in selecting a cultivar. What cultivar A lacks in grain yield potential is compensated by its superior harvest residues and grazing values; what cultivar B lacks in forage values is compensated by substantially higher grain yields. Another cultivar with the same grain yield distribution as cultivar B would be considered superior to both cultivars A and B if its forage qualities were only slightly better than those of cultivar B.

The comparisons outlined above are made on the basis of average revenues over time. These averages would be determined by weighting the revenue boundary values at each yield level by the probabilities of getting such yields. In practice it may be difficult to perform this kind of calculation with much confidence, due to limited information on the grain yield distribution and associated forage values for each new cultivar. Nevertheless, the necessity of considering the contribution of the forage aspects to total crop value, in terms of both quality and quantity still holds, particularly in the case of barley.

Figure 3. Counterbalanced forage and grain values of two cultivars.



Mature forage quantity and quality criteria should be part of the routine screening process in the barley breeding program. Straw and chaff yields are easy to measure. Inexpensive laboratory tests, requiring only about 50 grams of representative material, can be used to assess quality aspects by measuring crude protein, acid and neutral detergent fiber, ash and *in vitro* digestibility. Quality tests for advanced lines of barley should include voluntary intake and *in vivo* digestibility measures. A new cultivar which gives high grain yields, along with residues which are palatable to sheep, will be most readily adopted by farmers in the dry areas.

CONCLUSIONS

In the low rainfall barley growing areas, crop residue and direct grazing values account for a large proportion of the total crop value relative to grain sales. In these areas new barley cultivars will continue to be evaluated by farmers with respect to both mature forage and grain production characteristics. It is most unlikely that breeding by selection for grain yield alone, and ignoring forage aspects, will satisfy the goal of developing cultivars that are truly superior according to farmers' criteria.

ICARDA's barley breeding program should be supported in efforts to develop cultivars superior to the local ones with respect to forage quality and quantity as well as grain yield and stability. In Syria, barley has long been, and is likely to continue to be the number one forage and feed crop. Most of its above ground bio-mass is used in one form or another by livestock, and we need to recognize this fact explicitly.

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