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Livestock Production Science 88 (2004) 143–160

LIVESTOCK PRODUCTION SCIENCE

www.elsevier.com/locate/livprodsci

Economic values for traits in breeding objectives for sheep in the tropics: impact of tangible and intangible benefits

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Received 6 June 2002; received in revised form 15 July 2003; accepted 30 July 2003

Abstract

In traditional management systems in the tropics, sheep constitute a source of easily convertible capital for financing purposes and insurance, a means of cultural and ceremonial functions, and a source of prestige, meat, manure and skins. In this study, breeding objectives were derived for an indigenous tropical sheep breed under pastoral production. Economic values were calculated for five situations: (i) base accounting for both tangible and intangible roles of sheep; (ii) accounting for manure, skins and intangible roles; (iii) accounting for 20% of animals sold, insurance, manure and skins; (iv) accounting for intangible roles only; and (v) accounting for tangible roles only. Sensitivity analysis to different levels of financing and insurance benefit factors, reproduction, survival and live weight traits was performed for the situation accounting for both tangible and intangible roles, and with a constant number of ewes. The economic value for a trait considered in a particular situation was calculated from the difference between the average performance level of the trait before and after incrementing it by one unit. The traits considered were litter size, lambing frequency, pre-weaning and post-weaning lamb survival to 12 months, ewe survival, 12-month lamb live weight, mature ewe live weight, consumable meat and kg manure dry matter sold ewe^{-1} year^{-1}. Generally, in descending order of the profits and economic values, the situations studied ranked as follows: (i), (v), (iii), (ii) and (iv). For the base situation, financing and insurance benefits accounted for 13% and 6% of the total revenues, respectively. Situation (v) had a profit that was about 35% lower relative to situation (i). In terms of genetic standard deviations, the economic values (US\$ ewe^{-1} year^{-1}) for the base situation were: 2.81 for litter size, 6.40 for lambing frequency, 0.02 for pre-weaning survival, 0.03 for post-weaning survival, 0.05 for ewe survival, 1.81 for 12-month lamb live weight, 0.43 for mature ewe live weight, 0.09 for consumable meat and 0.01 for kg manure dry matter sold (ewe^{-1} year^{-1}). The economic values indicate that litter size, lambing frequency and 12-month lamb live weight are likely to be important traits in pastoral production. Sensitivity analysis showed that future economic values for all the traits considered, except kg manure dry matter sold ewe^{-1} year^{-1}, might change depending on levels of intangible benefit factors. Ewe survival and mature ewe live weight were not responsive to changes in reproductive traits, and pre- and post-weaning traits, and vice versa. It is concluded that it is necessary to include the intangible roles of sheep in tropical breeding programmes.

Keywords: Sheep; Breeding objectives; Economic values; Intangible roles; Tropics

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doi:10.1016/j.livprodsci.2003.07.013

1. Introduction

The vast majority of sheep in the tropics are managed in traditional ways (Gatenby, 1986) and perform several roles for the farmers, resulting in both tangible returns (TRs) and intangible returns (IRs) (Gatenby, 1986; Hunter, 1989; Slingerland et al., 1998; Jaitner et al., 2001; Seleka, 2001). IRs include financing, insurance and risk aversion (Upton, 1985; Jaitner et al., 2001), payment of bride price and use as gifts (Grandin et al., 1991; Breusers, 1996), as a status symbol or sign of wealth and as a form of "currency" in which social obligations are expressed (Rege, 1994). The implications of these additional roles of livestock on biological productivity are often disregarded in favour of technical facets such as nutrition and reproduction (Gatenby, 1986; Bosman et al., 1997), probably due to the difficulty of measuring and valuing them (Roeleveld, 1996). It is important to know the contribution of IRs in the breeding objective for sheep under traditional management in the tropics in order to design appropriate breeding schemes for them. The need to include IRs in breeding goal definition for low-input animal production environments is recognized (e.g. Bichard, 2000), but has not yet been implemented for sheep. The current study examines the impact of inclusion of IRs (i.e. financing and insurance) in a breeding goal for an indigenous hair sheep flock reared under pastoral production circumstances in the tropics.

2. Materials and methods

2.1. Bio-economic model description and definitions

The breeding goal is generally described as a linear function of traits to be improved, each multiplied by its economic value (EV), which expresses the value of a unit change in the trait while keeping the other traits in the breeding goal constant (Hazel, 1943). Several methods can be used to calculate EVs (Harris, 1970; Brascamp et al., 1985; Smith et al., 1986; Ponzoni, 1988; Groen, 1989). Deriving the EVs from the difference between costs (C) and revenues (R) has the advantage of simplicity (Ponzoni, 1988). Due to the complexity and diversity of tropical pastoral systems, and the lack of good estimates of inputs and outputs, a simplified bio-economic model was deemed appropriate to derive EVs for important traits of sheep in the current study.

Relevant adjustments of input parameters to the bio-economic model developed by Kosgey et al. (2003) were made to reflect pastoral production circumstances rather than the more intensive smallholder production system (see Kosgey et al., 2003 for full details and assumptions of the model). The model is deterministic and describes quantitative relationships between average performance levels for the traits considered and levels of output of the farm. The model combines aspects of nutrition, reproduction, production and economics at the animal and flock levels. It was extended to include benefits from IRs (i.e. financing and insurance) of sheep in the calculation of economic values. Sensitivity of EVs to changes in levels of IRs and with respect to changes in reproduction, survival and live weight traits was also studied.

Total annual profit of the flock was derived as the difference between C and R. Throughout this study all costs and prices are expressed in US dollars. The productive unit is the ewe and the time unit is 1 year. The inputs for the production system were management (i.e. labour, spraying/dipping, deworming and mineral supplementation) and marketing (i.e. transport of live animal and carcass, and levies for auction, slaughter and meat inspection). The outputs were revenues from financing and insurance benefits from yearlings, ewes and rams, sale of surplus yearlings, and cull-for-age ewes and rams, manure from all categories of animals, and surplus animals slaughtered for home consumption and skins from them. A constant number of ewes were used as a base of evaluation. The EV for a trait was calculated by evaluating annual flock profit (T_{f1}) numerically at the average value for all other traits, then evaluating it after incrementing by one unit the average performance level of the trait in question (thus obtaining T_{f2}) and taking the difference in $T_{f2} - T_{f1}$ (Ponzoni, 1992). This was then expressed per breeding ewe present in the flock per year (US\$ ewe^{-1} year^{-1}) in order to accommodate both production and reproduction traits. If desired, the EVs can be expressed on a per flock basis by multiplying by the number of ewes in the flock. Periodical fluctuations in animal performance and prices were not accounted for in the model.

2.1.1. Elements and traits of the model

Table 1 describes the assumptions for the input variables of the model in the base situation. Production parameters were chosen to represent an indigenous hair sheep under pastoral farming system in Kenya, and prices represent average values in the country for the period 1999–2000. Table 2 presents the traits, units and assumed values in the aggregate genotype that were studied using the model. These set of traits are those presented by Kosgey et al. (2003) and are also relevant under tropical pastoral circumstances.

2.1.2. Flock dynamics

For convenience of making calculations and comparisons, the same flock size and composition described by Kosgey et al. (2003) was assumed in the present study (Fig. 1). This was a hypothetical flock of 100 ewes present over the entire period. The values can be re-scaled to any desired flock size. Six animal categories were distinguished according to age: 1—lambs (0–3 months old), 2—yearlings (4–11 months old), 3—replacement females (12–18 months old), 4—replacement males (12 months old), 5—breeding ewes (over 18 months old) and 6—breeding rams (over 12 months old). These categories approximate the average age classes for indigenous tropical sheep under traditional management (e.g. Carles, 1983; Gatenby, 1986; Orji, 1988; Osinowo and Abubakar, 1988; Peeler and Omore, 1997). The number of animals in each category was expressed relative to number of ewes present over the year.

Details of animal sales and mortalities can be found in Kosgey et al. (2003). Briefly, it was assumed that only a few adult males were necessary for breeding and that ewe lambs were kept for replacement and the surplus were sold. All breeding males were culled after one productive year at 2 years of age and ewes after 7 productive years at 8 years of age. The number and distribution of animals dying in each category over the whole year was accounted for (see Kosgey et al., 2003 for full details). With the assumed 90% conception rate, the proportion of ewes with 0, 1 and 2 lambs were derived to be 0.1, 0.74 and 0.16, respectively. The figures were then adjusted to a 12-month basis by multiplying by 1.5.

2.1.3. Parameters and information for the model

Information for this study was derived from the literature, farmers, the market and expert opinions. Generally, production parameters under pastoral production approximate those of the smallholder except feed, healthcare and fixed costs (Table 1). Therefore, most of the parameters are similar to those presented by Kosgey et al. (2003). In this paper, the input/output parameters that differ from those in the model described by Kosgey et al. (2003) for smallholder production will be highlighted. The cost of recording in the flock or application of the selection index was ignored. Labour was taken as part of management. Supply of labour by the farmer was set to be fixed animal^{-1} year^{-1} but varied with the size of the flock. It was assumed to be half of that of a smallholder because of the pooling of animals by families for herding by a member of one of the families, and derived as described by Kosgey et al. (2003). Opportunity cost for the farmer's labour for other farm tasks in pastoral farming systems was used to arrive at the cost of labour. The current study assumed that one shepherd taking care of 200 head of sheep and working for 8 h day^{-1} earned about US\$25.71 month^{-1}.

Marketing charges were assumed to be equal for all animal classes sold and were calculated as the sum of the average costs incurred between buying a live animal and selling its carcass. Values presented by Kosgey et al. (2003) for transport of live animal to the market, auctioning, slaughter, carcass inspection and carcass transport were used (Table 1). Slaughter charges, carcass inspection fee and carcass transport were assumed to be charged to the farmer because traders essentially reduce the price of the live animal by the same margin (Kosgey et al., 2003). The other variable costs of the flock were provision of minerals and healthcare. The latter was assumed not to be optimal (Gatenby, 1986). Only endo- and ecto-parasite controls were taken into account. It was assumed that animals were sprayed or dipped twice per month (e.g. Gatenby, 1986) to control ecto-parasites as is increasingly becoming the practice in pastoral production circumstances (Kosgey et al., unpublished), and dewormed two times per year for young stock up to 12 months of age and once per year for older stock.

Unlike in commercial systems, farmers in pastoral systems may have no alternative types of land use and

Table 1
Overview of the assumed values of the input variables of the model in the base situation[a]

Variables	Abbreviation	Production circumstances		Variables	Abbreviation	Production circumstances	
		Pastoral	Smallholder			Pastoral	Smallholder
Production variables							
Average daily gain lambs (g day^{-1})	–	80.00	80.00	Mortality rate of ewes (% $year^{-1}$)	m_5	10.00	10.00
Average daily gain yearlings (g day^{-1})	–	60.00	60.00	Mortality rate of lambs (% $year^{-1}$)	m_1	20.00	20.00
Birth weight (kg)	–	3.00	3.00	Mortality rate of rams (% $year^{-1}$)	m_6	10.00	10.00
Body weight at 12 months of age (kg)	12mLW	25.00	25.00	Mortality rate of replacement males and females (% $year^{-1}$)	m_3 and m_4	10.00	10.00
Consumable meat yield (%)	CM	60.00	60.00	Mortality rate of yearlings (% $year^{-1}$)	m_2	15.00	15.00
Litter size (average over parities ewe^{-1} lambing $year^{-1}$)	LS	1.18	1.18	Weaning rate (lambs ewe^{-1} 12 $months^{-1}$)	–	1.27	1.27
Mature weight of ewes (kg)	ELW	30.00	30.00	Weaning weight (kg)	–	10.00	10.00
Mature weight of rams (kg)	–	40.00	40.00				
Management variables							
Age at attainment of mature weight (months)	–	18.00	18.00	Proportion of cull-for-age ewes, excluding mortality (8 years)	–	0.12	0.12
Age of ewe at first lambing (months)	–	18.00	18.00	Proportion of cull-for-age rams, excluding mortality (2 years)	–	1.00	1.00
Age at first mating (months)	–	12.00	12.00	Proportion of yearlings sold at hogget or wether age (12 months)	–	0.82	0.82
Age of replacement stock at selection (months)	–	12.00	12.00	Lambing frequency (lambings ewe^{-1} $year^{-1}$)	LF	1.50	1.50
Age of surplus yearlings when sold (months)	–	12.00	12.00	Weaning age of lambs (months)	–	3.00	3.00
Ewe culling age (years)	–	8.00	8.00	Ram culling age (years)	–	2.00	2.00
Feed intake variables							
Average roughage intake for ewes (kg DM $head^{-1}$ day^{-1})	RF_5	–	0.60	Average roughage intake for replacement stock (kg DM $head^{-1}$ day^{-1})	RF_3 and RF_4	–	0.60

Table 1 (*continued*)

Variables	Abbreviation	Production circumstances		Variables	Abbreviation	Production circumstances	
		Pastoral	Smallholder			Pastoral	Smallholder
Feed intake variables							
Average roughage intake for lambs (kg DM head^{-1} day^{-1})	RF_1	–	0.20	Average roughage intake for yearlings (kg DM head^{-1} day^{-1})	RF_2	–	0.43
Average roughage intake for rams (kg DM head^{-1} day^{-1})	RF_6	–	0.68				
Management costs (C_h) per adult ewe							
Spraying or dipping (US$ head^{-1} year^{-1})	$C_{d:y}$	1.70	1.70	Helminth control (US$ dose^{-1} head^{-1})	C_{wc}	0.39	0.39
Drugs and veterinary service charge (US$ head^{-1} year^{-1})	C_v	–	1.50	Mineral supplements (US$ head^{-1} year^{-1})	C_{ml}	2.70	2.70
Marketing costs (C_m)							
Costs of animal sale and slaughter (US$ head^{-1})	C_l	2.00	2.00	Transport of live animal to market (US$ head^{-1})	C_t	0.71	0.71
Prices							
Manure price (US$ kg^{-1})	P_o	0.02	0.02	Labour costs (US$ shepherd^{-1} 100 head^{-1} month^{-1})	P_{lb}	1.29	2.57
Meat price (US$ kg^{-1} carcass)	P_m	2.00	2.00	Price of a piece of skin	P_{kh}	0.57	–
Fixed costs (US$ head^{-1} year^{-1})—fencing, troughs, equipment, etc.	FCF	–	1.00	Roughage feed price (US$ kg^{-1} DM)	P_{rf}	–	0.04
Manure							
Average amount collected (% DM intake head^{-1} day^{-1})	O	50.00	50.00				

[a] All costs and prices in US$, US$1.00 ≈ Kshs. 70.00 (Kenya shillings) at the time.

no costs are incurred in forage production. There is also sufficient area for flock expansion. It was assumed that no concentrate supplements were provided to the flock. Therefore, feed costs were assumed to be negligible and ignored. This may not be consistent with a long term planning horizon usually involved in animal breeding. However, it was assumed that the environmental conditions were unchangeable, and breeding activities and breeding plans have to operate under this set of conditions (Sölkner et al., 1998). It was also assumed that capital has no alternative uses, and the opportunity costs were set to zero.

Table 2
List of breeding goal traits evaluated in this study

Trait	Unit	Abbreviation
Litter size	Average number of lambs born over parities, ewe^{-1} lambing year^{-1}	LS
Lambing frequency	Average number of lambings ewe^{-1} year^{-1}	LF
Pre-weaning lamb survival	Lambs surviving to weaning as a % of lambs born	PRWS
Post-weaning lamb survival	Lambs surviving to 12 months of age as a % of lambs weaned	PWS
Ewe survival	Ewes surviving as a % of ewes present over the year	ES
12-month lamb live weight, i.e. live weight at slaughter	kg	12mLW
Mature ewe live weight	kg	ELW
Consumable meat	Consumable meat output as a % of live weight at slaughter	CM
Manure sold	kg dry matter (DM) ewe^{-1} year^{-1}, i.e. summed over all animal categories in flock and then expressed on per ewe basis	MS

Under pastoral systems, there is hardly any fencing of grazing areas, feeding structures and maintenance of such facilities, field clearing and equipment that would contribute to fixed costs. Subsequently, it was assumed that fixed costs per animal were minimal and therefore disregarded (e.g. Gatenby, 1986). In addition, given the approach used in this study, fixed costs do not affect EVs (Ponzoni, 1988). This eliminates the need to determine the magnitude of fixed costs, especially in developing sheep industries, where sheep are commonly integrated with other farming activities or share some of the facilities with another species (Ponzoni, 1992).

It was assumed that 10% of the surplus animals were retained for home slaughter and therefore income from skins was included in the calculation of revenue although skins from sheep often have little value in most parts of the tropics (e.g. Carles, 1983). It was assumed that animals slaughtered at home had attained a significant part of their mature body weight and were of the same age and size. Therefore, skins produced were taken to be uniform, and sold per piece and not on weight basis. Skin sales from animals sold were considered to accrue to the butcher and were excluded from revenue calculations. Animals slaughtered for home consumption were accounted for as part of the revenue to the production system. The amount of manure was derived for each category of animals based on body weight, and the amount and digestibility of the roughage fed (see Kosgey et al., 2003 for details). In the calculation, a linear relationship of manure with feed intake was assumed. It was assumed that only half of it was collected because it is difficult to collect manure during the day as animals are grazing in the fields, but they are kept in penned enclosures at night (Gatenby, 1986; Jaitner et al., 2001) for security reasons. Manure was assumed to be traded. Farm-gate price was assumed for manure sold and therefore no transport or marketing costs were incurred.

Surplus and cull-for-age animals were assumed on the average to be sold twice a year in equal proportions. Although prices are mostly established on the basis of observation (head^{-1}) rather than sale on weight, it was assumed that animals were weighed, with a consumable meat yield of 60% (Kosgey et al., 2003). The meat price used in this study was internal to Kenya and does not reflect international market prices. To simplify the situation, all carcasses were assumed to have the same grade and the different cuts of the carcass to have the same price (Gatenby, 1986; Kosgey et al., 2003).

The farmer periodically reduces the flock in order to obtain disposable income for consumption or production requirements (Ifar, 1996; Nibbering et al., 2000). However, farmers rarely define in advance when the animals will be sold. Disposal of animals forms a clearly identifiable event, and measuring the outflow covers previous saving behaviour through the accumulation of embodied production and the purchase of animals (Bosman et al., 1997). Embodied production refers to change in body weight, or changes in animal numbers if analysis is at flock level. This could also include pregnancy (as proof of fertility). Note that due to loss of body weight, or reduced production pros-

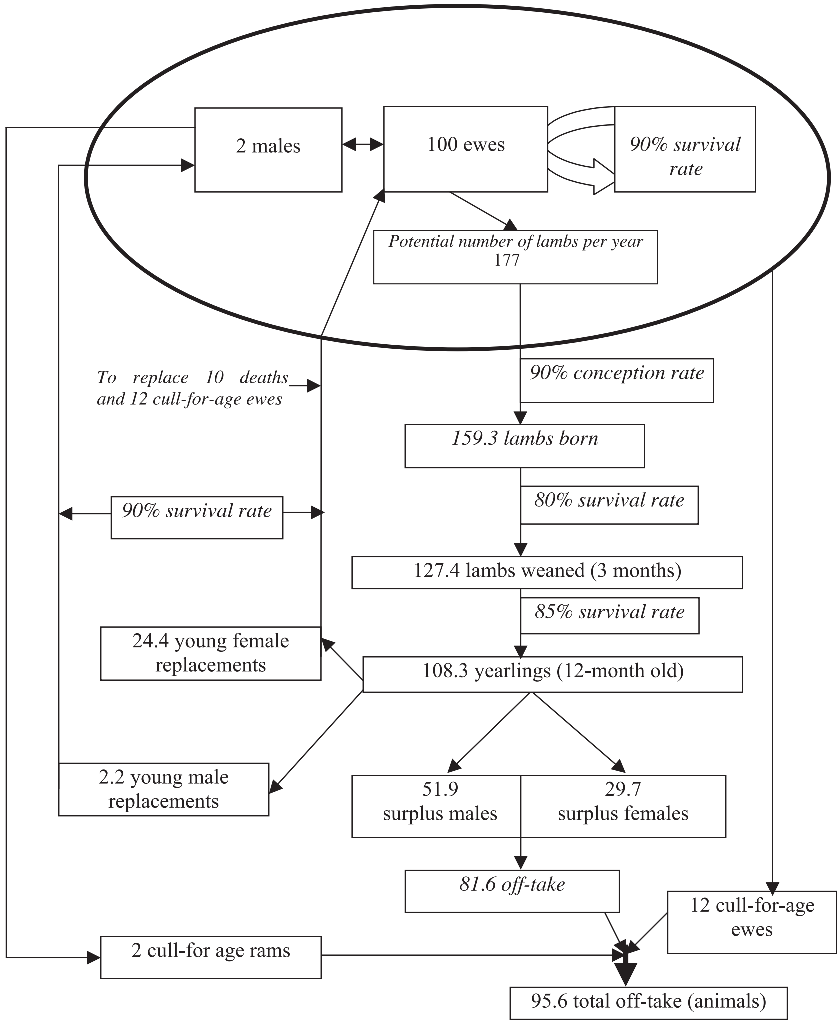

Fig. 1. Flock dynamics for an indigenous tropical hair sheep breed (adapted from Kosgey et al., in press).

pects, embodied value can be negative in some years. The extra benefit derived from the financing role may be estimated by considering the costs or losses incurred in alternative ways of financing such as operating a savings account or obtaining credit other than through outflow of livestock (Ifar, 1996; Bosman et al., 1997).

Insurance involves the maintenance of capital stock embodied in the flock present on the farm, as a guarantee for offsetting shortfalls in earnings and unforeseen expenses in the future (Ifar, 1996; Bosman et al., 1997; Nibbering et al., 2000), for instance, a medical bill. Consequently, owning animals substitutes for paying insurance premiums in situations where markets for insurance are absent. The farmers' perspective of risks, particularly related to the weather, may influence the range of the insurance benefit factor. Formal insurance premiums provide cover to a certain limit and for a specific period. Therefore, insurance benefit is related to the average flock value for a given period of time (Ifar, 1996; Bosman et al., 1997), assuming that the whole flock is available to provide security through liquidation at any one time if the need arises. In this study, this period was set to 1 year.

The function of livestock in providing prestige to owners is related to the presence or absence of other means to display wealth, such as durable consumer goods, building materials and other spending possibilities. The estimation of the prestige benefit requires an understanding of the farmers' perception of social status as regarded by the community. This aspect was not considered in the current study due to lack of a good estimate of the prestige benefit factor.

2.2. Profit equations

Total annual profitability of the sheep flock (T_f) was described by the following equation:

$$T_f = N_e \times (R_e - C_e) \qquad (1)$$

where: N_e = number of ewes in the flock year^{-1}, R_e = average revenue (ewe^{-1} year^{-1}) and C_e = average variable costs (ewe^{-1} year^{-1}).

2.2.1. Revenues

Average revenue (R_e) ewe^{-1} year^{-1} was derived as the sum of values from Eqs. (2)–(6).

Intangible benefits were calculated from the procedures described in Eqs. (2)–(4), which are based on Ifar (1996) and Bosman et al. (1997). The total benefit from financing (B_f) is related to the value of the outflow per ewe (i.e. the part of the flock actually used to meet the farmers' lumpy cash needs) as:

$$B_f = (1 + b_f) \times \text{outflow value} \qquad (2)$$

where the outflow value represents the average value of the sales during 1 year and b_f represents the financing benefit factor. There was insufficient evidence to apply estimates of interest rates from the informal credit markets. Inflation rate and the current interest rates of the formal credit market were applied. The factor b_f was assumed to be an average of 6.5% (i.e. reduction in purchasing power of cash savings) (CBK, 1999, 2000) plus 12% (the current average interest rate on a short- to medium-term credit obtainable by a member from a credit and savings society in Kenya for lumpy cash needs) (Bebe et al., 2002). Therefore, b_f was taken to be 18.5%.

The outflow value (US$) can be obtained from:

$$\text{Outflow value} = \sum_{i=1}^{6}\left[N_i \times f_i \times (1 - m_i) \times \left(\text{LW}_i \times \frac{\text{CM}_i}{100}\right) \times P_m\right] \qquad (3)$$

where: i = animal category (1—lambs, 2—yearlings, 3—replacement females, 4—replacement males, 5—breeding ewes and 6—breeding rams), f = fraction of animals sold (outflow) during the year, N = in this and the following equations N refers to number of animals present in each category relative to number of ewes present (i.e. the proportion of animals in each category with respect to the total number of ewes present in the flock = 100), m = annual mortality rate of animals (%), LW = average live weight at slaughter of an animal (kg), CM = consumable meat, including 20% offal at half price of meat of an animal (%), and P_m = price kg^{-1} of meat.

The benefit derived from insurance, B_a (US$ ewe^{-1} year^{-1}), was expressed as a fraction of the average flock value during 1 year (i.e. animals not sold):

$$B_a = b_b \times \sum_{i=1}^{6}\left[N_i \times (1 - f_i) \times (1 - m_i) \times \left(\text{LW}_i \times \frac{\text{CM}_i}{100} \times P_m\right)\right] \qquad (4)$$

where: b_a = insurance benefit factor assuming average weather conditions (%).

As effectively no institutional insurance services are accessible to most pastoral communities, the factor b_a was set equal to 6%, which is the current average annual payment on an average medical insurance premium in Kenya (e.g. Bebe et al., 2002), as medical expenses is one of the key reasons for keeping livestock by the farmers (e.g. Bebe et al., 2002; Kosgey et al., unpublished).

Manure revenue (O_s) ewe^{-1} year^{-1} was calculated from the following equation:

$$O_s = \sum_{i=1}^{6}[N_i \times Z_i \times O_i \times P_o] \qquad (5)$$

where: Z = fraction of animals producing manure during the year, O = manure production of an animal (kg year^{-1}) and P_o = price of manure.

Revenue from animals slaughtered for home consumption (HK_e) ewe^{-1} year^{-1} was calculated from the following equation:

$$HK_e = \sum_{i=1}^{6}\left[N_i \times K_i \times \left\{\left(LW_i \times \frac{CM_i}{100} \times P_m\right) + P_{kh}\right\}\right] \quad (6)$$

where: K = fraction of animals that are slaughtered for home consumption and P_{kh} = price of a piece of skin.

2.2.2. Costs

Variable costs (C_e) ewe^{-1} year^{-1} were calculated from Eq. (7).

$$C_e = \sum_{i=1}^{6}[N_i \times (C_{hi} + C_{mi})] \quad (7)$$

where: C_h = management costs animal^{-1} and C_m = marketing costs animal^{-1}.

Average management costs (C_h) ewe^{-1} year^{-1} were described by the following equation:

$$C_h = \sum_{i=1}^{6}[N_i \times \{P_{lbi} + (N_{d:yi} \times C_{di}) + (D_{mli} \times P_{mli} \times L_i)\}] \quad (8)$$

where: P_{lb} = opportunity cost of labour year^{-1} animal^{-1}, L = number of days an animal is present in the year, $N_{d:y}$ = average number of sprays/dippings year^{-1} animal^{-1}, C_d = cost spraying/dipping^{-1} animal^{-1}, D_{ml} = average daily mineral requirements animal^{-1} and P_{ml} = average price kg^{-1} of mineral.

Average marketing costs (C_m) animal^{-1} sold were described by the following equation:

$$C_m = \sum_{i=1}^{6}[N_i \times f_i \times (C_{ti} + C_{li})] \quad (9)$$

where: C_t = cost of transport of live animal to the market and C_l = levies (auction fee, slaughter fee, meat inspection fee and carcass transport) animal^{-1}.

2.3. Scenarios evaluated

The primary objective of the current study was to examine the impact of inclusion of intangible returns on the economic values for traits of sheep in the breeding goal. This necessitated a study of alternatives that would clearly capture and quantify the benefits of IRs. Consequently, EVs for the traits considered were calculated for the following five scenarios: (i) base situation accounting for both TRs (i.e. meat, manure and skins) and IRs (i.e. financing and insurance); (ii) situation accounting for manure, skins and IRs; (iii) situation accounting for 20% of all theoretically saleable animals compared to scenario (i), insurance, manure and skins; (iv) situation accounting for IRs only and (v) situation accounting for TRs only. In some pastoralist communities (e.g. Grandin et al., 1991), fewer animals are sold, hence the basis of assuming 20% of the animals to be involved in total

Table 3
Estimates of population means (μ), heritabilities (h^2), phenotypic (σ_p) and genetic (σ_G) standard deviations of the breeding goal traits studied

Trait[a]	Parameters of the trait[b]			
	μ	h^2	σ_p	σ_G
LS	1.18	0.10	0.355	0.112
LF	1.50	0.07	1.225	0.324
PRWS	0.80	0.02	0.287	0.04
PWS	0.85	0.05	0.291	0.07
ES	0.90	0.10	0.500	0.158
12mLW	25.00	0.25	2.867	1.434
ELW	30.00	0.30	3.713	2.034
CM	0.60	0.40	0.228	0.144
MS	0.409	0.30	0.072	0.039

[a] See Table 1 for definition of units and abbreviations.
[b] Derived from Chopra and Acharya (1971), Magid et al. (1981), Oltenacu and Boylan (1981), Notter (1981), Rae (1982), Carles (1983), Wilson (1985), Baker and Steine (1986), Fahmy (1986), Fogarty and Hall (1986), Gatenby (1986), Van Vleck et al. (1987), Mbah (1988), Odubote (1992), Olayiwole and Adu (1988), Orji (1988), Osinowo and Abubakar (1988), Wilson (1991), Rajab et al. (1992), Waldron and Thomas (1992), Fogarty (1995), Lewis et al. (1996), Matika (1995), Olesen et al. (1995), Boujenane et al. (1998), Cloete et al. (1998), Sormunen-Cristian and Suvela (1999), Vagenas and Bishop (1999), Ingham and Ponzoni (2000), Michels et al. (2000), Mukasa-Mugerwa et al. (2000), Conington et al. (2001), Banos et al. (2002), Ermias et al. (2002), François et al. (2002), Rege et al. (2002), Rosati et al. (2002), Tosh et al. (2002), Kosgey et al. (2003) and Robert Banks (personal communication).

financing benefit. It is important to note that, in the present study, changes in costs (C) and revenues (R) are given per % change in the average performance level for the trait considered, while EVs are expressed per unit change in the average performance level for the trait. Consequently, EVs in Table 7 may not be obtained directly as the differences in total marginal C and R. Inconsistencies may also arise due to rounding, since more decimals were used in the calculation of EVs than are shown here. To be able to make comparisons of EVs from the different production circumstances studied easier, relative economic values (REVs) were calculated by arbitrarily taking the EV for 12mLW as the standard.

In comparing the value of traits, it is important to consider the units in which the traits are expressed and the amount of genetic variance. Published data on population parameters of the traits considered in the current study for tropical circumstances are scanty, a situation limiting the scope of comparison of the traits using their genetic variances. Therefore, literature estimates (Table 3) were collected and used to evaluate the value of traits per genetic standard deviation. Genetic parameters of feed intake were used for kg manure dry matter sold ewe^{-1} year^{-1}. Since lambing frequency is a biological trait that follows the Poisson distribution (with random outcomes of 0, 1, 2 and 3 lambings per 2 years), its phenotypic variance was assumed to be equal to its mean.

2.4. Sensitivity analysis

Given the uncertainty in the financing (b_f) and insurance (b_a) benefit factors, an analysis was performed on the sensitivity of the EVs to changes in levels of these factors. The same analysis was done with respect to changes in reproduction, survival and live weight traits. Changes of ±20% with respect to original values were evaluated, under the base situation accounting for both TRs and

Table 4
Costs and revenues per proportion of animals in each category to number of ewes present and profit ewe^{-1} year^{-1} (US$) in the base situation accounting for both tangible and intangible roles of sheep

	Animal category								
	Lambs	Yearlings off-take[a]	Replacement females	Replacement males	Breeding ewes[b]	Cull ewes[c]	Breeding rams[b]	Cull rams[c]	
Proportion of animals to ewes	1.27	0.82	0.24	0.02	1.00	0.12	0.02	0.02	Total[d]
Input									
Management	1.47	7.97	0.79	0.07	6.21	–	0.13	–	16.64
Labour[e]	0.53	1.83	0.14	0.01	1.50	–	0.03	–	4.05
Marketing	–	2.10	–	–	–	0.33	–	0.05	2.48
Total	1.47	10.07	0.79	0.07	6.54	–	0.18	–	19.12
Output									
Meat	–	24.50[f]	–	–	–	4.32	–	0.96	29.78
Financing benefit	–	4.53	–	–	–	0.80	–	0.18	5.51
Total financing benefit[g]	–	29.03	–	–	–	5.12	–	1.14	35.29
Insurance benefit	–	1.36	0.48	0.05	0.44	–		–	2.33
Manure	0.28	1.67	0.30	0.03	1.88	–	0.03	–	4.20
Skins	–	0.02	–	–	–	–		–	0.02
Total	0.28	32.08	0.78	0.08	7.44	–	1.17	–	41.84
Profit	– 1.19	22.01	– 0.01	0.01	0.9	–	0.99	–	22.72

[a] Insurance from those retained for replacement.
[b] Financing value from footnote c.
[c] Input parameters already accounted for in breeding groups.
[d] Weighted by animal proportions.
[e] Already included in management.
[f] Includes animals slaughtered for home consumption.
[g] Includes meat and intangible financing benefit.

Table 5
Estimated annual average costs and benefits (US$) ewe^{-1} in the flock for the base situation[a]

Economic variables	Amount (US$ year^{-1})
Production output	
Cash from animal sales (meat)	29.78
Cash from skin sales	0.02
Total cash income	*29.80*
Net recurrent cash income[b]	*10.68*
Income in kind	
Home-slaughtered animals (10% surplus stock)	1.24
Manure	4.20
Change in stock value	23.26
Total income in kind	*28.70*
Benefits	
Value added[c]	39.38
Insurance benefit (6%)	2.33
Financing benefit (12% + 6.5% = 18.5%)	5.51
Total benefits	*47.22*
Production costs	
Management	
Purchased acaricide (spraying/dipping)	5.55
Purchased anthelmintic (dewormers)	1.14
Mineral supplements	5.90
Opportunity cost of family labour	4.05
Marketing	
Transport (animals and carcasses)	0.65
Levies	1.83
Total purchased inputs	*19.12*

[a] Multiply by 100 to get the averages for the flock.
[b] Total cash income minus total purchased inputs.
[c] Total cash income plus total income in kind minus total purchased inputs.

IRs, and with constant number of ewes. Changes were performed separately, holding all other parameters constant.

3. Results

Tables 4 and 5 present the costs, revenues and profit for the base situation accounting for both tangible and intangible roles of sheep. The values presented are weighted by the proportion of each animal category with respect to number of ewes present, and the totals are expressed ewe^{-1} year^{-1}. For example, in Table 4, management costs for 0.24 replacement females was US$0.79 and insurance value from breeding ewes was US$0.44. Total management and marketing costs ewe^{-1} year^{-1} were US$16.64 and US$2.48, respectively. Management costs represented about 87% of the total cost and marketing about 13%. The total profit ewe^{-1} year^{-1} was US$22.72.

Financing and insurance benefits accounted for about 13% and 6% of the total revenues, respectively. Contribution of skins to revenue was negligible due to the small proportion of animals slaughtered at home that solely contributed skins sold by the farmer. All the animal categories had positive profits except lambs and replacement females. The lambs had only manure as a source of revenue. Their role in financing and insurance was included in the

Table 6
Initial costs and revenues (US$ ewe^{-1} year^{-1}) with marginal changes for the base situation accounting for both tangible and intangible benefits of sheep after a 1% increase in the average performance level for the traits considered

	Initial	Trait[a]								
		LS	LF	PRWS	PWS	ES	12mLW	ELW	CM	MS
Costs										
Management	16.64	0.09	0.09	0.09	0.07	− 0.02	0.00	0.00	0.00	0.00
Marketing	2.48	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00
Revenue										
Meat	29.78	0.33	0.33	0.33	0.33	0.30	0.25	0.04	0.30	0.00
Financing	5.51	0.06	0.06	0.06	0.06	0.06	0.05	0.01	0.06	0.00
Insurance	2.33	0.01	0.01	0.01	0.01	− 0.04	0.01	0.01	0.02	0.00
Manure	4.20	0.02	0.02	0.02	0.02	− 0.02	0.01	0.01	0.00	0.04
Skins	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[a] See Table 2 for definition of units and abbreviations.

yearlings to avoid double counting. Replacement females had insurance and manure as sources of revenue, the total sum of which was lower than the cost of inputs.

Table 6 gives the initial costs and revenues, and marginal changes ewe^{-1} $year^{-1}$ for the base situation accounting for both TRs and IRs. The marginal values are weighted by animal proportions. The marginal values result from a 1% change in the average performance level for the trait considered. For instance, the initial cost of marketing was US\$2.48 and increased by US\$0.03 when LS was increased by 1%. Similarly, the initial financing and insurance revenues were US\$5.51 and US\$2.33, respectively, and correspondingly increased by US\$0.06 and US\$0.01 when PWS was increased by 1%. Increase in the average performance level for 12mLW, ELW, CM and MS did not result in any marginal changes for management and marketing costs. Increase in the average performance level for ES had a negative effect on management costs, insurance benefits and manure, but a positive influence on financing. Increase in the average performance level for LS, LF, PRWS and PWS had similar positive effects on IRs.

Table 7 compares the profits and EVs for the traits considered for all the situations studied. To gauge the impact of IRs, the main focus will be on the base situation accounting for both TRs and IRs, compared to the situation accounting for TRs only. The situation accounting only for TRs showed a profit of US\$14.88 ewe^{-1} $year^{-1}$, that was about 35% lower relative to that of the base situation. In this situation, all the costs were similar as for the base situation but meat, manure and skins were the only sources of revenue. Economic values for the traits in both situations were all positive. Economic values for LS, LF and 12mLW were relatively higher when IRs were included in the calculation of the breeding objective, suggesting the importance of these three traits in pastoral production. On the other hand, PRWS, PWS, ES and ELW were correspondingly similar under the two situations. As expected, MS was unaffected by inclusion of IRs in the derivation of EVs. The situation accounting for manure, skins and IRs had a profit of − US\$7.05, while that accounting for 20% of the animals sold, insurance, manure and skins showed a profit of US\$4.11. The situation accounting for only

Table 7
Profits and economic values (US\$ ewe^{-1} $year^{-1}$) per unit increase in the average performance level for traits under the different situations[a,b,c]

Situation	Profit	Trait[d]								
		LS	LF	PRWS	PWS	ES	12mLW	ELW	CM	MS
Base (with both tangible and intangible roles)	22.72	25.11	19.75	0.37	0.37	0.33	1.26	0.21	0.62	0.08
		(19.93)	(15.67)	(0.29)	(0.29)	(0.26)	(1.00)	(0.17)	(0.49)	(0.06)
		2.81	6.40	0.02	0.03	0.05	1.81	0.43	0.09	0.01
With manure, skins and intangible roles	− 7.05	− 2.43	− 1.91	− 0.03	− 0.01	0.00	0.28	0.06	0.13	0.08
		(− 8.68)	(− 6.82)	(− 0.11)	(− 0.04)	(0.00)	(1.00)	(0.21)	(0.46)	(0.29)
		− 0.27	− 0.62	0.00	0.00	0.00	0.40	0.12	0.02	0.01
With 20% animals sold, insurance, manure and skins	4.11	4.18	3.29	0.06	0.08	0.08	0.52	0.21	0.31	0.08
		(8.04)	(6.33)	(0.12)	(0.15)	(0.15)	(1.00)	(0.40)	(0.60)	(0.15)
		0.47	1.07	0.01	0.01	0.01	0.75	0.43	0.05	0.01
With intangible roles only	− 11.27	− 4.11	− 3.23	− 0.06	− 0.03	0.01	0.24	0.04	0.13	0.00
		(− 17.13)	(− 13.46)	(− 0.25)	(− 0.13)	(0.04)	(1.00)	(0.17)	(0.54)	(0.00)
		− 0.46	− 1.05	0.00	0.00	0.00	0.34	0.08	0.02	0.00
With tangible roles only	14.88	18.86	14.84	0.28	0.28	0.31	1.02	0.17	0.49	0.08
		(18.49)	(14.55)	(0.27)	(0.27)	(0.30)	(1.00)	(0.17)	(0.48)	(0.08)
		2.11	4.81	0.01	0.02	0.05	1.46	0.35	0.07	0.01

[a] Changes in costs and revenues are given per % change in the average performance level for the trait, while economic values are per unit change in the average performance level for the trait.

[b] Relative economic values in brackets and are related to the economic value for 12mLW for the particular situation.

[c] Figures without brackets in second row for each situation are economic values per genetic standard deviation.

[d] See Table 2 for definition of units and abbreviations.

IRs resulted in a profit of − US$11.27. These results illustrate the importance of the multiple roles of sheep in traditional production systems in the tropics.

The situation accounting for 20% animals sold, insurance, manure and skins had positive EVs for all the traits considered. The REVs generally indicated a similar trend to the situation accounting for both TRs and IRs. However, the EVs were smaller. As expected, the EV for MS was zero for the situation accounting only for IRs and was the same (US$0.08, i.e. US$0.01 per genetic standard deviation) for the other situations. However, the REVs were different. In this situation, the EVs for LS, LF, PRWS and PWS were negative.

Table 8 shows the EVs for the traits considered and their sensitivity to different levels of b_f and b_a, reproduction, survival and live weight traits, for the situation accounting for both TRs and IRs, and with a constant number of ewes. Economic values for most of the traits considered were relatively sensitive to different levels of b_f and b_a. As expected, EV for MS was not sensitive to different levels of financing and insurance benefit factors. Ewe survival and ELW were not responsive to changes in LS, LF, PRWS and PWS and vice-versa.

4. Discussion

4.1. Revenues and costs

The results from this study attest to the fact that financing and insurance roles of sheep are important in traditional production circumstances alongside TRs. However, they are unlikely to be important on their own. It is shown that total profit ewe^{-1} year^{-1} turns out to be higher when benefits from IRs are accounted for along with those from TRs (Tables 4, 5 and 7). This could explain why farmers in the tropics persist in keeping livestock despite apparent net economic losses in their flocks as shown for smallholder production discussed by Kosgey et al. (2003). Exclusion of feed and fixed costs also positively influenced the apparent profitability of the situations studied. The net effect is that the EVs are higher than for the smallholder production but the REVs are about the same. Table 6 shows how marginal changes arise

Table 8
Economic values (US$ ewe^{-1} year^{-1}) for the traits for the situation accounting for both tangible and intangible roles of sheep with changes in levels of financing and insurance benefit factors, reproduction, survival and live weight traits, and constant number of ewes

Output	Level (%)	Trait[a]								
		LS	LF	PRWS	PWS	ES	12mLW	ELW	CM	MS
Financing benefit factor (b_f)	−20	24.09	18.95	0.35	0.35	0.32	1.22	0.20	0.60	0.08
	+20	26.13	20.56	0.38	0.38	0.34	1.30	0.21	0.64	0.08
Insurance benefit factor (b_a)	−20	24.88	19.57	0.36	0.36	0.34	1.25	0.21	0.61	0.08
	+20	25.34	19.94	0.37	0.37	0.32	1.27	0.21	0.63	0.08
LS	−20	–	15.80	0.29	0.29	0.33	0.94	0.21	0.49	0.08
	+20	–	23.71	0.44	0.44	0.33	1.58	0.21	0.75	0.09
LF	−20	20.09	–	0.29	0.29	0.33	0.94	0.21	0.49	0.08
	+20	30.13	–	0.44	0.44	0.33	1.58	0.21	0.75	0.09
PRWS	−20	20.07	15.79	–	0.29	0.33	0.94	0.21	0.49	0.08
	+20	30.15	23.72	–	0.44	0.33	1.58	0.21	0.75	0.09
PWS	−20	19.77	15.55	0.29	–	0.33	0.94	0.21	0.49	0.08
	+20	30.45	23.96	0.45	–	0.33	1.58	0.21	0.75	0.09
ES	−20	25.11	19.75	0.37	0.37	–	1.26	− 0.05	0.49	0.08
	+20	25.11	19.75	0.37	0.37	–	1.26	0.46	0.75	0.08
12mLW	−20	18.33	14.42	0.27	0.27	0.25	–	0.21	0.52	0.08
	+20	31.90	25.09	0.47	0.47	0.40	–	0.21	0.72	0.09
ELW	−20	25.11	19.75	0.37	0.37	0.37	1.26	–	0.60	0.08
	+20	25.11	19.75	0.37	0.37	0.32	1.26	–	0.64	0.09

[a] See Table 2 for definition of units and abbreviations.

with marginal increases in the average performance levels for the traits considered.

Profitability of small ruminants under traditional management in the tropics has been a contentious issue, with some results indicating a low productivity due to high mortality or low utilization rates (e.g. Seleka, 2001) and others profitability (e.g. Jaitner et al., 2001). This points to the fact that both the biological and economic parameters are likely to vary amongst tropical production systems. For instance, mortality rates could be substantially higher, and reproductive rates lower than currently assumed. In addition, very few previous studies have attempted to account for IRs. Therefore, the profit and, subsequently, the EVs are likely to be slightly higher in the current study.

In the calculation of financing benefit in this study, only interest and inflation rates were considered. It is worthy of note that savings in a bank may be even less attractive when transaction costs, transport and other obstacles farmers may experience in dealing with formal financial institutions are taken into account (Slingerland et al., 1998). Similarly, the stakes could be high in insurance given the marginal and fragile environmental conditions most pastoralist communities live in. If accounted for, these may further positively influence the EVs for the traits considered in the current study.

The estimation of the benefits from IRs is difficult and ideally would require comprehensive field research to establish the farmers' perception of the future and therefore, uncertain financial requirements and their abilities to meet these directly or through other means, including relevant alternative insurance options. In the current study, benefits from IRs essentially involve subjective estimates for factors b_f and b_a, directly as a result of lack of markets or imperfect markets for financing and insurance. Therefore, the estimation of these factors is inevitably open for discussion, and the estimated revenue of US\$41.84 ewe^{-1} year^{-1} in the base situation is simply a first estimate (Table 4).

4.2. Economic values

The EVs for the situation accounting for both TRs and IRs were all positive (Table 7). This implies that total revenues resulting from a unit increase in the average performance level for each of the traits considered were higher than the resultant total costs (Tables 4 and 6). The EVs in the current study are generally higher than those reported by Kosgey et al. (2003) for smallholder production in the tropics suggesting a lot of saving on feed costs and a higher contribution of IRs to revenue. However, the general trend is similar. Fixed costs are negligible in pastoral circumstances, and management costs marginal. This would lead to increased EVs. As would be expected, EVs for MS were the same in both studies. Increase in the average performance level for this trait resulted in the same marginal revenue for manure only and did not affect costs of inputs or other outputs. Litter size, LF and PRWS had the same marginal changes for all inputs and outputs (Table 6) because they had similar number of expressions. Ewe survival had a negative effect on management costs due to reduction in expenses associated with rearing replacement females because fewer replacements were required then. Insurance benefit is derived from animals that are not sold during the year, and therefore increase in the average performance level for ES would result in the sale of more replacements not required that would have contributed to insurance. For this reason, increase in the average performance level for ES by 1% had a negative effect on insurance.

The trend of EVs for the situation with TRs only was similar to the base situation but values were lower except for MS that was the same (Table 7). Consumable meat had the same REV as in the base situation. As shown by the REVs for the situation with 20% of the animals involved in financing, selling fewer animals remarkably lowered EVs for the traits considered except for ELW and MS. This was due to lower returns from surplus animals sold and financing benefit, and increased management costs. Generally, LS, LF and 12mLW appear to be the most important traits in pastoral production where IRs of sheep are important. Relative to the situation accounting for TRs only, the EVs for both LS and LF increased by about 33% when IRs were included in the model along with TRs.

4.3. Sensitivity analysis

Sensitivity analysis of EVs to changes in financing and insurance benefit factors is important given the subjective estimates used. Sensitivity analysis of EVs for traits to circumstances also gives information on the likely direction of future genetic improvement and production system (Smith, 1988; Kosgey et al., 2003). It is demonstrated that future EVs for responsive traits might change dependent on levels of the intangible benefit factors, and with respect to reproduction, survival and live weight traits. This is not surprising given the uncertainty in the estimation of b_f and b_a, and variation of reproductive and survival rates, as well as live weights of animals amongst tropical production systems. A point to always bear in mind is that the effort it takes to change a trait can vary considerably between traits i.e. the trait can be of great importance but cannot be changed easily. However, decisions about which traits to target for genetic improvement should ideally be based on the extent to which each trait affects profitability (head^{-1} or unit^{-1}) of labour or land, not on whether the trait is difficult or easy to measure or change genetically.

4.4. General

Raising animals has often been found to be superior to saving money in a bank account, because net annual returns from livestock are higher than interest rates in the bank (Nibbering et al., 2000). Studies in other parts of the tropics indicate that revenues from small ruminants might be greatly improved when farmers could concentrate on animal production and have viable alternatives for financing (Slingerland et al., 2000; Slingerland and van Rheenen, 2000). Emergency (premature) sales are associated with considerable losses in forgone offspring, forgone live weight and when animals are sold in periods with low market prices, i.e. sales for financing can mostly not be optimally timed (Ifar, 1996; Bosman et al., 1997; Slingerland and van Rheenen, 2000). When these animals are not needed for emergency financing, they can generate higher revenues when sales are planned to coincide with important festivities such as religious ceremonies like Christmas, Tabaski, Ramadan, etc. (Slingerland et al., 1998).

According to Slingerland et al. (1998), when high monetary inputs are required, it will be more and more difficult to solve problems through social networks because money is not always promptly available, neither to give loans nor to repay loans. In fact, in most transactions, only small amounts change hands. Friends and family may also try to escape their responsibility of helping out or may not respect promises normally met in better times. Therefore, sheep facilitate the farmer to meet unexpected expenditures, e.g. medical care, ceremonies like marriages and funerals, etc. (Slingerland and van Rheenen, 2000). This may impact positively on EVs for most of the traits considered in this study. However, the development of formal markets may break the tendency of farmers to treat livestock as a store-of-wealth (Seleka, 2001).

To our knowledge, no other studies exist on the inclusion of IRs of sheep in the breeding objective for indigenous tropical genotypes, although the importance of these roles have been discussed in general terms (e.g. Carles, 1983; Gatenby, 1986; Hunter, 1989; Bosman et al., 1997; Slingerland et al., 1998).

5. Conclusion

Intangible benefits (financing and insurance) are a reasonable proportion of the total income from sheep under traditional production circumstances. These benefits had a considerable influence on EVs for most traits considered. Generally, IRs appear to greatly influence the EVs for reproductive traits and 12-month lamb live weight. Therefore, IRs need to be included in the breeding objectives for sheep under traditional management in the tropics. The current study provides a basis for inclusion of IRs in sheep breeding programmes in tropical conditions but further fine-tuning of the model may be necessary in future research.

Acknowledgements

The financial support from The Netherlands Foundation for the Advancement of Tropical Research (WOTRO) for the first author and the provision of facilities by the International Livestock Research Institute (ILRI, Nairobi), Wageningen University (The Netherlands) and The University of New England (Armidale, Australia) are gratefully acknowledged. Thanks to Prof. B.P. Kinghhorn, Drs. Ab Groen, Henk A.J. Moll, Henk Udo, Keith Hammond and Peter Amer for helpful comments on the paper.

We further wish to acknowledge Dr. Henk A.J. Moll for most of the terminology and language used in the paper relating to the economics of intangible benefits. This paper was written as part of a PhD study while the first author was on leave from Egerton University (Njoro, Kenya).

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