Herd Dynamics of Smallholder Dairy in the Kenya Highlands

Promotor: **Prof. Dr. Ir. A.J. van der Zijpp**
Hoogleraar Dierlijke Productiesystemen
Wageningen Universiteit

Co-promotoren: **Dr. Ir. H.M.J. Udo**
Universitair hoofddocent
leerstoelgroep Dierlijke Productiesystemen
Wageningen Universiteit

Dr. W. Thorpe
Deputy Director General
International Livestock Research Institute

Promotie Commissie:

Prof. Dr. Ir. J.A.M. van Arendonk
Wageningen Universiteit

Prof. Dr. K.J. Peters
Humboldt University of Berlin

Dr. E.A. Mukisira
Kenya Agricultural Research Institute

Ir. C. de Haan
World Bank, Washington D.C.

Bockline Omedo Bebe

Herd Dynamics of Smallholder Dairy in the Kenya Highlands

Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit
Prof. dr. ir. L. Speelman
in het openbaar te verdedigen
op dinsdag 21 januari 2003
des namiddags te half twee in de Aula.

Bebe, B.O., 2003. Herd dynamics of smallholder dairy in the Kenya highlands

PhD Thesis, Wageningen University, The Netherlands, with references - with summary in Dutch

Subject headings: smallholder systems, dairy development, intensification, herd dynamics, feeding, breeds, breeding

ISBN: 90-5808-788-3

Abstract

Smallholder dairy farmers in the Kenya highlands generally intensify their farming systems by integrating dairy with crop production and shifting from free-grazing to semi-zero- or zero-grazing. They consequently change the breed composition, size and structure of their herds with resultant change in herd demographic rates. The intensification of smallholder dairying has underpinned changes in the farming systems to sustain more intensive land use and support more people per unit area of land in smallholder households. However, the concern is whether smallholders will continue to benefit from dairying through continued intensification when facing the pressures of continuously shrinking landholdings, worsening soil fertility and reduced access to formerly public delivered livestock input and output services, while imported nutrients remain relatively low and non-agricultural job opportunities remain lacking. The objective of this study was therefore to quantify the consequences of the intensification of farming systems in the Kenya highlands on the dynamics of smallholder dairy herds in order to better understand the constraints to, and opportunities for, the continued intensification of smallholder dairying. Data collection was through a random stratified cross-sectional survey of smallholder households. Data from the cross-sectional survey sample were complemented with additional information from longitudinal and targeted semi-structured interviews, which involved a randomly selected sub-sample of the previous cross-sectional survey. The drivers of intensification of smallholder dairying were identified and the relative changes were quantified at the level of the farms and farming systems. Intensification requires increased use of external resources including sources of replacement animals, feed resources, animal health and breeding services and credit to sustain the herd population and production. Prospects for maintaining and expanding smallholder dairying in the Kenya highlands depend upon the proportion of free-grazing farms maintained within the farming systems, because these supply semi-zero- and zero-grazing farms with dairy replacements. The rational underlying smallholders' breeding decisions is based on multiple objectives of more milk, adaptability to local feed conditions and diseases and the provision of non-marketed production such as manure, insurance and financing roles of cattle. Feeding interventions to support continued intensification of smallholder dairying must be within the context of the household's economy, which is characterised by limited cash flow and low risk bearing capacity. Smallholders need affordable working capital to sustain intensification with use of external resources. Solutions to constraints of intensification must concurrently involve both technical and institutional innovations that may encourage greater complementarities and stratification in the dairy sub-sector.

Acknowledgements

Writing of this thesis has been achieved by relentlessly asking questions, seeking answers and knocking in and out volumes of knowledge. Many institutions and individuals facilitated my achievement and I express my gratitude most sincerely to them all. Painfully I confront the fact that I cannot acknowledge all individually by names. Necessarily, however, I have to be transparent about key facilitation without which this thesis would not have been a product for the public.

S. A. Abdulrazak, you fuelled me on to putting my thoughts on paper and ensured my entry into a network with International Livestock Research Institute (ILRI, Nairobi). Alex Kahi, I am a proud product of your refereeing. James Tuitoek, you expeditiously took charge of the necessary administrative requirements on my way to this program.

Egerton University granted me a study leave. ILRI awarded me graduate fellowship position. The Netherlands Foundation for the Advancement of Tropical Research (WOTRO), awarded me the fellowship to study the dynamics of intensification of smallholder dairy systems in the Kenya highlands. Smallholder Dairy (R&D) Project (SDP) of the Kenya Ministry of Agriculture and Rural Development, the Kenya Agricultural Research Institute (KARI) and ILRI funded the bulk of the fieldwork and my participation in international conferences. Animal Production Systems Group (DPS) of Wageningen University funded the completion of this program as well as my participation in international conferences.

I had the benefit of working with an experienced team on the material content of this thesis. Bill Thorpe, my ILRI co-promotor, we worked relentlessly from the proposal to the very end. You immensely shaped this thesis through thorough conceptualisation of scientific content and critique. And that is not all: I am an admirable disciple of that art of getting more from less. Henk Udo, my University co-promotor, you efficiently coped with my volume of scripts, simplified my complex sentences and with continuous question marks, you ensured I remained on the track to this very end. John Rowlands, I immensely benefited from your vast experience in statistics, which ensured that the models were appropriately applied. Of course there was also my promotor, Akke van der Zijpp, you paid special attention to my progress.

Bernardo Vargas, I was able to use SAS software for statistical analyses because you made the apparently complex statements simpler for me. The ILRI house staff, painfully

I am unable to mention you individually by names: collectively and individually, you frequently gave me a push over many huddles I had to go through to this other end. Mulinge Wellington, you turned my fieldwork a smooth operation with your unique skills in driving, fixing mechanical troubles and interpreting the different languages. Gerrit Zemmelink and Wakhungu Jacob: the special attentions the two of you gave me over my numerous consultations are a major pillar of this thesis. Then Fokje Steenstra, Erwin Mollenhorst and Karen Eilers of DPS group, I counted on your skills to ensure adherence to the technical details that go with a serious thesis.

Many individuals checked that my social emotions remained conducive to completion of this thesis. The Sango families, I counted on you most dearly. The students of ANP Hostel, University of Nairobi: Angela, Beatrice, Christian, Korir, Maud, Nancy, Tablique and Tezira, together we remained unbwogable by the gun-touting thugs! Thanks To God, we are alive in pursuit of our ambitions. Fellow students and colleagues in Wageningen: Beatriz Waltrick, Okoth Peter, Niyibigira Emmanuel, Were James, Mukabana Richard, Gohole Linnet, V. Nicole and Abachi Nobert, I am fully aware that reaching this end would have been more difficult for me without the timely encouragement you offered. René Kwakkel, you deserve special mention for your "continuous yelling", which were humorous with a therapy towards emptying my "filled recycled bin".

Finally, I am a lucky man to have had mum Patronalla, wife Rose, son Dereek and daughters Danjis and Sharon: you always had only new ways of supporting and encouraging me on, even during some difficult moments we had to go through in our family so far. To you all, I dedicate this thesis.

Table of Contents

CHAPTER ONE

General Introduction

General Introduction

1. Relevance of smallholder dairying

In developing countries, smallholder dairy production is generally a component of mixed farming systems in which dairy and crop production is integrated on the same farm. Crop-dairy farming is important in these countries in terms of the numbers of households and livestock populations it supports and their contributions to total domestic milk production. It is estimated that smallholders represent about 60 to 80% of dairy farmers in developing countries. They account for 30 to 80% of the domestic cattle population, of the milk production and of the marketed milk in these countries (De Jong, 1996; Schelhaas, 1999). At the household level, dairy production contributes to food security and spreading of risks, generates income, supports crop production through traction and manure, and is a means to accumulate capital assets for emergency cash needs (ILRI, 1999; Tulachan *et al.,* 2000). In many cases dairy production contributes as much as 60% of the total income of the household (Delgado *et al.,* 2001). Many developing countries thus support smallholder dairying as a key development pathway for creating employment, catalysing agricultural development and reducing the growing deficits in domestic demand for milk fuelled by human population growth, urbanisation and increased purchasing power.

1.2. Smallholder farming systems in the Kenya highlands

Kenya highlands comprise areas with elevations ≥1000 m above sea level where agro-ecological potential for cropping and dairying is medium to high (Jaetzold and Schmidt, 1983). Smallholder farming predominates over other farming systems. The crops grown and livestock species kept are generally a function of the agro-ecological conditions (which influences the feed resource base and disease prevalence), subsistence needs and market opportunities. Dairy production is usually integrated on the same farm with other ruminant and non-ruminant livestock and with a variety of subsistence and cash crops. Kenya is prominent among developing countries for integrating dairy into smallholder farming systems, particularly in the highlands where milk market opportunities vary depending on human population densities and marketing infrastructure. It is estimated that dairy production is the main source of income for over 600,000 mixed farmers, of which about three-quarters are in the highlands (Omore *et* *al.,* 1999). Recent characterisation studies of smallholder farming systems in the Kenya highlands have estimated that approximately 60% of the rural households have integrated dairy into their farming systems (Staal *et al.,* 2001). In order of importance as source of income, smallholders ranked milk sales, off-farm income and sale of crop produce, in that order. Poultry, an average of 13 birds per flock, were the most frequently kept livestock by smallholder households (78%). Small ruminants were kept by about 36% of the households. Donkeys (16%) and pigs (8%) were least frequently kept.

Because of the prevalence of dairy production in the farming systems in the highlands of Kenya, Jaetzold and Schmidt (1983) defined the major land-use systems as tea-dairy, coffee-dairy, horticulture-dairy, wheat-dairy, sheep-dairy and urban-dairy. Horticulture broadly includes the growing of maize, bananas, beans, Irish potatoes and vegetables mainly for subsistence but also for cash. Maize is the predominant staple food and smallholders produce 70% of the total domestic crop. Tea, horticulture and coffee respectively, rank second, third and fourth after tourism as top foreign exchange earners in Kenya's economy. Smallholders produce approximately 60% of the tea and coffee (CRF, 1999). However, per capita crop production is on a downward trend because of negative nutrient balances. Some studies have shown that 60 to 80% of farm income is based upon nutrient mining and that replacement costs of mined nutrients amounts to 32% of the average net farm income (De Jager *et al.,* 1998; De Jager *et al.,* 2001). Integration of dairy with crops is one way to correct nutrient depletion problems.

Over recent years the proportion of households growing traditional crops such as sorghum, millet, cassava and sweet potatoes has declined whereas those growing fruit trees, horticultural crops and napier grass fodder has increased (Staal *et al.,* 2001). These changes reflect a shift in resource allocations from low- to high-value farming activities. The increase in the growing of napier is associated with the intensification of smallholder dairy production systems, which involves the adoption of management practices and technologies to increase the output quantity and/or value from the major limiting production resources of land, capital and labour. Dairy production is central to the intensification of smallholder farming particularly when reduced farm size, resulting from farm subdivision and its inheritance by the owner’s children, constrain the expansion of crop and livestock production using existing management practises and technologies. The adoption of dairying and its integration with cropping is a means to increase productivity, for example through nutrient cycling, and to reduce risks through diversification, thereby increasing the output quantity and/or value from land, capital and labour.

1.3. Constraints to intensification of smallholder dairying

With human population densities continuing to rise and landholdings to shrink in the Kenya highlands, crop-dairy farmers practising free-grazing are shifting to semi-zero- or zero-grazing (stall feeding). Table 1 summarises this shift towards more intensive feeding practises using the example of the smallholder dairy systems in Kiambu district where agro-ecological potential, human population densities and milk market access are some of the highest in the Kenya highlands. The size of holdings have decreased by more than half over the past two decades, mainly because of subdivision through family inheritance. Correspondingly, the numbers of holdings have increased and so is the integration of dairying as an integral component of the farming system. Associated with the increased numbers of holdings has been the increase in the cattle population, putting pressure on available feed resources, and probably limiting further increases in the dairy herd and its production performance. This is expected to have implications for the future structure and productivity of Kenya's dairy sub-sector. Continued intensification of crop-dairy systems is expected to effect dairy feeding practices, herd sizes and structures, breeding and replacement decisions, milk production and reproductive performances, and consequently impacting upon crop production.

Table 1. Changes in grazing systems for smallholder dairy production between 1977 and 1996 in Kiambu district within the Kenya highlands

Year of survey	Farm size (ha)	Households (%) by grazing system			Reference
		Free-	Semi-zero-	Zero-	
1977	2.9	65	13	25	Stotz, 1979
1992	1.9	33	19	48	Gitau *et al.*, 1994
1996	1.1	28	5	67	Staal *et al.*, 1998

Past increases in Kenya's domestic milk production have resulted mainly from increases in the cattle population (Nicholson *et al.,* 2001). Further herd increases on the scale of the past are limited because of the high pressure on animal feed resources resulting from shrinking landholdings, the small proportion (19%) of land suitable for cropping and dairying and the high human population density (Reynolds *et al.,* 1996; Zemmelink *et al.,* 1999). Intensification of production is a prerequisite for increasing farm productivity and the incomes of the farming households in the Kenya highlands. Intensification in the highlands through dairying has been associated with farmers growing napier grass fodder and purchasing feeds to alleviate shortages of animal feeds. Land allocation will determine the availability of napier fodder (Muia *et al.,* 2000) and access to cash and source of supply will influence the availability of purchased feeds (Freeman *et al.,* 1998). Feed availability is likely to have a large influence on the production performance of the dairy herd as intensification continues.

In these smallholder dairy systems the Friesian and Ayrshire breeds dominate despite several studies concluding that their use should be discouraged in favour of Jersey and Guernsey. Friesian and Ayrshire have heavier mature body mass with higher nutritional demands and have performed poorly under smallholder feeding conditions (Kahi *et al.,* 1998; Rege, 1998; Ojango, 2000; Wakhungu, 2000). However, breeding practices generally evolve in response to changes in farmers' preferences and production objectives, the production systems used to achieve the objective, farmers' perceptions about breed characteristics and market opportunities (Amer *et al.,* 1998; Jabbar *et al.,* 1998). A better understanding of the rationale underlying smallholders' breeding decisions is necessary to guide public and private research and development programmes supporting smallholder dairy producers through focusing on breeds and traits of importance to meet smallholders' production objectives.

A typical crop-dairy farm in the Kenya highlands is one hectare with a herd of one to three cattle, generally Friesians or Ayrshires, and often there is no replacement heifer (Bebe *et al.,* 1999). The herd structure reflects efforts by smallholders to maximise the most productive class. However, since smallholder farms dominate dairy production, the majority of replacement stock has to be generated from within smallholder herds. In the past, public-owned, large-scale dairy farms produced replacements for smallholder farmers at subsidised prices, but the large majority of these farms have collapsed or have been subdivided for resettlement (Conelly, 1998). Similarly, the number of private large-scale dairy farms is dwindling. The changes in the structure of the national dairy herd and the continuing human pressure on land mean that the reproductive performance of the smallholder owned portion of the national herd has to be able to produce its own replacements if smallholders are to at least maintain the population of their herds. However, current low rates of reproductive performance raise concerns about whether this is attainable especially in some communities where densities of human and cattle populations are already very high and levels of imported nutrients are relatively low. These dynamics of land use have implications for domestic milk production and the sustainability of crop production (for example through their effects on manure availability from the dairy herd), and consequently incomes and the livelihoods of smallholder families.

The Kenya government, in common with others in developing countries, and international development agencies, support the role that dairying plays in the intensification of smallholder agriculture with its benefits of reducing hunger, poverty and environmental degradation among the rural poor (ILRI, 1999; Omore *et al.,* 1999). Governments and development agencies see intensification as a strategy to attain self-sufficiency in dairy to meet the expected demand increases fuelled by rapid changes in human population growth, urbanisation and expected economic progress. A key issue motivating this study is the concern about the constraints to and the prospects for sustaining the benefits of dairying for smallholders when human population pressure results in farms continuously shrinking, soil fertility getting poorer and when new policies lean towards the withdrawal of public participation in the delivery of livestock input services and output markets. These pressures faced by smallholders in the highlands of Kenya are spilling over into other farming systems (in which the production potential is often less favourable) in response to the relentless demographic and economic changes. Against that background, the need is clear for the analysis of the dynamics of intensification of smallholder dairying in order to gain insights into the aggregate effects of these pressures on smallholder farming and the responses of farmers to those pressures. This understanding is critical if we are to address the research and development needs of smallholder dairy farmers and for development agencies to be effective in their support to the continued intensification of smallholder agriculture through dairying.

1.4. Objective of the study

The objective of this study was to quantify the consequences of the intensification of farming systems on the dynamics of smallholder dairy herds in the Kenya highlands. The results of the study will contribute to improved understanding of the constraints to, and opportunities for, the continued intensification of smallholder dairying. The following research questions were thus addressed to achieve the objective of the study:

(i) What are the driving forces for intensification of smallholder dairy production systems in the Kenya highlands?

(ii) What is the impact of the intensification strategies of smallholders on their ability to produce their own replacement animals required to maintain and expand the existing dairy herd in smallholder systems?

(iii) What is the rationale underlying the breed preferences and breeding practices of smallholder dairy farmers when they intensify their production systems?

(iv) What is the influence of smallholders' feeding practices on dairy production performances?

1.5. Outline of the thesis

Chapter two following the general introduction addresses the first research question. It is divided into three sections. The first section, based on a literature review, describes the historical development of smallholder dairy systems in the Kenya highlands. The second and third sections and the subsequent chapters were achieved through empirical approaches in which relevant data were collected through a mix of survey methodologies. Stratification by agro-ecology and market access was applied in selecting prospective sampling sites to allow for inclusion of diverse farming areas with long history of, and diverse potential for, dairy development in Kenya. Using existing maps of agro-ecological zones and road infrastructure together with expert knowledge, the sites were differentiated into regions of medium and high agro-ecological potential (for cropping and dairying), and low, medium and high market access. The three categories of market access were based on human population densities, local demand for milk, type of roads (tarmac, passable all weather, seasonally passable) and the availability of milk marketing institutions. Relevant farm data relating to one-year recall period and on-farm observations were obtained first in a stratified random cross-sectional survey of smallholder households. Thereafter, a random sub-sample of the cross-sectional survey was selected to obtain additional complementary information through a longitudinal survey and targeted follow-up semi-structured interviews. A checklist of information not captured in the cross-sectional survey guided these follow-up surveys.

The second section of chapter two examines intensification strategies used by smallholder farmers, based on the cross-sectional survey data in which varying intensification levels were represented. The last section of chapter two is a quantitative estimation of both tangible and intangible benefits of dairy production under varying intensification levels, from the longitudinal survey data. Based on the analysis of cross-sectional survey data complemented with additional information collected in the follow-up interviews, the dynamics of the cattle population under increasing intensification are presented in chapter three and the description of the rationale underlying smallholders' breeding decisions is presented in chapter four. Chapter five is an explorative study to quantify the influence of smallholders' feeding practices on production performances of dairy cattle under increasing intensification. In chapter six, empirical estimates obtained in the previous chapters were used as inputs in a deterministic model to estimate the potential for producing dairy replacements in numbers sufficient for maintaining current herd size and surplus for farmers aspiring to adopt semi-zero- or zero-grazing dairy production. Finally, chapter seven integrates the results in a general discussion of the constraints to, and opportunities for, the continued intensification of smallholder dairying in the Kenya highlands and draws broad lessons for intensification of smallholder dairying.

References

Amer, P.R., Mpofu, N., Bondoc, O., 1998. Definition of breeding objectives for sustainable production systems. Proc. 6th World Congr. Genet. Appl. Livest. Prod. 28, 97-103.

Bebe, B.O. Thorpe, W., Owango, M., Muriuki, H.G., 1999. Replacement heifer generation in smallholder dairy herds in Central Highlands of Kenya. In: Proc. Anim. Prod. Soc. Kenya Symposium, 10-12 March, 1999, Dairy Training Institute, Naivasha, Kenya. pp 3-9.

Conelly, W.T., 1998. Colonial Era Livestock Development Policy: Introduction of improved dairy cattle in high potential farming areas of Kenya. World Development. 26, 1733-1748.

CRF, 1999. Strategies to enhance coffee production in Kenya. Coffee Research Foundation (CRF) Technical Committee Report. Ruiru, Kenya. 109 pp.

De Jager, A., Karuiki, I., Matiri, F.M., Odendo, M., Wanyama, J.M., 1998. Monitoring nutrient flows and economic performance in African farming systems (NUTMON) IV. Linking nutrient balances and economic performance in three districts in Kenya. Agric. Ecosyt. Environ. 71, 81-92.

De Jager, A., Onduru, D., van Wijk, M.S., Vlaming, J., Gachini, G.N., 2001. Assessing sustainability of low-external input farm management systems with the nutrient monitoring approach: a case study in Kenya. Agric. Syst. 69, 99-118.

De Jong, R., 1996. Dairy stock development and milk production with smallholders. PhD Thesis, Department of Animal Production Systems, Wageningen Agricultural University, The Netherlands. 303 pp.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., Courbois, C., 2001. Livestock to 2020: the next food revolution. Outlook on Agric. 30, 27-29.

Freeman, H.A., Ehui, S.K., Jabbar, M.A., 1998. Credit constraints and smallholder dairy production in the East African highlands: application of a switching regression model. Agric. Econ. 19, 33-44.

Gitau, G.K., O'Callaghan, C.J., McDermott, J.J., Omore, A.O., Odima, P.A., Mulei, C.M., Kilungo, J.K., 1994. Description of smallholder farms in Kiambu District, Kenya. Prev. Vet. Med. 21, 155-166.

ILRI, 1999. Medium-term plan 2000-2002: Improving the productivity of smallholder livestock systems and protecting the natural resources that support them. International Livestock Research Institute (ILRI), Nairobi, Kenya. 50 pp.

Jabbar, A.M., Swallow, B.M., Rege, J.E.O., 1999. Incorporation of farmer knowledge and preferences in designing breeding and conservation strategy for domestic animals. Outlook on Agric. 28, 239-243.

Jaetzold, R., Schmidt, H., 1983. Farm management Handbook of Kenya Vol.II. Part B, Central Kenya. Ministry of Agriculture, Nairobi, Kenya. pp 510-620.

Kahi, A.K., Kosgey, I.S., Cardoso, L., Arendonk, J.A.M., 1998. Influence of production circumstances and economic evaluation criteria on economic comparison of breeds and breed crosses. J. Dairy Sci. 81, 2271-2279.

Muia, J.M.K., Tamminga, S., Mbugua, P.N., Kariuki, J.N., 2000. The nutritive value of napier grass (*Pennisetum purpureum*) and its potential for milk production with or without supplementation: A review. Trop. Sci. 40:109-131.

Nicholson, C., Tambi, E., Staal, S.J., Thorpe, W., 2001. Patterns of change in dairy production and consumption in developing countries from 1985 to 1998. Market-oriented Smallholder Dairy Research Working Document No. 17, ILRI, Nairobi, Kenya. 65 pp.

Ojango, J. M., 2000. Performance of Holstein-Friesian cattle in Kenya and the potential for genetic improvement using international breeding values. PhD Thesis, Wye College, University of London, U.K. 182 pp.

Omore, A., Muriuki, H., Kenyanjui, M., Owango, M., Staal, S., 1999. The Kenya Dairy Sub-Sector: A Rapid Appraisal. Smallholder Dairy (Research & Development) Project Report. 51 pp.

Rege, J.E.O., 1998. Utilization of exotic germplasm for milk production in the tropics Proc. 6th World Cong. on Genet. Appl. Livest. Prod. 25, 193-200.

Reynolds, L., Metz, T., Kiptarus, J., 1996. Smallholder dairy production in Kenya. World Anim. Rev. 87, 66-72.

Schelhaas, H., 1999. The dairy industry in a changing world. In: Falvey L. and Chantalakhana C. (Eds.), Smallholder dairying in the tropics. International Livestock Research Institute, Nairobi, Kenya. 462 pp.

Staal, S., Chege, L., Kenyanjui, M., Kimari, A., Lukuyu, B., Njubi, D., Owango, M., Tanner, J., Thorpe, W., Wambugu, M. 1998. Characterisation of dairy systems supplying the Nairobi milk market: a pilot survey in Kiambu District for the identification of target groups of producers. Smallholder Dairy (R&D) Project. KARI/MoA/ILRI Collaborative Dairy Research Programme, ILRI, Nairobi, Kenya. 85 pp.

Staal, S.J., Owango, M., Muruiki, H., Kenyanjui, M., Lukuyu, B., Njoroge, L., Njubi, D., Baltenweck, I., Musembi, F., Bwana, O., Muruiki, K., Gichungu, G., Omore A., Thorpe, W., 2001. Dairy Systems Characterisation of Greater Nairobi Milk Shed. SDP (Smallholder Dairy (R&D) Project) Research Report, Ministry of Agriculture, Kenya Agricultural Research Institute and International Livestock Research Institute, Nairobi, Kenya. 73 pp.

Stotz, D., 1979. Smallholder dairy development in past, present and future in Kenya. PhD Thesis, Hohenheim University, Germany. 169 pp.

Tulachan, M.P., Partap, T., Maki-Hokkonen, J., Saleem, M., Rajbhandari, B., 2000. Livestock in the mountains and highlands of Asia, Africa and South America: an overview of research and development issues and challenges. In: Tulachan, P.M., Saleem, M.A.A., Maki-Hokkonen, J., Partap, T. (Eds), Contribution of livestock to mountain livelihoods: research and development issues, International Centre for Integrated Mountain Development (ICIMODD), Systemwide Livestock Programme (SLP), Food and Agriculture Organization (FAO), International Potato Centre (CIP). pp 3-31.

Wakhungu, W.J., 2000. Dairy cattle breeding policy for Kenyan smallholders: An evaluation based on demographic stationary state productivity model. PhD

Thesis, College of Agriculture and Veterinary Sciences, University of Nairobi, Kenya. 164 pp.

Zemmelink, G., Romney, D.L., Kaitho, R.J., 1999. Dairy farming in Kenya: Resources and nitrogen flows. In: Outcome and Perspective of Collaborative Research, 11th International Symposium on Tropical Animal Health and Production. Utrecht University, Faculty of Veterinary Medicine,The Netherlands, 5th November 1999. pp 46-50.

CHAPTER TWO

Development of smallholder dairy systems in the Kenya highlands

B. O. Bebe[a,b,c], H.M.J. Udo[b], W. Thorpe[c]

[a]Animal Science Department, Egerton University, Box 536 Njoro, Kenya

[b]Animal Production Systems Group, Wageningen Institute of Animal Sciences, Wageningen University and Research Centre, P.O. Box 338, 6700 AH Wageningen, The Netherlands

[c]International Livestock Research Institute, P.O. Box 30709, GPO Nairobi 00100, Kenya

This chapter is published in Outlook on Agriculture, 31:113-120 (2002)

Development of smallholder dairy systems in the Kenya highlands

Abstract

Kenya is recognised among developing countries for its success in integrating dairy into smallholder farming systems, particularly in the highland areas. The major determinants of this success were colonial history, its favourable agro-ecology and supportive agricultural policies and the importance of milk in rural and urban diets. In response to agricultural policies, market opportunities and human population pressure on land, smallholders have changed their farming systems by introducing the Friesian and Ayrshire breeds, keeping smaller herds with fewer heifers but more cows, increasing stocking rates through stall-feeding, growing fodder, purchasing of feeds and becoming more dependent on external inputs and services. As a result, they can sell more milk. This increasing intensification, here defined as the use of external inputs and services to increase the output quantity and/or value per unit input, has ensured that more people are maintained per unit of land through increased returns per ha of family land. Because the level of intensification varies with agro-ecological potential for cropping and dairying and with the level of milk market access and household resources, recommendations for production practises supporting intensification will be site-specific. Identifying appropriate recommendations will require a thorough understanding of farmers' objectives for keeping cattle.

Keywords*: Smallholder dairying; Intensification; Kenya highlands*

1. Introduction

Smallholder dairying is an important avenue for rural development in developing countries through its contributions to increases in livestock and farm productivity, income generation from milk and dairy product sales, the provision of jobs and the transfer of money from urban to peri-urban and rural areas. Farming households integrate dairy with crop enterprises to maximise the returns from limited land and capital with dairy production a means to achieve multiple objectives: improve food security, support crop production, build capital assets and generate cash income (Paris, 2002).

Sustainable dairy development requires a good infrastructure and effective support services and institutions. Kenya, among developing countries, has a dairy sub-sector, which is a prime example of the integration of dairy into smallholder farming systems. Smallholders own 80% of the total dairy cattle population and account for over 70% of the total milk production and of domestic marketed milk (Omore *et al.,* 1999). Most smallholder dairy farms are in the highlands, ≥1000 m above sea level. Compared to the lowlands, the highlands of Kenya have a more favourable agro-ecology for dairy and crop production and better market opportunities because of the high population density of people with a tradition for consuming milk. Nevertheless, human population growth rates of 3% annually and inter-generation inheritance of land have resulted in farm sizes being reduced (and which will continue to reduce) through subdivision and fragmentation (CBS, 2000). These land use changes will require policy and institutional support if smallholder farming systems are to sustain dairy production, demand for which is expected to grow strongly in the region in response to continuing population growth, urbanisation and increased purchasing power (Delgado *et al.,* 2001). Intensification, defined in this paper as the increased use of external inputs and services to increase the output quantity and/or value per unit input, has underpinned the successful adoption of dairy by smallholders in Kenya. Although this production strategy has resulted in large social benefits, continuing rapid demographic changes and the related policy and institutional changes may threaten dairy's contribution to smallholder agricultural development. In order to address those challenges it is necessary to understand the constraints to, and opportunities for, the continued intensification of smallholder agriculture through dairying. As a step towards that improved understanding, this paper describes the historical development of smallholder dairy systems (SMD) in Kenya and, using recent characterisation studies, analyses the intensification strategies used by smallholder dairy farmers in the Kenya highlands.

2. Smallholder dairy production in pre-independence Kenya

Important determinants of SMD in pre-independence Kenya included the presence of European settlers, favourable agro-ecological conditions, the importance of milk as part of smallholders' diet and agricultural reforms by the colonial administration.

2.1. European settlers

Before the arrival of the colonial settler farmers, the local cattle population consisted of East African Zebu (EAZ). As documented by Stotz (1979), gradual upgrading of the EAZ cattle to combine adaptability to local conditions and higher milk yields began in early 1890s when the settlers introduced Bos taurus dairy breeds from South Africa and Europe. The settlers used the upgraded cattle population to initiate marketed dairy production on specialised large-scale farms. In developing marketed dairy production, the settlers established supportive input services and output market organisations. These included: the Veterinary Research Laboratories in 1910; the Kenya Co-operative Creameries (KCC) in 1925; the Animal Husbandry Research Station in 1935; the Central Artificial Insemination Station (CAIS) in 1946; and in 1958 the Kenya Dairy Board (KDB) to regulate dairy marketing. The presence of these input service and output market organisations and the settler dairy herds provided the basis for the subsequent development of SMD.

2.2. Favourable agro-ecological conditions

Dairy farming by the settlers was mainly in the agriculturally productive highland areas that suited the keeping of *Bos taurus* dairy cattle. Factors favouring *Bos taurus* cattle included temperatures (15-24 ^{0}C) moderated by the high altitude, lower risk of diseases relative to the lowlands and the bimodal rainfall pattern which supports high biomass production for forage-based dairy production. The soils, predominantly nitosols, suited the growing of tea, coffee, wheat and pyrethrum as cash crops, and maize, now the predominant staple food crop. Clearing of the tropical forests that covered the highlands opened up large plantation farms for the growing of these crops.

2.3. Milk as part of smallholders' diet

The pioneer smallholder dairy farmers were those who provided the labour force in the settlers' farms, which during pre-independence had the monopoly of producing marketed milk (Conelly, 1998). The pioneers initially bought cull cows from their employers. Subsistence needs were the drive to own dairy cattle because milk was, and still is, an important part of the diet for the smallholder communities who by tradition are cattle keepers. Milk marketing by smallholders gradually increased in response to the expansion of the local market formed by immigrants into the highlands for salaried jobs.

2.4. Agricultural reforms in pre-independence Kenya

A marked turning point in the development of SMD came in 1954 when the colonial administration implemented the Swynnerton Agricultural Reforms, opening the way for marketed dairy production by smallholders (Jahnke, 1982). The reforms introduced the consolidation of farmers' fragmented pieces of land into one piece under individual ownership with a title deed, securing land tenure for indigenous farmers. Consequently, they could invest in land, establish fodder and use their title deed as collateral for credit. Growing of cash crops (coffee, tea and pyrethrum) for sale to the export market provided farmers with earnings to finance the purchase of dairy cows. Feeder roads, improved as part of the reforms, enhanced accessibility to milk collection centres serving KCC and the distribution of AI (Artificial Insemination) services to smallholders. Consequently, this enhanced the participation of smallholders in marketed milk production.

Agricultural reforms gave smallholders access to subsidised veterinary services, communal cattle dips for tick control, AI services for upgrading of EAZ cattle and credits for investments in dairy. The reforms promoted co-operatives for smallholders as focal points to provide milk collection and marketing and input services. In the highland areas where human population densities were rapidly rising, the government extension services recommended the use of Guernsey and Jersey cattle breeds and their crossbreeds (Conelly, 1998).

3. Smallholder dairy production in post-independence Kenya

Following Kenya's independence in 1963, development policies strongly supported the subdivision and selling of former large-scale farms in the highlands to smallholder farmers. This resulted in the rapid expansion of smallholder farms, in which the integration of crop and dairy production gained in importance. The expansion of SMD attracted government interventions, which included dairy breeding programmes, reforms in marketing and service delivery and assistance from donor countries.

3.1. The integration of dairy into crop farming

Table 1 summarises changes in the cattle population between 1960 and 1998, which show the rapid increase in the population as a whole, and particularly on smallholder farms, and the rapid decline in the proportion of dairy cattle on large-scale farms. These were responses to the changes in land tenure systems and the strong government support for smallholders after independence. The government transferred land and dairy cattle at subsidised prices to smallholders from settlers who opted to leave the country (Stotz, 1979). At the same time, government continued to provide smallholders with subsidised agricultural credits, of which 70% obtained by smallholders in the 1970s directly financed dairy development (Jahnke, 1982), showing the importance smallholders gave to dairy production. Consequently, dairy production in the highlands rapidly shifted from specialised large-scale to smallholder farms (2 to 10 ha) in which dairy became an integral part of farming systems having coffee or tea as the main cash crops and maize, potatoes, beans and vegetables as the main subsistence crops.

The integration of crops and dairy supported by a market infrastructure provided and continues to provide smallholder farmers with an opportunity to reduce the risks inherent in production from a single crop or livestock enterprise, a strategy crucial to food security and poverty alleviation. Crop-dairy integration is considered one of the most benign systems from the environmental perspective, because the system is at least partially closed: crop production provides crop residues fed to cattle, which return manure as fertilizer for maintaining soil structure and fertility and crop production (Blackburn, 1998).

Table 1. Cattle population changes in Kenya from 1960 to 1998

Year	Cattle population (million)		Proportion (%) of dairy cattle in:	
	East African Zebu	Dairy	Large-scale farms	Smallholder farms
1960	6.9	0.4	88	12
1970	8.2	0.8	37	63
1980	9.7	1.3	35	65
1990	10.1	2.9	25	75
1998	10.3	3.1	23	77

Sources: Stotz, 1979; MoA, 1998

3.2. Dairy breeding programmes

To facilitate the sourcing of breeding stock by smallholders, the government established dairy multiplication farms to produce heifers (Stotz, 1979). Smallholders bought the heifers at subsidised prices, but the government could not sustain this because production costs were high. Consequently, the government subdivided many of those farms for settling smallholder farmers.

As a means of supporting the expansion of the smallholder dairy herd, in 1966 the government established the Kenya National Artificial Insemination Service (KNAIS) to widen the distribution of AI semen to farmers (CAIS, 2000). KNAIS has a complementary role to CAIS, whose responsibilities include bull recruitment and semen production. From late 1980s, however, the decline in funding from the government has threatened the sustainability of these organisations. Because of this, these organisations are presently in the process of commercialising their goods and services, yet the transition still requires substantial government support because the efficiency of the private market is contingent upon the ability of the state to provide public goods, particularly infrastructure (e.g. roads) and institutional support.

Dairy breeding in Kenya, as for most developing countries, relies heavily on imported genetic material. Of the 354 recorded grandsires and sires used between 1986 and 1997 in both large-scale and smallholder farms in Kenya, only 29% were from local populations; the remainder were imported, mainly from the USA, UK, Canada and The Netherlands (Ojango, 2000). Dependency on imported germplasm from temperate countries may affect the adaptive trends among the local population. Ojango (2000) showed that genetic x environment interactions were important (genetic correlations of 0.49 to 0.58 between populations in Kenya and the exporting countries), indicating that when importing germplasm there is need to give due considerations to local production conditions.

3.3. Reforms in marketing and service delivery

Marketing reforms in the dairy sub-sector targeted at smallholder farmers began in 1971 when the government abolished the contract and quota systems of KCC (then the national marketing organisation), because it had effectively excluded smallholders from selling milk to KCC. A further major policy change came in 1992 when milk marketing was liberalised, following the recommendations of the Dairy Master Plan (Danida, 1991). The policy change ended the monopoly in milk marketing to urban centres hitherto enjoyed by KCC, and decontrolled producer and consumer prices. In the Kenya highlands the benefits of liberalisation have included an increased diversity of market outlets, higher prices to producers and lower prices to consumers (Owango *et al.,* 1998) and employment opportunities in small-scale milk trading (Table 2) (Omore *et al.,* 2001). The delivery of subsidised public livestock services to smallholders were effective until the late 1980s and early 1990s when their quality began to decline due to budgetary constraints. Consequently, the government effected policy changes to enhance private sector participation in the delivery of livestock health and breeding services to smallholders, recognising them as private goods that could not be funded by tax revenue (MoA, 1998). Presently, for instance, the private sector and farmer co-operatives provide 85% of inseminations whereas in 1980s, before fiscal constraints, the government provided 97% of the services (CAIS, 2000).

Table 2. Number of jobs created per every 100 litres of milk traded by small-scale dairy marketing and processing in Kenya

Jobs created	Enterprise type		
	Mobile milk trader	Milk bar	Small processor
Directly	1.7	1.1	0.2
Indirectly	0.3	0.3	0.1
Total	2.0	1.4	0.3

Source: Omore *et al.*, 2001

3.4. Assistance from donors

The post-independence Kenya government sought the assistance of donor countries to complement her efforts in enhancing the development of SMD, particularly in the highlands. The goal was to improve the living standards of rural households through increased milk production for home consumption and for generating cash income. UNICEF, FAO and the Danish government assisted in developing market infrastructure and processing capacity for KCC, the Finnish government assisted in rural milk marketing and the Dutch government assisted in developing and disseminating zero-grazing (stall feeding) technologies to improve farm productivity in the land-scarce farming areas (De Jong, 1996).

Zero-grazing technologies have marked complementarities in resource use: manure from dairy cattle is used to maintain yields of napier grass and other crops, which in turn are offered to cattle as the main feeds. According to De Jong (1996), about 85% of the 6400 farmers in Kenya targeted between 1980 and 1992 adopted zero-grazing technologies within the first two years. Milk yields per lactation increased five times and milk production per hectare of land planted with forage rose by a factor of 40. Individual households had more milk for home consumption and a marketable surplus for cash income, resulting in improved food security and increased income. Zero-grazing technologies constitute an important strategy through which smallholders in the highlands intensify their farming systems particularly as farm sizes decrease.

4. Current smallholder dairy production

Smallholder farms, in which crops and dairy are integrated, produce 1.5 to 2 million MT of milk annually in Kenya. In 1997, they produced an estimated 1.73 MT of milk, of which the producer households and calves consumed about a third (Omore *et al.,* 1999). The other two thirds were marketed, of which 37% went directly to consumers, 19% through smallholder co-operative societies, Self Help Groups and individual milk traders and 8% through processors. The factors driving raw milk marketing are traditional preferences for fresh raw milk (which is boiled before consumption), the predominance of low-income consumers unwilling to pay the extra costs of pasteurisation and packaging. Other driving factors include the difficulty of accessing distant urban markets because of poorly developed road networks and inadequate facilities for collection and cooling in some production areas (De Leeuw *et al.,* 1999). Despite high transactions costs arising from the low economies of scale in raw milk marketing, it is expected to remain the major outlet for smallholders because substantial improvements in the road and collection infrastructure are unlikely in the near future. Consequently, in Kenya as elsewhere in the tropics, marketed dairy production by smallholders tends to be concentrated in areas with good market infrastructure and close to urban consumption centres. These facilitate access to external inputs and services, reduce transaction costs and support further intensification in SMD.

Kenya is one of the few countries in the sub-Saharan Africa where per capita milk availability is increasing. Between 1985 and 1998, availability increased from 83 to 85 kg, 10% of which could be attributed to increases in the cattle population, 18% to increased cow productivity and 61% to a higher proportion of milking cows (Nicholson *et al.,* 2001). The increases in total dairy output were sufficient to more than match the 3% annual increase in human population in the same period. However, demand is expected to be at least 15% higher than the production by the year 2010 due to the rising human population, urbanisation and higher incomes accompanied with changes in consumer preferences (Omore *et al.,* 1999). If these projected shortfalls in the supply of marketed milk are to be avoided, increases in total dairy output will be required through continued adoption of dairy production by smallholders and the intensification of smallholder crop-dairy systems.

5. Intensification strategies in the Kenya highlands

Recent characterisation studies of smallholder farming systems in the Kenya highlands provide some insights into intensification strategies. The Smallholder Dairy Project (SDP) initiated to contribute to the sustainable development of smallholder dairying and led by Kenya's Ministry of Agriculture and Rural Development, carried out the studies. Households were sampled within sites selected to reflect variation for agro-ecological potential (for cropping and dairying) and milk market access as the two main determinants of dairy system development (Staal *et al.,* 2001). The studies involved cross-sectional and longitudinal (15 month) surveys in areas of smallholder farming with dairy in which varying levels of intensification were represented. The low, medium and high intensive systems were respectively characterised by high agricultural potential-low population density-low market access, medium agricultural potential-medium population density-medium market access and high agricultural potential-high population density-high market access.

5.1. Changes in farm size, stocking rate and feeding practices

Table 3 gives the human population density and the mean farm sizes and stocking rates in three farming systems with contrasting levels of intensification. As human population density increases, less land is used for grazing and stocking rates increase. Figure 1 shows changes over the last ten years in grazing management of the three farming systems. The trend is towards intensified feeding systems through the adoption of semi-zero-grazing or zero-grazing as farm size decreases.

Table 3. Average human population density, farm size and stocking rate in the smallholder farming areas in the Kenya highlands

Farming system	Number of farms	Population (persons km2)[p]	Farm size (ha)		Stocking rate (TLU ha-1)[k]	
			Mean	SD	Mean	SD
Low intensive	96	206[b]	5.4[a]	8.1	1.2[b]	1.7
Medium intensive	230	288[b]	2.0[b]	2.0	1.7[b]	1.9
High intensive	261	583[a]	1.1[c]	1.0	2.6[a]	3.0

[p]C.B.S, 2000
[k]TLU= 1 for bull, 0.7 for cow, 0.5 for post weaned cattle, 0.2 for pre-weaned cattle
Means with different letter superscripts in a column are significantly different ($p<0.05$)

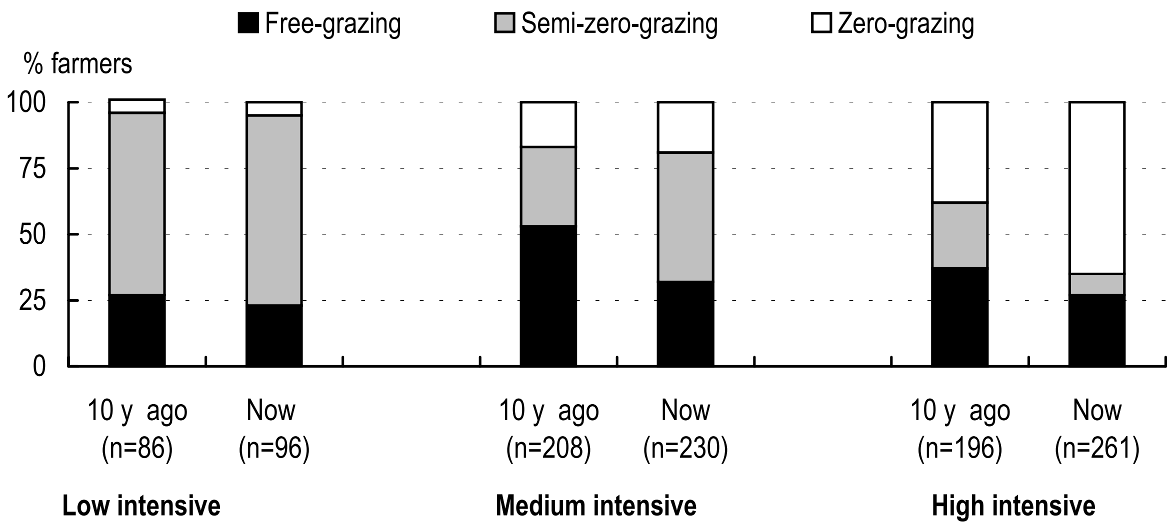

Figure 1. Main grazing systems practised ten years before the survey (10 y ago) and at the time of the survey (now) in smallholder farms in the Kenya highlands

5.2. Changes in farm and animal productivity

Farmers practising more intensive-systems attach higher importance to genetic improvement of their cattle. They achieve higher milk productivity per unit land and per cow by using planted fodder (mainly napier grass) supplemented with purchased fodder and concentrates, and the contribution of fodder from the maize crop become more important (Table 4). When asked about the constraints to increasing the current levels of milk yields in their herds, smallholders ranked (in order) lack of feed as the most important followed by lack of labour, poor animal performance and lack of cash to purchase inputs. These constraints are associated with smallholder dairy cattle showing late maturity, high animal mortality rates, infertility and poor lifetime production, relative to performances observed on large commercial farms in the Kenya highlands.

Table 4. Availability of feeds produced on the farm (own) and purchased feeds, cow productivity and stated strategies to increasing milk production in smallholder farms in the Kenya highlands

Variables	Low intensive systems (n=96)		Medium intensive systems (n=230)		High intensive systems (n=261)	
	Mean	SD	Mean	SD	Mean	SD
Own produced feed ($ha \cdot TLU^{-1}$)[k]						
Maize planted	0.17[b]	0.23	0.30[a]	0.32	0.14[b]	0.25
Napier planted	0.03[b]	0.08	0.04[b]	0.10	0.15[a]	0.19
Purchased feed ($Ksh \cdot TLU^{-1}$)[k]						
Fodder	354[b]	961	306[b]	877	1282[a]	2872
Concentrate	1243[b]	2535	831[b]	3003	5545[a]	6471
Milk production						
$L \cdot ha \cdot day^{-1}$	0.65[b]	1.14	0.79[b]	1.03	1.58[a]	2.61
$L \cdot cow \cdot day^{-1}$	5.1[b]	2.9	4.8[b]	2.9	7.2[a]	3.7
Strategy to increasing milk production (%)						
Keep more cows	47		14		14	
Upgrading	8		40		47	
Produce more feeds	38		29		24	
Others[d]	9		17		15	

Data source: Staal *et al.*, 2001.

[k]TLU= 1 for bull, 0.7 for cow, 0.5 for post weaned cattle, 0.2 for pre-weaned cattle

[d] Others =Seek extension advice, buy more feeds, improve disease control

Means with different letter superscripts in a row are significantly different ($p<0.05$)

5.3. Changes in herd size and structure and cattle breeds

Table 5 gives the herd sizes and structures and the breeds in the three farming systems. As farmers intensify their systems, they keep smaller herds with a lower proportion of heifers. This allows farmers to use more of the scarce planted-fodder and the purchased feeds for cows, the most productive class. However, because of high reproductive wastage, a reliable external source of replacement animals is required to maintain individual herds.

Contemporaneously to changes in feeding practises, smallholders replace their zebu cattle with *Bos taurus* dairy cattle breeds, mostly Friesian and Ayrshire, as a means for increasing productivity per unit of land and per animal. The large number of Friesian and Ayrshire cattle breeds in the low intensive systems, which are in high agricultural potential areas, reflects the historical presence of settler dairy farmers, whose cattle were distributed when their farms were subdivided for smallholder farmers.

Table 5. Average herd size, herd structure and dominant cattle breeds in smallholder farms in the central Kenya highlands

Variables	Farming system		
	Low intensive (n=96)	Medium intensive (n=230)	High intensive (n=261)
Herd size (TLU)[k]			
Mean	3.2[a]	2.6[a]	1.8[b]
Standard deviation	2.7	3.2	1.1
Proportion of herd composed of:			
Cows	0.57	0.61	0.60
Heifers	0.28[a]	0.20[b]	0.20[b]
Heifer-calves	0.02	0.03	0.04
Male-calves	0.02	0.02	0.02
Immature bulls	0.06	0.10	0.09
Bulls	0.05	0.04	0.05
Dominant cattle breed (% farms)			
Friesian	69	46	51
Ayrshire	26	23	23
Guernsey and Jersey	4	12	16
Sahiwal and Boran	1	12	7
East African Zebu	0	7	3

Data source: Staal *et al.,* 2001.
[k]TLU= 1 for bull, 0.7 for cow, 0.5 for post weaned cattle, 0.2 for pre-weaned cattle
Means with different letter superscripts in a row are significantly different ($p<0.05$)

5.4. Benefits from dairy production

Dairy production in smallholder systems provides multiple benefits through marketed and non-marketed outputs, with important socio-economic functions. Table 6 is a summary of the estimated average annual costs and benefits of dairy production based on farm-gate prices and opportunity costs from the SDP longitudinal survey. A partial measure of the benefits obtained in dairy production is the net recurrent cash income, defined as cash income less purchased inputs. This cash flow is critical for the household: it contributes to paying for school fees, medical treatment and purchasing household goods and farm inputs. The estimated annual average cash flow from dairy production ranges from 360 to 573 US$, and is complemented by similar amounts of 473 to 592 US$ in kind due to the substantial home consumption of milk and the other multiple benefits of dairying.

Table 6. Estimated annual average costs and benefits (US \$ y^{-1})[a] of dairy production per household for smallholder farms in the Kenya highlands

Economic variables	Farming system		
	Low intensive (n=11)	Medium intensive (n=11)	High intensive (n=21)
Production output			
cash from milk sales	532	811	538
cash from cattle sales	127	77	164
Total cash income	**659**	**888**	**702**
Net recurrent cash income	**473**	**573**	**360**
Income in kind (non-marketed)			
milk	372	333	227
manure	87	97	49
change in stock value	104	162	197
Total income in kind	**563**	**592**	**473**
Benefits			
value-added	1036	1165	833
insurance	40	64	36
financing	15	9	20
Total benefits	**1091**	**1238**	**889**
Production costs			
purchased feeds	62	188	217
purchased veterinary and AI services	24	76	41
hired labour	100	51	84
Total purchased inputs	**186**	**315**	**342**
Household resources			
capital in stock	759	1147	705
family labour	148	229	193
farm size (ha)	3.1	3.4	1.5

[a]1 US \$=Ksh 70
Data source: Staal *et al.*, 2001.

As a proportion of total milk produced, the value of milk consumed at home decreases from 0.41 to 0.3 as farmers intensify their dairying. Manure, a major component of incomes-in-kind, has an estimated value (per kg dry matter) equivalent to 28% the price of one litre of milk (Lekasi *et al.,* 1998) and is important for continued intensification through its contribution to the maintenance of soil fertility and supporting crop production.

The sum of net recurrent cash income and income-in-kind gives the value-added, which is a measure of the total returns for the utilisation of the household's production factors of land, labour and capital. The annual returns to land, a major constraining resource, increase from 334.2 US$/ha in the less intensive to 555.3 US$/ha in the more intensive systems, demonstrating that intensification is a means of supporting a growing number of people on shrinking land holdings.

The sum of net recurrent cash income and income-in-kind gives the value-added, which is a measure of the total returns for the utilization of the household's production factors including land, labour and capital. The annual returns to land, a major constraining resource, increase from 334.2 US$/ha in the less intensive to 555.3 US$/ha in the more intensive systems, demonstrating that intensification is a means of supporting a growing number of people on shrinking land holdings. For smallholder dairy producers, value-added does not reflect the total value of production obtained and resources used because the cattle also contribute through their insurance and financing functions (Moll *et al.,* 2001).

Insurance benefit from keeping cattle is related to the capital invested in the herd as a guarantee for meeting unexpected expenditures, for instance, medical bill. Taking the example of a medical insurance policy, for a benefit cover of Ksh 200,000, one pays an annual of Ksh 12,000, implying a 6% annual premium. This premium value times the average value of a herd during the year represents the estimate of the insurance benefits of cattle for dairy households without formal medical insurance. Financing benefits accrue from the disposal of animals as and when required to enable households to meet lumpy cash needs. The majority of Kenyans in formal employment have income savings for lumpy cash needs with co-operative savings and credit societies for which interest on loans is 12% a year. This value times the average value of animals sold during one year is an estimate of the financing benefits. In addition, therefore, to the returns from milk and manure, the benefits from the insurance and financing functions increases the value of keeping cattle by 5 to 7%, which is important to households without access to, or confidence in, formal financial institutions.

6. Conclusion

Through adopting dairying, smallholder farmers in the Kenya highlands have intensified their farming systems to sustain their livelihoods in response to declining farm sizes. Intensification requires more investment by farmers in external inputs and services, the efficient delivery of these inputs and services by market agents and the provision of an improved infrastructure by government. Because the level of intensification varies with agro-ecological potential for cropping and dairying and with the level of milk market access and household resources, recommendations for production practises supporting intensification will be site-specific. Identifying appropriate recommendations will require a thorough understanding of farmers' objectives for keeping cattle.

Acknowledgements

The first author was supported by a research grant from The Netherlands Foundation for the Advancement of Tropical Research-WOTRO. The authors acknowledge the support of the Smallholder Dairy (R&D) Project (SDP) of the Kenya Ministry of Agriculture and Rural Development, the Kenya Agricultural Research Institute (KARI) and the International Livestock Research Institute (ILRI) for this study. SDP was funded by the UK Department for International Development (DFID) for the benefit of developing countries.

References

Blackburn, H., 1998. Livestock production, the environment and mixed farming. In: Livestock-Environment, Wageningen, International Agricultural Centre, The Netherlands. pp 114-123.

CAIS, 2000. Elite sires for the year 2000 and beyond. Central Artificial Insemination Service Magazine, CAIS, Kabete, Nairobi, Kenya.

C.B.S, 2000. The 1999 population and housing census Volume I: Population distribution by administrative area and urban centres, Central Bureau of Statistics, Ministry of Finance and Planning, Nairobi, Kenya.

Conelly, W.T., 1998. Colonial Era Livestock Development Policy: introduction of improved dairy cattle in high potential farming areas of Kenya. World Development. 26, 1733-1748.

Danida, 1991. Kenya Dairy Master Plan Final Report: A study funded by Danida for the Ministry of Agriculture, Livestock Development and Marketing, Kenya Government, Nairobi, Kenya.

De Jong, R., 1996. Dairy stock development and milk production with smallholders. PhD Thesis, Department of Animal Production Systems, Wageningen Agricultural University, The Netherlands. 303 pp.

De Leeuw, P.N, Omore, A., Staal, S., Thorpe, W., 1999. Dairy production systems in the tropics, In Falvey, L., Chantalakhana, C. (Eds), Smallholder dairying in the tropics. International Livestock Research Institute, Nairobi, Kenya, 1999. pp 19-44.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, E., Courboi, C., 2001. Livestock to 2020: the next food revolution. Outlook on Agric. 30, 27-29.

Jahnke, E.H., 1982. Livestock Production Systems and Development in Tropical Africa, Kieler Wissenschaftsverlag Vauk, Kiel, Germany. pp165.

Lekasi, J.K., Tanner, J.C., Kimani, S.K., Harris, P.J.C., 1998. Manure management in the Kenya Highlands: practices and potential. Kenya Agricultural Research Institute, Nairobi, Kenya, pp 24.

MoA, 1998. Kenya Dairy Development Policy: Towards the development of a sustainable dairy industry*,* Ministry of Agriculture, Nairobi, Kenya.

Moll, H.A.J., Staal, S.J., Ibrahim, M.N.M., 2001. From meat to milk: smallholders livelihoods and markets. In: Dairy Development in the Tropics. 12th International Symposium on Tropical Animal Health and Production. Utrecht University, Faculty of Veterinary Medicine, The Netherlands, 2nd November 2001. pp 13-17.

Nicholson, C., Tambi, E., Staal, S. J., Thorpe, W., 2001. Patterns of change in dairy production and consumption in developing countries from 1985 to Market-oriented Smallholder Dairy Research Working Document No. 17, ILRI, Nairobi, Kenya.. 65 pp.

Ojango, J. M., 2000. Performance of Holstein-Friesian cattle in Kenya and the potential for genetic improvement using international breeding values. PhD Thesis, Wye College, University of London, U.K. 182 pp.

Omore, A., ChengóleMulindo, J., Fakhrul Islam, S.M., Nurah G., Khan, M.I., Staal, S.J., Dugdill, B.T., 2001. Employment generation through small-scale dairy marketing and processing: experiences from Kenya, Bangladesh and Ghana, Report for FAO Animal Production Division, Dairy Section (press).

Omore, A., Muriuki, H., Kenyanjui, M., Owango, M., Staal, S., 1999. The Kenyan dairy sub-sector: A rapid appraisal report by the MoA-KARI-ILRI. Smallholder Dairy (Research and Development) Project, International Livestock Research Institute, Nairobi. pp 50.

Owango, M., Lukuyu, B., Staal, S., Kenyanjui, M., Njumbi, D., Thorpe, W., 1998. Dairy co-operatives and policy reforms in Kenya: effects of livestock service and milk market liberalisation. Food Policy. 23, 173-185.

Paris, T.R., 2002. Crop-animal systems in Asia: socio-economic benefits and impacts on rural livelihoods. Agric. Syst. 71, 147-168.

Staal, S.J., Owango, M., Muruiki, H., Kenyanjui, M., Lukuyu, B., Njoroge, L., Njubi, D., Baltenweck, I., Musembi, F., Bwana, O., Muruiki, K., Gichungu, G., Omore A., Thorpe, W., 2001. Dairy Systems Characterisation of Greater Nairobi Milk Shed. SDP (Smallholder Dairy (R&D) Project) Research Report, Ministry of Agriculture, Kenya Agricultural Research Institute and International Livestock Research Institute, Nairobi, Kenya. 73 pp.

Stotz, D., 1979. Smallholder dairy development in past, present and future in Kenya. PhD Thesis, Hohenheim University, Germany. 169 pp.

CHAPTER THREE

Smallholder dairy systems in the Kenya highlands: cattle population dynamics under increasing intensification

B.O. Bebe[a,b,c], H.M.J. Udo[b], G.J. Rowlands[c], W. Thorpe[c]

[a]Animal Science Department, Egerton University, Box 536 Njoro, Kenya

[b]Animal Production Systems Group, Wageningen Institute of Animal Sciences, Wageningen University and Research Centre, P.O. Box 338, 6700 AH Wageningen, The Netherlands

[c]International Livestock Research Institute, P.O. Box 30709, GPO Nairobi 00100, Kenya

This chapter has been accepted for publication in Livestock Production Science

Smallholder dairy systems in the Kenya highlands: cattle population dynamics under increasing intensification

Abstract

A cross-sectional stratified random sample survey of 1755 households in the Kenya highlands was conducted between June 1996 and April 1998 to quantify cattle population dynamics in smallholder herds. The free-, semi-zero- and zero-grazing systems practised represented increasing levels of intensification of the farms. Additional data were collected in a follow-up survey of 50 households from the main survey sample. In the main survey there were 987 cattle-keeping households, of which 44, 33 and 23% practised zero-, semi-zero- and free-grazing systems, respectively. Compared to free-grazing, zero-grazing farms had a higher proportion of cows in the herd (0.62 vs 0.51) but lower calving rates (0.52 vs 0.69), higher losses of potential heifer replacements (0.47 vs 0.38), fewer heifer replacements as a proportion of cows disposed (0.46 vs 1.11) and shorter productive life (3.8 vs 4.8 years). Semi-zero-grazing farms had intermediate performance. They and the zero-grazing farms were unable to maintain their herds without acquiring replacements externally. Animal class mortality rates were high (7-19%) regardless of grazing system practised. Diseases accounted for the largest proportion of animal exits: 85% of heifer-calves, 38% of heifers and 36% of cows. According to farmers, East Coast fever and Anaplasmosis diseases assumed less importance with a shift from free-grazing to zero-grazing. A household's needs for cash was the second most frequent reason after disease for animal exits: 33% of heifers and 27% of cows, indicating the importance of cattle as liquid capital assets. The results showed that many zero-grazed herds required external sources of replacement animals to sustain their population. Solutions to this constraint will include technical and institutional innovations to serve small-scale farms that may result in greater complementarities and stratification in the dairy sub-sector.

Key words: *Smallholder dairying; Intensification; Herd dynamics; Kenya highlands*

1. Introduction

Human demographic growth and changes in economic conditions in developing countries are driving the need for increases in animal production (output) and animal productivity (output per unit input) (Delgado *et al.,* 2001). To increase animal output and productivity, agricultural policies advocate intensification of production, which requires external inputs and services (De Jong, 1996; Devendra, 2001; Bebe *et al.,* 2002). Intensification of ruminant production in developing countries is commonly through smallholder dairying, which is a response by rural and peri-urban households to market demand for milk. Smallholder dairying is the dominant dairy production system in much of sub-Saharan Africa and South Asia. It is generally characterised by the integration of crops and dairy production on holdings usually less than 5 ha, with one to five cattle or buffalo that play important multiple roles (Tulachan *et al.,* 2000; Devendra, 2001; Devendra and Thomas, 2001). Dairying contributes to food production, generates cash income, produces manure to support crop production and is a means to accumulate capital assets for emergency cash needs.

Kenya's dairy development, among developing countries, exemplifies this intensification through smallholder dairying (Bebe *et al.,* 2002). Zero-grazing (stall-feeding) is the common strategy of intensifying dairying. It is widespread in the Kenya highlands where landholdings are continuously declining due to intergenerational subdivision of farms driven by the rapid growth in human population (C.B.S., 2001). Studies of these systems in the Kenya highlands show that growth rates among calves and heifers are less than 0.25 kg day^{-1}, mortalities among cows, heifers and calves range from 10 to 30%, age at first calving is about 3 years and calving rate is about 0.60 (Omore, *et al.,* 1996; Lanyasunya *et al.,* 1999). These performances raise concerns about the maintenance of smallholder dairy herds both at individual and community levels. This has implications for the future structure of the dairy sub-sector and its productivity.

In the past, public-owned, large-scale dairy farms produced dairy replacements for smallholders at subsidised costs (Conelly, 1998). These sources are now very limited, because the majority of the large-scale farms have collapsed or have been subdivided for resettlement. In order to better understand the constraints and prospects for maintaining and expanding smallholder dairying, the objective of this study was to quantify cattle population dynamics in free-, semi-zero- and zero-grazing systems, representing increasing levels of intensification in smallholder farms in the Kenya highlands.

2. Materials and methods

2.1. Study area and herd management systems

The Kenya highlands comprise areas with elevations ≥1000 m above sea level, annual mean temperatures of 10 to 18 ^{0}C, a bimodal rainfall pattern with >800 mm annually and fertile soils with good potential for biomass production (Jaetzold and Schmidt, 1983). The highlands constitute the most important milk sheds (areas where milk is produced) supplying the Nairobi urban market. The dairy herds comprise Friesian, Ayrshire, Guernsey and Jersey breeds and their crosses with *Bos indicus* cattle (local zebu, Boran and Sahiwal). Grazing systems include free-, semi-zero- and zero-grazing, representing increasing levels of intensification. In the free-grazing systems, farmers graze cattle on private or public owned pastures during the day and keep them within the homestead at night. Zero-grazing is a cut-and-carry, stall-feeding system in which napier grass and crop residues are the main feeds. Concentrate supplementation is generally restricted to milking cows. Semi-zero-grazing is a combination of free-grazing and stall-feeding, depending on the seasonal availability of feeds and labour.

2.2. Survey methodology

A two-phase, cross-sectional characterization survey of 1755 smallholder households was conducted in nine districts within the major milk sheds of Kenya. The first phase was conducted in Kiambu district during June-July 1996 and the second phase during March-April 1998 in eight districts: Nairobi; Machakos; Kirinyanga; Maragua; Murang'a; Nakuru; Nyandarua and Narok. The sites selected within each district reflected variation, firstly for agro-ecological potential (medium and high) for cropping and dairying as defined by Jaetzold and Schmidt (1983), and secondly for milk market access (low, medium and high). Grouping districts according to human population densities, local demand for milk, type of roads (tarmac, passable all weather, seasonally passable) and the availability of milk marketing institutions defined the three categories of market access (Staal *et al.,* 2001). Five sub-locations (the smallest administrative unit within a district) were selected within each land-use system in a district by a stratified random sampling method. Two pairs of major landmarks (permanent features such as trading centres, schools and churches) in each of the selected sub-locations were randomly selected on a map, and transect lines were drawn between each pair. Sampling was then done as closely as possible following the marked transects. A trained enumerator interviewed each fifth household, first on the right and then on the left. A total of 365 households from 24 sub-locations in Kiambu district and 1390 households from 82 sub-locations in the other 8 districts were interviewed. The total sample size in a sub-location represented approximately 1% of the total number of households based on population census figures of 1989 (C.B.S., 1994).

2.3. Data collection

Data collection was through household interviews, conducted in the local language by trained enumerators using a pre-tested, structured questionnaire. Information obtained from each household was on farm size, grazing system and total number of animals by class: heifer-calves (pre-weaned females), heifers (post-weaned females until first calving), cows (after first calving), male-calves (pre-weaned), immature males (post-weaned to 3 years old) and bulls (after 3 years old). Information collected included age at first calving and parities and ages of cattle both present and sold or died over the past 12 months. The herd demographic data collected for each animal class included births, purchases, deaths and sales based on the respondents' recall of events over the past 12 months. Farmers ranked, in order of importance (1= low and 3= high), named diseases to indicate perceptions about the relative importance of these diseases in their herds.

A follow-up, cross-sectional survey, based on semi-structured interviews of 50 households randomly selected from a stratified sample of the main survey sample was carried out to obtain complementary information on the origins of cows and disposal patterns. Stratification was by level of intensification in dairying activities, available household resources and level of market access using a combined method of principal component and cluster analysis applied to the cross-sectional survey sample (Staal *et al.,* 2001). Information on sources of replacement animals in the main survey was collected on purchases over the past 12 months but ignored replacements originating from within the herd. Complementary information was thus obtained in the follow-up survey on the history of each cow present in the herd: whether born within the herd or purchased from other smallholders or larger-scale farmers. Additional information on cow disposals included parity and physiological status at disposal: lactating/pregnant or dry/open. The 50 respondents also stated the size of herd that they considered manageable within their available resources.

2.4. Definitions and calculation of herd demographic rates

Replacement was defined as entry of a female of breeding age into the breeding herd and disposal as exit of a female of breeding age from the herd. Disposal comprised animals that died or were sold over the past 12 months. Reasons for disposal were in eight categories: disease (death from disease); poisoning (death from acaricide poisoning, snake bite and bloat); injury (sale or death due to accidents); sale to meet household needs for cash; sale because of poor performance (low milk yield, slow growth or infertility); sale because of old age; slaughter for meat; and unspecified reasons (death and sale).

Annual demographic rates of calving, mortality, selling and buying were calculated for each grazing system. Calculating these rates from the population as at 12 months preceding the survey would have ignored the purchases and shifts in age classes during the year. Therefore, for each animal class, except for calves, the denominator was the population on the day of survey (which included purchased animals) plus half the number of withdrawals (deaths and sales) over the past 12 months. Rates describing events for calves were calculated with the total number born over the past 12 months as the denominator.

The number of heifer replacements reaching the breeding age as a proportion of the cows disposed (R) was estimated as:

$$R = [\,(F/C)*(1 - f_m - f_s)*(1 - h_{m1} - h_{s1})*(1 - h_{m2} - h_{s2})]/\,(c_m + c_s) \qquad (1)$$

where F is the number of heifer-calves born to C cows; f_m and f_s are their mortality and selling rates to weaning age, respectively; h_{m1} and h_{m2} are heifer mortality rates in the first year and in year two to breeding age, respectively; h_{s1} and h_{s2} are heifer selling rates in the first year and in year two to breeding age, respectively; and c_m and c_s are mortality and selling rates defining disposal rate of cows. The calculation of the rate R in equation 1 uses, in this case, a denominator C representing the number of cows 12 months previously.

2.5. Statistical analyses

The variables farm size, herd size, stocking rate, age at first calving and age at disposal had skewed distributions, hence they were log transformed for least square analyses using the general linear model:

$$Y_{ijk} = \mu + M_i + G_j + (M \times G)_{ij} + e_{ijk} \quad (2)$$

where Y_{ijk} is the log-transformed value of the relevant variable, M_i (i=1, 2, 3) is the effect of market access, G_j (j=1,2,3) is the effect of grazing system, $(M \times G)_{ij}$ is the market access x grazing system interaction and e_{ijk} is the residual error term for household k within $(M \times G)_{ij}$. This model, without the interaction term, was also fitted to logits of the proportions (r_{ij} / n_{rj}) of births, deaths, sales and purchases in two-way tables (market access by grazing system) to estimate the annual demographic rates for each grazing system adjusted for market access. Because of evidence of over-dispersion in these models, influences of fixed effects on demographic rates were tested using an F-test based on the ratio of deviance values (Collett, 1991).

Correlations between farm size, herd size, stocking rate and proportions of animals sold within each grazing system (ignoring the market access) were determined using the Spearman rank correlation method. The statistical differences between pairs of grazing systems for the relative ranking of diseases of importance was determined using the Mann-Whitney rank sum test.

3. Results

3.1. Characteristics of dairy production system

More than three-quarters (1355) of the stratified random sample of 1755 households were engaged in agricultural activities, with 73% (987) practising integrated crop-dairy production. Of the 987 crop-dairy households, 44, 33 and 23% practised zero-, semi-zero- and free-grazing systems, respectively. Most of the crop-dairy farmers (71%) kept 1 to 3 cattle. This is consistent with a preference for a herd size of not more than three cattle stated by 68% of the 50 households in the follow-up survey.

The analysis in Tables 1, 2 and 3 focuses on herd dynamics under the influence of intensification, and consequently results for the effect of market access included in the model are not reported. The average farm size, herd size, number of cows and stocking rate was 1.7 ha, 3.2 cattle, 1.7 cows and 1.2 TLU·ha^{-1}, respectively, (Table 1). Farm size, herd size and number of cows owned decreased but the proportion of cows in the herd increased with an increase in intensification level, represented by free-, semi-zero- and zero-grazing systems, in that order (P<0.01).

Table 1. Antilogarithms of least square means (with 95% confidence intervals) for farm size, herd size, number of cows and stocking rate for free-, semi-zero- and zero-grazing systems in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Grazing system	Farms (n)	Farm size (ha)	Herd size (n)	Cows (n)	Stocking rate ($TLU \cdot ha^{-1}$)*
Free-grazing	227	2.4 [a] (2.0, 2.6)	4.3 [a] (3.9, 4.7)	2.2 [a] (2.0, 2.3)	1.1 [b] (0.9, 1.2)
Semi-zero-grazing	326	1.8 [b] (1.6, 2.0)	3.1 [b] (2.8, 3.4)	1.7 [b] (1.6, 1.8)	1.0 [b] (0.9, 1.1)
Zero-grazing	434	0.9 [c] (0.7, 1.2)	2.1 [c] (1.7, 2.6)	1.3 [c] (1.1, 1.6)	1.4 [a] (1.1, 1.8)
Total	987	1.7	3.2	1.7	1.2

* TLU=1 for bull; 0.7 for cow; 0.5 for heifer and young bull; 0.2 for calves
Estimates with different letter superscripts are significantly different at P<0.05

The proportion of cows in the herd averaged 0.51 (2.2/4.3) in free-grazing, 0.55 (1.7/3.1) in semi-zero-grazing and 0.62 (1.3/2.1) in zero-grazing farms (Table 1). However, stocking rate was 27% higher in zero-grazing than in free-grazing farms (P<0.01), corroborating correlation analyses showing that small farms kept smaller herds (r=0.34 to 0.58; P<0.001), but with higher stocking rates (r= -0.60 to –0.74; P<0.001).

Table 2 displays the estimated annual calving rates, ages at first calving, ages and parities of cows kept and ages of cows sold for the three grazing systems in the main cross-sectional survey. On average, annual calving rate was 0.58 and age at first calving 2.7 years. Calving rate was higher in free-grazing farms (0.69) than in semi-zero-grazing (0.51) and zero-grazing farms (0.52), whereas age at first calving was earlier in zero-grazing (2.5 years) than in semi-zero-grazing (2.7 years) and free-grazing farms (2.8 years) (P<0.05). Cows were on average 5.7 years old with 2.5 parities and were sold when 6.2 years old. Parities and ages of cows kept and sold indicated that cows kept were on average generally younger as farmers intensified their dairying, as represented by free-, semi-zero- and zero-grazing farms, in that order.

Table 2. Estimates of average annual calving rates, age at first calving, ages and parities of cows kept and ages of cows sold for free-, semi-zero- and zero-grazing systems in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Variable	Grazing system	n	Average estimate	95% confidence interval
Annual calving rate [ML]	Free	697	0.69 ± 0.04^{a}	
	Semi-zero	678	0.51 ± 0.04^{b}	
	Zero	642	0.52 ± 0.05^{b}	
	Total	2017	0.58	
Age at first calving (years)[ALS]	Free	116	2.8^{a}	2.6, 2.9
	Semi-zero	198	2.7^{a}	2.6, 2.8
	Zero	295	2.5^{b}	2.3, 2.6
	Total	609	2.7	
Age of cows kept (years)[ALS]	Free	171	6.4^{a}	6.0, 6.6
	Semi-zero	309	5.8^{ab}	5.5, 6.1
	Zero	349	5.0^{b}	4.5, 5.6
	Total	829	5.7	
Parity of cows kept (number)[ALS]	Free	171	2.6	2.3, 3.0
	Semi-zero	314	2.5	2.0, 3.1
	Zero	365	2.4	2.2, 2.6
	Total	850	2.5	
Age of cows sold (years)[ALS]	Free	38	6.6	5.5, 7.9
	Semi-zero	65	6.1	5.1, 7.3
	Zero	57	6.0	4.1, 8.9
	Total	160	6.2	

[ML]maximum likelihood estimates from logistic regression
[ALS] Antilogarithms of least square mean estimates
Estimates with different letter superscripts are significantly different at P<0.05.

3.2. Disposal and replacement patterns

Table 3 shows the predicted maximum likelihood estimates of annual demographic rates for the three grazing systems in the main cross-sectional survey. Mortality rates were high, ranging from 7 to 19%, depending on animal class, but not significantly different across the grazing systems for any of the animal classes. Selling rate of heifers and cows tended to be higher in zero- than in semi-zero- and free-grazing farms (Table 3). This corroborated the correlation analyses, which indicated that small herds sold larger proportions of the total herd (r= -0.74 to –0.86; P<0.001). When averaged over all age classes, animal sales were highest (17%) in zero-grazing, intermediate (12%) in semi-zero-grazing and lowest (9%) in free-grazing farms (not shown in table), suggesting an increased animal turnover as farmers intensified their dairying (P<0.05). Farmers practising zero-grazing reported higher buying rates for heifers (0.12) and cows (0.09) than those practising semi-zero- or free-grazing, where the corresponding rates ranged from 0.02 to 0.07 (P<0.05) (Table 3).

Table 3. Estimates from logistic regression of annual rates of mortality, selling and buying for each animal class for free-, semi-zero- and zero-grazing systems in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Animal class	Grazing system	n	Mortality rate	Selling rate	Buying rate
Heifer-calves	Free	264	0.15 ± 0.03	0.01 ± 0.01	0
	Semi-zero	191	0.13 ± 0.03	0.03 ± 0.01	0
	Zero	147	0.15 ± 0.05	0.01 ± 0.01	0.01 ± 0.004
	Total	602	0.14	0.01	0
Heifers	Free	386	0.08 ± 0.02	0.07 ± 0.02	0.05 ± 0.01^{b}
	Semi-zero	326	0.12 ± 0.02	0.09 ± 0.02	0.07 ± 0.02^{ab}
	Zero	308	0.07 ± 0.02	0.15 ± 0.03	0.12 ± 0.02^{a}
	Total	1020	0.09	0.10	0.08
Cows	Free	697	0.13 ± 0.02	0.08 ± 0.01	0.02 ± 0.01^{b}
	Semi-zero	678	0.14 ± 0.02	0.11 ± 0.02	0.04 ± 0.01^{ab}
	Zero	642	0.12 ± 0.02	0.14 ± 0.02	0.09 ± 0.02^{a}
	Total	2017	0.13	0.11	0.05
Male-calves	Free	238	0.21 ± 0.04	0.01 ± 0.01	0
	Semi-zero	164	0.19 ± 0.04	0.02 ± 0.01	0
	Zero	164	0.14 ± 0.04	0.03 ± 0.01	0
	Total	566	0.18	0.02	0
Immature-males	Free	143	0.16 ± 0.04	0.14 ± 0.06	0.03 ± 0.01
	Semi-zero	164	0.16 ± 0.04	0.31 ± 0.07	0.05 ± 0.01
	Zero	170	0.11 ± 0.03	0.32 ± 0.08	0.05 ± 0.01
	Total	476	0.14	0.27	0.05
Mature bulls	Free	235	0.13 ± 0.03	0.34 ± 0.08	0.07 ± 0.02
	Semi-zero	98	0.10 ± 0.04	0.41 ± 0.12	0.13 ± 0.04
	Zero	140	0.13 ± 0.04	0.46 ± 0.11	0.07 ± 0.03
	Total	472	0.12	0.39	0.08

Estimates with different letter superscripts are significantly different at P<0.05.

Using demographic rates obtained in Table 2 (calving rates) and in Table 3 (mortality and selling rates), Table 4 gives the estimated proportions of cows disposed, proportion of females born, proportion of females that died or were sold before breeding age and by applying equation 1, the number of heifers available for replacement per cow disposed for the three grazing systems in the main cross-sectional survey. The annual average cow disposal rate was 0.21, 0.25 and 0.26 in free-, semi-zero- and zero-grazing systems, respectively. The reciprocal of the disposal rate yields the length of productive life, corresponding to 4.8, 4.0 and 3.8 years for the free-, semi-zero- and zero-grazing systems, respectively. The estimates indicate a tendency towards shorter productive life in those herds with increasing intensification.

On average 0.43 of heifer-calves born were removed before reaching breeding age. Deaths (0.28) accounted for about two-thirds of the removals and the remaining third was due to sales (0.15). Sale of heifers before the breeding age increased from a proportion of 0.11 to 0.22 with shift from free- to zero-grazing systems. The removal of heifers was such that those reaching breeding age each year as a proportion of cows disposed were 1.11 in free-, 0.61 in semi-zero- and 0.46 in zero-grazing farms. The estimates imply that, on average, semi-zero- and zero-grazing farms maintained insufficient number of heifers to replace the cows leaving the herd, whereas free-grazing farms had an annual surplus of 11%.

Table 4. Estimated proportions of cows disposed, proportion of females born, proportion of females that died or were sold before breeding age for free-, semi-zero- and zero-grazing systems in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Variables	Grazing system			Total
	Free	Semi-zero	Zero	
Proportion of cows disposed	0.21	0.25	0.26	0.24
Proportion of females born	0.38	0.28	0.23	0.30
Proportion of females born that:				
died before reaching breeding age [a]	0.27	0.31	0.25	0.28
were sold before reaching breeding age [a]	0.11	0.15	0.22	0.15
reached breeding age	0.62	0.54	0.53	0.57
Number of females reaching breeding age as a ratio of cows disposed	1.11	0.61	0.46	0.71

[a]Cumulative proportions from birth to breeding age

3.3. Exit reasons and farmers' perception of the relative importance of diseases

Diseases accounted for the largest proportion of female exits: 85% among heifer-calves, 38% among heifers and 36% among cows (Table 5). The needs of households for cash were the second most frequent reason for female exits, accounting for over a quarter (27%) of the cow exits and a third (33%) of the heifer exits. Exits due to diseases or cash needs were each three to five times greater than those attributed to poor performance, which accounted for 10% of the cow exits and 5% of the heifer exits. On average, cows left the herd for poor performance at 7.2 years of age and for old age at 12.6 years of age.

The follow-up survey data showed that a large majority (76%) of cows left a herd when lactating or pregnant, mainly in their second and third parities (Figure 1). When asked to whom they sold their animals, farmers in most cases said that sales were within their local community.

Table 5. Frequency of reasons for exits of heifer-calves, heifers and cows in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Reason for disposal	Heifer-calves (n=79)	Heifers (n=167)	Cows (n=434)
Involuntary reasons (%)			
Diseases	85	38	36
Unspecified reasons	7	12	9
Injury	3	9	7
Poisoning	0	2	3
Total involuntary	*95*	*61*	*55*
Voluntary reasons (%)			
Cash needs	5	33	27
Poor performance	0	5	10
Old age	…	…	6
Slaughter for meat	0	1	2
Total voluntary	*5*	*39*	*45*

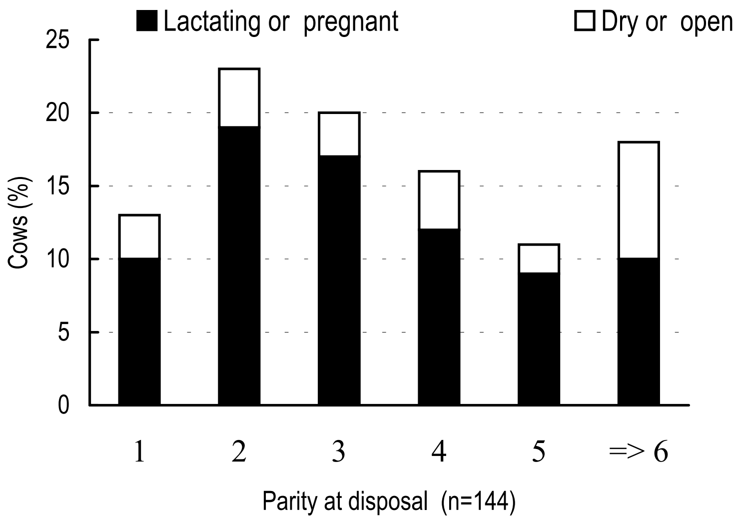

Figure 1. Frequency (%) of cow disposals by parity and physiological status (lactating/pregnant or dry/open) in a follow-up survey of 50 smallholder farms in the Kenya highlands

Table 6 displays farmers' ranking of diseases of importance in the three grazing systems from the main cross-sectional survey sample. We present only those diseases that farmers ranked differently (P<0.01). These were East Coast fever, Anaplasmosis and intestinal worms infestation, in that order. Farmers' ranking corroborated with the reported death cases. Suspected and/or confirmed cases of East Coast fever were 296 of which 51% died, and corresponding cases of Anaplasmosis were 135 of which 24% died. East Coast fever and Anaplasmosis were rated more important in free-grazing and in semi-zero-grazing than in zero-grazing farms. Diseases that farmers did not rank differently across systems were abortion, pneumonia, mastitis, milk fever, foot problems and poisoning.

3.4. Sources of breeding stock

The households in the cross-sectional survey reported purchasing more cows (102) than heifers (78) as replacement animals over the previous 12 months. By origin, 90% of the cows and 94% of heifers were purchased from other smallholdings whereas 10% of cows and 6% of heifers were from large-scale farms. Households in the follow-up survey owned a total of 149 cows of which 68% were born within the herd, 25% had been purchased from other smallholdings and 7% were purchased from large-scale farms. When cows and heifers were purchased they were mostly, in both surveys, from within the local community. Thus, the majority of dairy replacement animals were either reared in the herd in which they were producing or were purchased from another smallholding.

Table 6. Farmers' average ranking of diseases of importance (1= low and 3= high) affecting dairy production in free-, semi-zero- and zero-grazing systems in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Grazing system	n	Diseases		
		East Coast fever	Anaplasmosis	Intestinal worms
Free-	227	2.5 ± 0.02^{a}	1.8 ± 0.02^{a}	1.2 ± 0.11
Semi-zero-	326	2.0 ± 0.01	1.7 ± 0.02^{b}	1.5 ± 0.13
Zero-	434	1.8 ± 0.01^{a}	$1.4 \pm 0.01^{a,b}$	1.4 ± 0.08
Total	987	2.1 ± 0.01	1.7 ± 0.02	1.4 ± 0.06

Significant difference (Mann-Whitney test, P <0.01):
[a] between free- and zero-grazing
[b] between semi-zero- and zero-grazing

4. Discussion

4.1. Dairy production system

For a large majority of smallholders (73%) dairying is an integral part of mixed farming on holdings, which, on average, are less than two hectares. They integrate crops (for food and cash) and dairy production to diversify risks from dependency on a single crop or livestock enterprise. Mixed farming derives complementarities in resource use: crop residues and by-products from crop production constitute feeds for cattle, which return manure to maintain soil fertility and crop production (De Haan *et al.,* 1997).

Zero-grazing is an important strategy through which smallholders in the densely populated highlands intensify their farming systems, particularly as farm sizes decrease. This is a consequence of high human population growth rate (3% annually) in the Kenya highlands (C.B.S., 2001) where inter-generation inheritance results in subdivision and fragmentation of farms. Consequently, the number of holdings increases, but they get smaller with smaller herds. Where dairying is an integral part of the farming system the increased number of individual holdings has increased the overall cattle population, putting pressure on feed resources. Indeed, Zemmelink *et al.* (1999) estimated that the actual herd size (211,000 Tropical Livestock Units (TLU)) in parts of the Kenya highlands was far in excess of the optimum herd size (130,000 TLU) to be supported by the available feed resources. This pressure on feed resources explains why the majority (70%) of the smallholders either kept or preferred a herd of not more than three cattle. Associated with intensification through the change from free- to zero-grazing were changes in herd structure with more emphasis on milk production and increased stocking rates. Higher stocking rates were maintained through cut-and-carry feeding of napier fodder and crop residues, fodder purchased from neighbours, forages collected from common properties (road and reserves, forests, schools) and purchased concentrate feeds (Reynolds *et al.,* 1996; Lekasi *et al.,* 1998; Utiger *et al.,* 2000). The findings highlight the need for adequate access by smallholders to external feed resources if farmers are to sustain the intensification of their dairying.

4.2. *Cattle population dynamics*

Diseases were the major cause of involuntary animal losses. Vector-borne and infectious diseases are locally important but often their incidence decreases with change from free- to zero-grazing systems, because of lowered exposure to ticks (Gitau *et al.,* 1997, Siamba *et al.,* 1999). Cattle in semi-zero- and free-grazing farms are commonly tick infested throughout the year, but those in zero-grazing experience increased tick infestation only during periods of drought when feeds are imported from common properties (Siamba *et al.,* 1999). Farmers practising zero-grazing therefore attached less importance to the risk of East Coast fever and Anaplasmosis than those who practised semi-zero- and free-grazing.

Nevertheless, mortality rates in all animal classes, which were generally high (7 to 19%), did not vary with grazing system. Losses due to animal diseases and their interaction with nutritional level are therefore a major constraint to smallholder dairying irrespective of grazing system. Current policies in Kenya promote private sector participation in the delivery of livestock health inputs and services, including advice on dairy production (Owango *et al.,* 1998). Efficient delivery of these private goods will be critical in enhancing the competitiveness of intensive smallholder dairying. This will require government support, because the efficiency of the private market is contingent upon the ability of the state in providing the public goods of infrastructure (e.g. rural access roads) and institutional support.

Whereas calving rate declined as smallholders intensified their dairying, age at first calving improved. Earlier age at first calving in zero-grazing farms may be attributed to the dominance of *Bos taurus* dairy breeds in these farms (Bebe *et al.,* 2003) and also farmers' management strategy of retaining a fewer heifers (Table 3), possibly only when a need for a replacement was anticipated or when there were sufficient feed resources. On the other hand, lower calving rates in the most intensive systems may have resulted partly from under-nutrition and partly from a management strategy of delaying service of cows after calving in order to maintain milk supply for the household (Odima, *et al.,* 1994).

The high mortality and low reproductive rates, considered together, resulted in high reproductive wastage in these smallholder herds, irrespective of the level of intensification. Reproductive wastage in smallholder dairying in the Tanzania highlands (Kanuya *et al.,* 2000) and in Asia (Hermans *et al.,* 1989; De Jong, 1996) has been associated with inadequate quantity and quality of feeds, lack of bulls, inefficient delivery of artificial insemination (AI), poor access to veterinary services and difficulties in oestrus detection. These also apply to smallholder dairying in the Kenya highlands (Odima *et al.,* 1994; Omore *et al.,* 1996; Owango *et al.,* 1998; Lanyasunya *et al.,* 1999). To overcome these constraints improved access to effective input services will be required. The strengthening of farmer cooperatives is one way to achieve this. For instance, a recent study in Kenya highlands showed that smallholder farmers were willing to invest in supplementary feeds, mainly milling by-products, when given credit (Romney *et al.,* 2000).

A high proportion of voluntary exits of female cattle (60% of cows and 85% of heifers) was due to a household's need for cash, and not poor performance (22% of cows and 13% of heifers), demonstrating the importance of dairy cattle as a means of accumulating fluid capital assets for the household. Cattle were frequently sold to generate cash for financing school fees, hospital bills and household investments, which required larger amounts of money than were available from daily sales of milk. Meeting these cash needs was of high priority to the household regardless of the herd size (small herds sold a larger proportions of the total herd) or reproductive status of the individual animals (a large proportion of the exits in the follow-up survey were lactating or pregnant cows before their fourth parity). This resulted in a large turnover of animals, which was particularly high in the zero-grazing farms, explaining why cows were younger and of shorter productive life as intensification progressed.

The high reproductive wastage and the high turnover of females were such that herds in zero- and semi-zero-grazing farms were often unable to maintain a sufficient number of heifers for replacement of cows leaving the herd (Table 4). This implies that these systems are unable to maintain their herds without an external supply of replacement animals. Consequently, farmers practising semi-zero- and zero-grazing systems purchased more replacement animals than those practising free-grazing systems. Purchased replacement animals comprised more cows (57%) than heifers (43%), possibly due to inadequate feed resources to raise heifers.

Sourcing of replacement animals was generally from within the local community, which allowed smallholders to more confidently verify the fertility and milk yield of the animal being purchased. Replacement animals from large-scale farms are generally expensive for the majority of smallholder farmers, who perceive them to be less adaptable to their feeding systems. The surplus replacement animals available in free-grazing farms thus served as replacement or foundation stocks for the existing or new farmers in the area. The change from free- to zero-grazing systems, however, can be expected to continue, given the continued subdivision of land through family inheritance. Therefore, the primary concern with this anticipated change in smallholder dairy production systems will be how to maintain a continuous supply of replacement animals for the zero-grazing systems.

5. Conclusion

Increasing intensification influenced herd dynamics such that farmers practising semi-zero- and zero-grazing systems were unable to maintain sufficient heifers to replace the cows leaving the herd. Constraints to rearing replacement animals included high losses from animal diseases and inadequate access to feed resources, breeding services and credit. Sustained intensification of smallholder dairying in the Kenya highlands will depend upon finding solutions to these constraints. These solutions will include technical and institutional innovations to serve small-scale farms that may result in more complementarities and stratification in the dairy sub-sector.

Acknowledgements

The first author was supported by a research grant from The Netherlands Foundation for the Advancement of Tropical Research-WOTRO. The authors acknowledge the support of the Smallholder Dairy (R&D) Project (SDP) of the Kenya Ministry of Agriculture and Rural Development, the Kenya Agricultural Research Institute (KARI) and the International Livestock Research Institute (ILRI) for this study. SDP was funded by the

UK Department for International Development (DFID) for the benefit of developing countries

References

Bebe, B.O., Udo, H.M.J, Thorpe, W., 2002. Development of smallholder dairy systems in the Kenya highlands. Outlook on Agric. 31, 113-120.

Bebe, B.O., Udo, H.M.J, Rowlands, G.J., Thorpe, W., 2003. Smallholder dairy systems in the Kenya highlands: breed preferences and breeding practices (*Livestock Production Science*)

C.B.S., 1994. Kenya Population Census 1989. Office of the vice president and ministry of planning and national development, Volume I, Central Bureau of Statistics, Nairobi, Kenya.

C.B.S, 2001. The 1999 population and housing census Volume I. Population distribution by administrative area and urban centres. Central Bureau of Statistics, Ministry of Finance and Planning, Nairobi, Kenya.

Collett, D., 1991. Modelling binary data. Chapman and Hall, London. pp 369. Conelly, W.T., 1998. Colonial Era Livestock Development Policy: Introduction of improved dairy cattle in high potential farming areas of Kenya. World Development. 26, 1733-1748.

Delgado, C.L., Rosengrant M.W., Meyer, S., 2001. Livestock to 2020: The revolution continues. Paper presented to the International Agricultural Trade Research Consortium, Auckland, New Zealand, January, 2001.

De Haan, C., Steinfield, H., Blackburn, H., 1997. Livestock and the environment. Finding a balance. FAO/USAID/The World Bank. WRENmedia, Eye, Suffolk, UK.

De Jong, R., 1996. Dairy stock development and milk production with smallholders. PhD Thesis, Department of Animal Production Systems, Wageningen Agricultural University, The Netherlands. 303 pp.

Devendra, C., 2001. Smallholder Dairy Production Systems in Developing Countries: Characteristics, Potential and Opportunities for Improvement, A Review. Asian-Aust. J. Anim. Sci. 14, 104-113.

Devendra, C., Thomas, D., 2001. Smallholder farming systems in Asia. Agric. Syst. 71, 17-25.

Gitau, G.K., Perry, B.D., Katende, J.M., McDermott, J.J., Morzaria, S.P., Young, A.S., 1997. The prevalence of serum antibodies to tick-borne infections in cattle in smallholder dairy farms in Murang'a district, Kenya: a cross-sectional study. Prev. Vet. Med. 30, 95-107.

Hermans, C., Udo, H.M.J., Dawood, F., 1989. Cattle dynamics and their implications in Pabna District, Bangladesh. Agric. Syst. 29, 371-384.

Jaetzold, R., Schmidt, H., 1983. Farm management Handbook of Kenya Vol.II. Part B, Central Kenya. Ministry of Agriculture, Nairobi, Kenya. pp 510-620.

Kanuya, N.L., Kessy, B.M., Bittegeko, S.B.P., Mdoe, N.S.Y., Aboud, A.A.O., 2000. Suboptimal reproductive performance of dairy cattle in smallholder herds in a rural highland area of northern Tanzania. Prev. Vet. Med. 45, 183-192.

Lanyasunya, T.P., Wekesa, F.W., Jong de R., Udo H., Mukisira, E.A., Ole Sinkeet, N.S., 1999. Effects of a calf rearing package introduced to smallholder dairy farms in Bahati division, Nakuru district, Kenya. In: Proc. 6th Biennial KARI Scientific Conf. 9-13 November, 1998, Nairobi, Kenya. pp 450- 457.

Lekasi, J.K., Tanner, J.C., Kimani, S.K., Harris, P.J.C., 1998. Manure management in the Kenya Highlands: Practices and Potential. HDRA Publications, Conventry, UK, 24 pp.

Odima, P.A.; McDermott, J.J., Mutiga, E. R, 1994. Reproductive performance of dairy cows on smallholder farms in Kiambu district, Kenya: The Kenya Veterinarian. 18, 366.

Omore, A.O., McDermott, J.J., Gitau, G.K., 1996. Factors influencing production on smallholder dairy farms in Central Kenya. In: Proc. 5th Scientific Conf. of the Kenya Agricultural Research Institute, October 14-16, 1996, Nairobi, Kenya. pp 370-379.

Owango, M., Lukuyu, B., Staal, S.J., Kenyanjui, M., Njumbi, D., Thorpe, W., Dairy co-operatives and policy reforms in Kenya: effects of livestock service and milk market liberalisation. Food Policy. 23, 173-185.

Reynolds, L., Metz, T., Kiptarus, J., 1996. Smallholder dairy production in Kenya. World Anim. Rev. 87, 66-72.

Romney, D., Kaitho, R., Biwott, J., Wambugu, M., Chege, L., Omore, A., Staal, S., Wanjohi, P., Thorpe, W., 2000. Technology development and field testing: access to credit to allow smallholder dairy farmers in Central Kenya to reallocate concentrates during lactation. Proc. 3rd All Africa Conf. on Animal Agriculture and 11th Conf. of the Egyptian Soc. Anim. Prod. Alexandria, Egypt from 6th –9th November 2000. pp 18.

Siamba, D.N., Lokwaleput, I., Onyango, T.A., Nampaso, J., Nyakira, B.S., 1999. Ticks and tick-borne diseases: Epidemiology, control practices and prospects for integrated ticks and tick-borne disease management in Bahati, Nakuru. In: Proc. 6th Biennial KARI Scientific Conf. held on 9-13 November, 1998,Nairobi, Kenya. pp 34-46.

Staal, S.J., Owango, M., Muruiki, H., Kenyanjui, M., Lukuyu, B., Njoroge, L., Njubi, D., Baltenweck, I., Musembi, F., Bwana, O., Muruiki, K., Gichungu, G., Omore A., Thorpe, W., 2001. Dairy Systems Characterisation of Greater Nairobi Milk Shed. SDP (Smallholder Dairy (R&D) Project) Research Report, Ministry of Agriculture, Kenya Agricultural Research Institute and International Livestock Research Institute, Nairobi, Kenya. 73 pp.

Tulachan, M.P., Partap, T., Maki-Hokkonen, J., 2000. Livestock in the mountains and highlands of Asia, Africa and South America: An overview of Research and Development Issues and Challenges. In: Tulachan, P.M., Saleem, M.A.A., Maki-Hokkonen, J., Partap, T. (Eds), Contribution of livestock to mountain livelihoods:Research and Development Issues, International Centre for Integrated Mountain Development (ICIMODD), pp 3-31.

Utiger, C. Romney, D., Njoroge, L., Staal, S., Lukuyu, B., Chege, L., 2000. Nutrient flows and balances in intensive crop-dairy production systems in the Kenya highlands. Proc. 3rd All Africa Conf. on Animal Agriculture and 11th Conf. of the Egyptian Soc. Anim. Prod. Alexandria, Egypt from 6th –9th November 2000. pp 137.

Zemmelink, G, Romney, D.L., Kaitho, R.J., 1999. Dairy farming in Kenya: Resources and nitrogen flows. In: Outcome and Perspective of Collaborative Research, 11th International Symposium on Tropical Animal Health and Production. Utrecht University, Faculty of Veterinary Medicine, The Netherlands, 5th November 1999. pp 46-50.

CHAPTER FOUR

Smallholder dairy systems in the Kenya highlands: breed preferences and breeding practices

B. O. Bebe[a,b,c], H.M.J. Udo[b], G.J. Rowlands[c], W. Thorpe[c]

[a]Animal Science Department, Egerton University, Box 536 Njoro, Kenya

[b]Animal Production Systems Group, Wageningen Institute of Animal Sciences, Wageningen University and Research Centre, P.O. Box 338, 6700 AH Wageningen, The Netherlands

[c]International Livestock Research Institute, P.O. Box 30709, GPO Nairobi 00100, Kenya

This chapter has been accepted for publication in Livestock Production Science

Smallholder dairy systems in the Kenya highlands: breed preferences and breeding practices

Abstract

A stratified random sample, cross-sectional survey of 1755 households in the Kenya highlands was conducted between June 1996 and April 1998 to evaluate the rationale underlying smallholders' breeding decisions. Additional data were collected in a follow-up survey of 50 households sub-sampled from the main survey sample. Cattle-keeping households were 987, of which 62% kept Friesian (FR) and Ayrshire (AY), 22% kept East African Zebu, Boran and Sahiwal (ZB) cattle and 16% kept Guernsey and Jersey (GJ) breeds. Farmers keeping ZB and GJ ranked producing milk for family consumption the most important reason for keeping cattle, whereas those keeping FR and AY ranked producing milk for cash income most highly. Farmers' relative preference for GJ, AY and FR for high milk yield over hardiness was respectively 3.46, 7.58 and 17.63 times more when compared with preference for ZB. Additional attributes rated highly in the *Bos taurus* breeds were high butterfat yields, heavier bodyweight, unselective feeding behaviour in zero-grazing systems, hardiness and disease resistance in semi-zero- and free-grazing systems and high market value. Breeding practices tended to favour the use of dairy breeds of larger body size, particularly Friesian, which is inconsistent with technical recommendations that favour the use of the smaller dairy cattle breeds. These findings suggest that multiple objectives, including the need for more milk, adaptability to local feed conditions and diseases, and the provision of non-market production such as manure, insurance and financing roles of cattle, underlie smallholders' breeding decisions in the Kenya highlands.

Keywords: *Smallholder systems; Breed preferences; Breeding practices; Dairy cattle, Kenya highlands*

1. Introduction

Smallholder farmers in developing countries usually take a broad perspective to dairy production. Dairying is practised to produce milk for feeding the family and for sale, to produce manure to support crop production, and to provide dairy animals for insurance and financing emergency cash needs and for social status (Udo and Cornelissen, 1998). This broad perspective to dairy production deviates from livestock development policies, which generally focus on the marketed inputs and outputs of livestock systems and on the services directly linked to these. The differences in perspectives to dairy production hamper the formulation of effective livestock policies aimed at improving the livelihoods of smallholders. For instance, a frequent recommendation for smallholder systems is the use of small mature sized dairy breeds (Guernsey and Jersey). The use of larger breeds (Friesian and Ayrshire) and/or upgrading to high exotic grades is generally discouraged because of their higher nutritional demand, low milk yield, adaptability and production efficiency under smallholder conditions (e.g. Rege, 1998; Kahi *et al.*, 2000; Wakhungu, 2000). However, smallholders in developing countries have often not followed the recommended breeding practices: they have preferred to keep the large mature size dairy breeds as a key component of their intensification strategies (Tulachan *et al.*, 2000; Devendra, 2001, Bebe *et al.,* 2002).

Adoption of technical recommendations at the farm level is dependent upon the social, cultural, economic and environmental conditions facing the farmers who own and use the animals (Solano *et al.*, 2000). Breeding strategies generally evolve in response to changes in production systems, farmers' preferences and production objectives and farmers' knowledge about breed characteristics and market opportunities (Amer *et al.*, 1998; Jabbar *et al.*, 1999). Among the developing countries, Kenya has one of the most rapidly expanding dairy sub-sectors (ILRI, 2000). Smallholder farmers using exotic dairy cattle breeds, mainly in the highland areas, dominate the dairy sub-sector (Omore *et al.*, 1999). Presently, smallholders own about 80% of the estimated 3 million dairy cattle population, comprising Friesian, Ayrshire, Guernsey, Jersey and their crosses with *Bos indicus* cattle (local zebu, Boran and Sahiwal). Scarcity of feed resources and their poor quality are major constraints to improving production and reproductive performance (Methu *et al.*, 2000 and 2001). Diseases, mainly East Coast fever and Anaplasmosis, result in significant losses of animals from smallholder herds, which usually hold no more than three cattle. Nevertheless, the herds represent important liquid capital assets (Bebe *et al.*, 2003). Given these production features it is important to know, not only which breeds farmers consider to be the most suitable to their circumstances, but also their perceptions of the breed attributes and the factors which affect their breeding decisions. This can help to focus research on traits of importance and to inform extension and to target public and private programmes supporting smallholder dairy producers. This study evaluated breed preferences and breeding practices by smallholders in order to understand better the rationale underlying breeding decisions by smallholder farmers in the Kenya highlands.

2. Materials and methods

2.1. Data collection

A stratified random sample cross-sectional survey of 1755 households in the Kenya highlands was conducted between June 1996 and April 1998 to obtain the reasons for keeping cattle and information on breed preferences and breeding practices. A detailed description of the study sites, survey methodology and herd management is presented in an earlier part of this study (Bebe *et al.,* 2003)*.* Each respondent keeping cattle was asked to rank his or her reasons (first, second and third) for keeping cattle: production of milk for family consumption; production of milk for cash income; advice from extension service; attractive looks of the animal; prestige from owning cattle; traction use; and cattle as collateral for loans. Based on the most frequent cattle breed in the herd, the respondents gave their primary preference for keeping that breed: high milk yield; high butterfat yield; attractive looks of the animal; unavailability of semen of a preferred breed; traction ability; hardiness (disease resistance, drought tolerance, mobility); and the advice of the extension service. Information was also gathered on how each respondent obtained the foundation dairy stock: direct purchase; gift (from a relative or a development project); or through upgrading from *Bos indicus* zebu cattle. Respondents gave information on their animal husbandry experience, the perceived importance (1= low, 2=average and 3= high) of diseases affecting their herds and the sources of breeding services (bull or artificial insemination (AI)) during the previous year.

A follow-up cross-sectional survey, based on semi-structured interviews of 50 households randomly selected from a stratified sample of the main survey, was carried out to obtain additional information on mating patterns and preferences attached to attributes of various cattle breeds. Stratification was by level of intensification in dairying activities, available household resources and level of market access using a combined method of principal component and cluster analysis applied to the main cross-sectional survey sample (Staal *et al.*, 2001). Additional information on mating patterns was obtained from the 50 respondents through probing each respondent about the breed of their foundation cow(s) and the breed of sires mated both to the foundation female(s) and the subsequent heifer progenies over the generations. Identification of the breed attributes of importance to these 50 smallholders was through respondents' rating of the breed they kept on a scale of 1 (low preference) to 4 (very high preference) for: milk yield; butterfat content; body weight; fertility; disease resistance (with respect to tick-borne diseases); feeding behaviour and market value.

2.2. Statistical analysis

For statistical analysis, a broad classification of dairy breeds into large and small mature bodyweight was adopted (Matthewman, 1993). The small mature size *Bos taurus* breeds comprised Guernsey and Jersey (GJ) and the large mature size *Bos taurus* breeds comprised Friesian (FR) and Ayrshire (AY). The *Bos indicus* comprised East African Zebu, Boran and Sahiwal (ZB). A non-parametric Kruskal-Wallis test was used to investigate the differences between cattle breeds in the relative importance (3=first, 2= second and 1=third) attached to reasons for keeping cattle in the main cross-sectional survey.

Stated primary preferences for different cattle breeds expressed by smallholders in the main cross-sectional survey were quantified using logistic regression models. The dependent variables were breed proportions: GJ/(GJ+ZB); AY/(AY+ZB); and FR/(FR+ZB) and the independent variable was the array of stated preferences (7 levels). Hardiness was chosen as the reference preference for the model as this was the most frequent preference stated for ZB, the breed against which GJ, AY and FR were to be compared. Age of head of the household and the year dairy cattle were introduced on the farm were grouped by source of foundation stock and the differences between these variables were compared using a t-test.

The respondents in the follow-up survey also attached preference ratings (ranked from 1 to 4) to attributes of breeds they were keeping. As very few of the farmers in this survey had husbandry experience with Jersey and Guernsey breeds, statistical evaluation was only performed for preference ratings attached to attributes of Friesian and Ayrshire breeds. The Mann-Whitney rank-sum test was used to compare mean ratings for the attributes between these two breeds.

3. Results

3.1. Reasons for keeping cattle

Of the 987 cattle-keeping households in the main cross-sectional survey, 43% kept Friesian, 19% kept Ayrshire, 16% kept Guernsey and Jersey cattle breeds and 22% kept *Bos indicus* cattle (East African Zebu, Boran, Sahiwal). The average ranking of reasons for keeping cattle (Table 1) indicated that farmers attached greater importance to milk production for feeding the family and for cash income than any other stated reason ($P<0.01$). Farmers keeping Friesian and Ayrshire breeds gave a slightly higher priority to milk production for cash income whereas those keeping *Bos indicus* cattle, Guernsey or Jersey breeds gave a slightly higher priority to milk production for feeding the family.

3.2. Preferences attached to cattle breeds

Table 2 displays the frequencies for cattle breed groups by primary preference reason, grazing system and agro-ecological zone. Attributes most frequently preferred (by more than 10% of the households) were high milk yield (Friesian, Ayrshire, Guernsey and Jersey, *Bos indicus*), hardiness (*Bos indicus,* Guernsey and Jersey, Ayrshire), traction ability (*Bos indicus*) and high butterfat yield (Guernsey and Jersey, Ayrshire) in that order.

Table 1. Means of rankings (3=first, 2=second, 1=third) with their standard errors for reasons for keeping cattle stratified by cattle breeds owned in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Reasons for keeping cattle	Cattle breeds			
	East African Zebu, Boran and Sahiwal	Guernsey and Jersey	Ayrshire	Friesian
Main cross-sectional survey				
Milk for family consumption	2.18 ± 0.06	2.15 ± 0.07	1.95 ± 0.06	1.98 ± 0.04
Milk for cash income	1.69 ± 0.05	1.98 ± 0.06	2.05 ± 0.06	2.09 ± 0.04
Attractive looks of the animal	1.15 ± 0.03	1.23 ± 0.05	1.20 ± 0.04	1.19 ± 0.03
Advice from extension	1.02 ± 0.01	1.10 ± 0.03	1.09 ± 0.02	1.09 ± 0.02
Traction use	1.10 ± 0.03	1.01 ± 0.01	1.00 ± 0.01	1.02 ± 0.01
Prestige from owning cattle	1.04 ± 0.02	1.03 ± 0.02	1.03 ± 0.01	1.04 ± 0.01
Others (obtaining loans, unspecified)	1.22 ± 0.04	1.21 ± 0.05	1.31 ± 0.05	1.27 ± 0.03
Number of respondents	217	157	189	424

Table 2. Frequencies for cattle breeds stratified by stated preference, grazing system and agro-ecological zone in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

	Cattle breeds			
	East African Zebu, Boran and Sahiwal	Guernsey and Jersey	Ayrshire	Friesian
Stated primary preference (%)				
Hardiness	37	23	13	5
High milk yields	22	47	59	78
Traction ability	15	1	0	0
Semen of choice unavailable	10	4	7	4
High butterfat yield	5	10	12	6
Attractive looks	5	8	6	4
Extension advice	6	7	3	3
Grazing system (%)				
Free	52	14	15	15
Semi-zero	28	24	45	34
Zero	20	62	40	51
Agro-ecological zone (%)				
Medium potential	72	20	29	28
High potential	28	80	71	72
Number of respondents	217	157	189	424

Bos indicus cattle breeds (ZB) were more frequently found in medium potential agricultural areas under free-grazing and *Bos taurus* dairy breeds in high potential agricultural areas under semi-zero- and zero-grazing systems.

Table 3 gives the odds ratio and their 95% confidence intervals estimated from logistic regression for the stated primary preferences for cattle breeds. The odds ratio presented is a measure of the relative preference for an attribute in a given breed when compared with ZB. An odds ratio equal to one (1) indicates no difference in the stated primary preferences, a higher primary preference when greater than one and a lower primary preference when less than one. The odds ratio is significant when its 95% confidence interval excludes one (1). Farmers' relative preferences for GJ, AY and FR for high milk yield and butterfat yields over hardiness were, respectively, 3.46 and 3.16, 7.58 and 6.36, and 17.63 and 4.00 times higher than those for ZB ($P<0.001$).

Table 3. Odds ratios (and their 95% confidence intervals) from logistic regression for stated preferences for cattle breeds in cross-sectional surveys of 987 smallholder farms in the Kenya highlands

Stated primary preference	Guernsey and Jersey	Ayrshire	Friesian
Hardiness[a]	ref.	ref.	ref.
High milk yields	3.46 (1.91, 6.25)	7.58 (4.10, 14.03)	17.63 (10.06, 30.92)
High butterfat yield	3.16 (1.23, 8.10)	6.36 (2.52, 16.04)	4.00 (1.58, 10.14)
Attractive looks	3.05 (1.13, 8.22)	3.58 (1.25, 10.22)	3.94 (1.48, 10.45)
Traction ability	0.07 (0.01, 0.56)	Not estimable	0.25 (0.07, 0.89)
Extension advice	2.26 (0.83, 6.21)	1.59 (0.48, 5.26)	2.75 (1.02, 7.38)
Semen of choice unavailable	0.60 (0.20, 1.77)	1.85 (0.75, 4.56)	1.59 (0.67, 3.76)

[a]Hardiness was the reference of comparison in the model as it was the most frequently stated preference for *Bos indicus* (ZB).

Bos taurus dairy breeds were more often preferred than ZB for their "attractive" looks (P<0.05) but the latter were more often preferred for their traction ability. Extension advice encouraged higher preference for FR relative to ZB (P<0.05). The unavailability of semen of a preferred breed did not significantly influence farmers' breed preferences.
Table 4 gives additional information on the relative preference rating for the attributes of Friesian and Ayrshire breeds from 36 of those 50 households in the follow-up survey sample. Farmers rated Ayrshire higher than Friesian for disease resistance (P<0.001). During the semi-structured interviews farmers said that Ayrshire also had good mobility, which they thought suited them better to semi-zero- and free-grazing systems where animals have to walk relatively long distances to watering points. Farmers rated Ayrshire more favourably than Friesian for feeding behaviour (P=0.08). Farmers' perceptions, elicited through the semi-structured interviews, were that Ayrshires had lower daily feed requirements than Friesians. On the other hand they perceived Friesians to be less selective in feeding, a characteristic more desirable in zero-grazing systems, where change in feeds offered is more frequent in both quantity and quality because of scarcity in feed resources. Farmers rated Friesian higher than the Ayrshire breed for body weight and reported Friesian to be of higher market value (P<0.05).

3.3. Past and present breeding practices

Smallholders obtained foundation dairy stock mainly through direct purchase (83% of the households) rather than through upgrading from *Bos indicus* zebu cattle or gifts (e.g. from development projects or relatives) (Table 5). The few farmers who had upgraded local zebu to dairy cattle were on average six years older and started dairying in the 1970s, about 7 years earlier than those who had purchased their foundation stock (P<0.05).

Table 4. Means with their standard errors of preference rating (1=low preference, 4=very high preference) of the attributes of Friesian and Ayrshire cattle breeds by smallholder farmers in a survey in the Kenya highlands

Breed attributes	Cattle breed	
	Ayrshire	Friesian
Body weight[b]	1.21 ± 0.14	1.64 ± 0.17[a]
Butterfat content[b]	1.16 ± 0.11	1.07 ± 0.07
Fertility[b]	1.09 ± 0.07	1.25 ± 0.12
Milk yield	3.63 ± 0.21	3.85 ± 0.09
Feeding behaviour[b]	2.05 ± 0.21	1.68 ± 0.15
Market value[b]	1.79 ± 0.21	2.18 ± 0.18[a]
Disease resistance[b]	2.16 ± 0.23	1.25 ± 0.14[a]
Number of respondents	15	21

[a]Significant difference (P<0.05) by Mann-Whitney rank sum-test
[b]Complementary information not in the main cross-sectional survey

Table 5. Frequencies (%) and the means with their standard errors of age of household's head and the year dairy cattle was introduced by source of foundation stock for 987 smallholder farms in the Kenya highlands

Source of foundation stock	Households (%)	Age of head of the household (y)	Year dairy cattle introduced
Purchased	83	50 ± 0.5[b]	1981 ± 0.4[a]
Gift	14	50 ± 1.2[b]	1980 ± 1.0[a]
Upgraded from zebu	3	56 ± 2.5[a]	1974 ± 2.0[b]

Means with different superscript letters within a column are significantly different at P<0.05

Figure 1 shows a summary of the mating patterns from information available from 45 households of those 50 households randomly selected from the main survey sample. For each breed of cow, the bars represent the proportion of cows mated to a specified breed of sire over the generations traced from the foundation cow. The results suggest that smallholders have tended to mate cows of Friesian and Ayrshire breeds to sires of the same breeds, whereas cows of Guernsey breed have been mated to sires of Friesian and Ayrshire breeds.

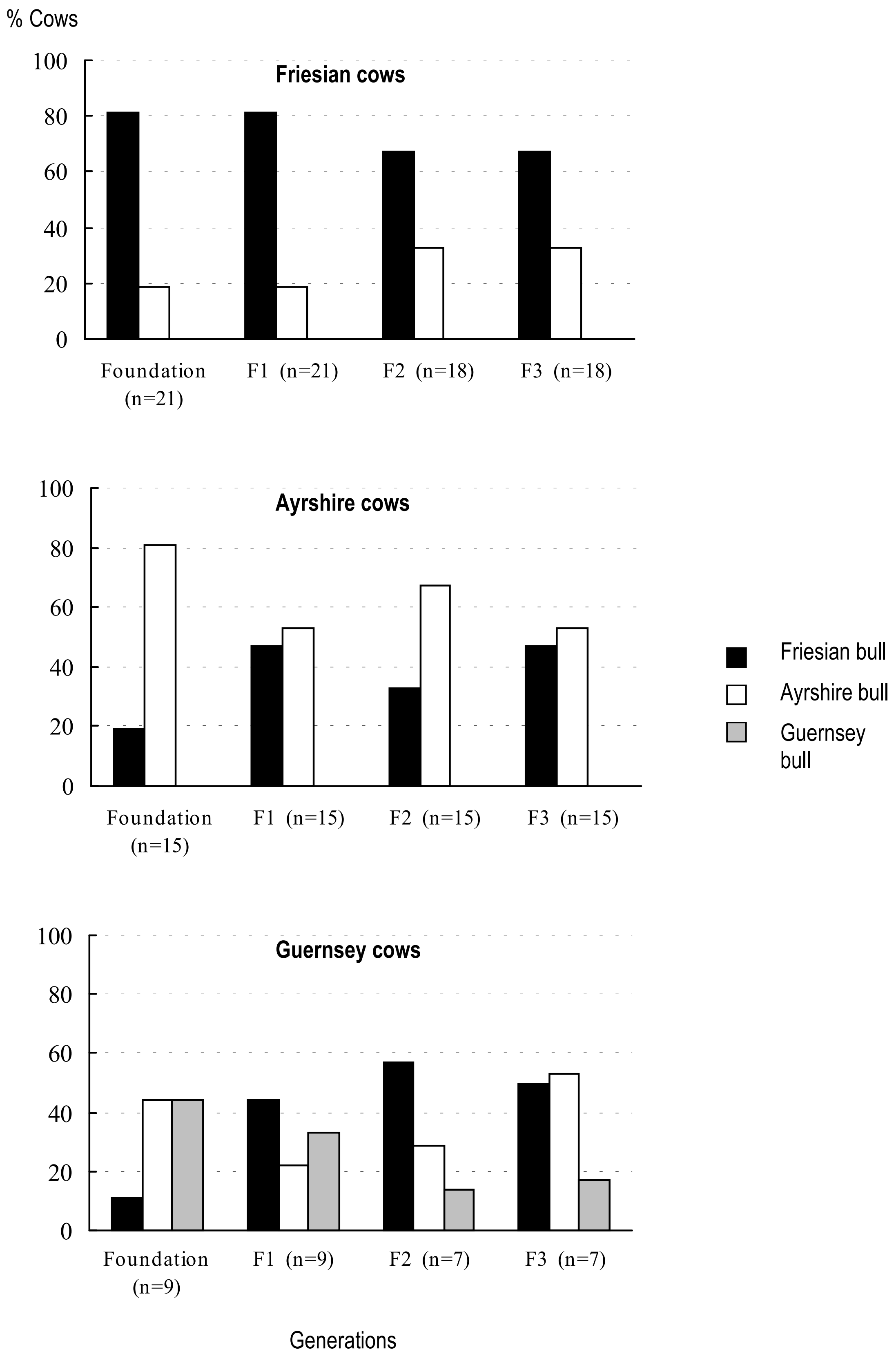

Figure 1. Proportion of cows for each breed by the breed of sires (see legend) mated to the foundation cows and the subsequent heifer progenies over the generations

Table 6 summarises the breeding practices reported for the year preceding the main cross-sectional survey. Natural mating was more frequent than AI service regardless of the breed of cattle owned. However, A.I service was more frequent used for *Bos taurus* than for *Bos indicus* breeds (P<0.001). Farmers who obtained AI services did so five times more frequently from farmer co-operatives and private providers than from government services. Record keeping of production performance was infrequent for all the breed groups. Years of husbandry experience were similar across breeds. On average, herds dominated by *Bos indicus* cattle were larger than those dominated by *Bos taurus* breeds (P<0.01). Farmers keeping *Bos taurus* breeds attached less importance to the risk of tick-borne diseases than those that kept *Bos indicus* cattle (P<0.01). This is associated with the fact that *Bos taurus* cattle are more often managed under stall-feeding systems where the incidence of these diseases is relatively lower.

Table 6. Breeding practices according to cattle breeds owned in 987 smallholder farms in cross-sectional surveys in the Kenya highlands

Breeding practices	Cattle breeds			
	East African Zebu, Boran and Sahiwal	Guernsey and Jersey	Ayrshire	Friesian
Sources of breeding services (%) [a]				
Bull from other farms	58	54	51	44
Bull from own farm	28	5	7	7
AI from cooperatives	9	21	18	25
AI from private providers	2	6	16	17
AI from government services	2	12	6	6
AI from projects	1	2	2	1
Record keeping (%)				
Yes	7	17	16	24
No	93	83	84	76
Husbandry experience (y)	16.3 ± 0.70	16.2 ± 0.83	15.1 ± 0.75	16.4 ± 0.50
Herd size (n) [b]	6.0 ± 0.21	2.5 ± 0.43	3.7 ± 0.16	3.9 ± 0.60
Importance of tick-borne diseases (1=important, 3=very important)[c]	1.9 ± 0.02	1.5 ± 0.02	1.3 ± 0.02	1.4 ± 0.01
Number of respondents	217	157	189	424

[a] Chi square test for general association between source of service and breed group (P=0.001)
[b] Student t-test P< 0.05 for *Bos indicus* vs each of the *Bos taurus* breeds
[c] Mann-Whitney U-test (P=0.01) for *Bos indicus* vs each of the *Bos taurus* breeds

4. Discussion

4.1. Farmers' production objectives and breed preferences

The dominance of *Bos taurus* dairy breeds (78% of the farms) over *Bos indicus* breeds (22% of the farms) indicates high priority to exotic dairy breeds for milk production by smallholder farmers in the Kenya highlands. According to farmers' rankings, the major objectives for keeping cattle were milk production for feeding the family and for generating cash income. However, priority attached to these objectives differed depending on the breed of cattle kept, indicating the influence of farmers' production objectives. Farmers giving top priority to the commercial objective must be able to produce a marketable milk surplus for income generation. Smallholders try to meet this objective by keeping Friesian and Ayrshire breeds, which they consider as high milk producers (Table 2 and 4). On the other hand, Guernsey and Jersey breeds, that were perceived as lower milk producers, were more often kept by households pursuing subsistence objectives as top priority (Table 1). This is probably because the level of investment needed for these breeds, being of smaller size, is lower relative to Friesian and Ayrshire.

Farmers acknowledged some differences between Friesian and Ayrshire breeds with respect to market value, disease resistance and suitability for different management systems. The heavier bodyweight rating attached to Friesian over Ayrshire can partly explain why Friesian was considered to have higher market value. Heavy bodyweight attracts high market value, which is important when selling cows either for slaughter or to other farmers for production, a practice common among smallholder dairy farmers in the Kenya highlands (Bebe *et al.*, 2003). Because of their higher market value Friesians represents a better storage of wealth for smallholders who use cattle to accumulate fluid capital assets and for insurance and financing emergency cash needs (Udo and Cornelissen, 1998; Bebe *et al.,* 2003).

The unselective feeding behaviour associated with Friesians, as perceived by respondents in this study, would be important to farmers in zero-grazing systems where they have to respond to seasonal changes in the availability of feed resources. It allows for adjusting to the intermittent and abrupt changes in the quantity and quality of feeds offered (Methu *et al.*, 2000 and 2001; Zemmelink and Ibrahim, 2000). The unselective feeding behaviour of the Friesian may be associated with a larger rumen capacity due to its larger body weight compared with the Ayshire. This would allow for a longer retention time in the rumen, and hence more extensive digestion, especially when feeds are of low quality (Illius and Gordon, 1991; Lechner-Doll *et al.*, 1991). In a study of manure management practices in the Kenya highlands, farmers indicated that obtaining manure is one of their objectives when using the feeds that are available (Lekasi *et al.*, 1998). Manure production is an important function of dairy cattle and their integration with cropping systems in the highlands. Dairy farmers intensify dairy production through the importation of nutrients in the form of dairy feeds, and the resultant manure contributes to the provision of plant nutrients and organic matter for crop production.

Farmers considered the Ayrshire to be less susceptible than the Friesian breed to diseases (especially those transmitted by ticks) and to have better mobility. These attributes were preferred for semi-zero- and free-grazing systems, reflecting the importance of adaptive traits to smallholders in situations where the relative risk of exposure to environmental stresses is likely to be higher. This is important because most smallholder farmers do not have adequate access to veterinary services, feeds and credits to purchase inputs (Devendra, 2001; Romney *et al.*, 2000). Therefore, where environmental stresses are high, attention should be given to breeds with good adaptive characteristics while at the same time aiming at higher productivity. This underscores the need to carefully consider production circumstances of smallholders when recommending the use of specific cattle genotypes.

Results from several studies (Syrstad, 1996; Rege, 1998; Kahi *et al.*, 2000; Wakhungu, 2000) have been used to discourage the use of larger breeds in favour of smaller ones because the former have higher nutritional demands and have performed poorly in terms of milk yield, adaptive traits and production efficiency. Despite this discouragement larger dairy breeds continue to dominate on smallholder farms found in developing countries (Tulachan *et al.*, 2000; Devendra, 2001) and in this study as well, an indication that smallholders' breeding practices do not conform to the recommended breeding practices. Smallholders' breeding practices reflect broad objectives, which combine need for more milk with adaptability to the prevalent diseases and local feed resources and to the additional benefits, generally non-marketed, such as manure, insurance and financing roles of cattle. Recognition that these multiple objectives influence breeding decisions is of central importance to the formulation of effective livestock policies aimed at improving the livelihoods of smallholders and serving the interests of the consumers of dairy products. Therefore, breeding practices targeted at smallholders should take into account smallholders' production systems, preferences, production objectives and their knowledge of breed characteristics.

4.2. Breeding practices

In this study the cattle breeds dominant in herds differed by system of cattle management. *Bos indicus* breeds were predominant in free-grazing systems whereas *Bos taurus* dairy breeds were predominant in more intensive systems where management strategies favoured smaller herds with higher milk production potential (Bebe *et al.*, 2003). Friesian and Ayrshire were the predominant dairy breeds on 62% of the farms. The large population of dairy cattle in public and private large-scale dairy farms in the Kenya highlands during 1960s and 1970s provided smallholders with the opportunity to directly purchase their foundation stock (Conelly, 1998). Consequently, the majority of smallholders (83%) did not have to start their dairy herds by upgrading Zebu cattle. Instead, they procured dairy cattle of breeds of their choice from what was locally available and they maintained these by mating to dairy breeds, with the tendency towards the use of Friesian and, to a lesser extent, Ayrshire (Figure 1).

Very few farmers raised their own bulls for breeding because, apparently, they preferred to use their limited fodder supplies for cows for milk production (Bebe *et al.*, 2003). Most farmers (63%) bred their cows to bulls owned within the community (Table 6). However, the fact that few farmers owned a bull in a region implies that few bulls are likely used for along time. This can potentially increase the inbreeding levels in the population. Furthermore, most of the bulls would be of unknown pedigree, although generally of known genotype, implying that systematic selective breeding is lacking. Increased inbreeding and the use of unproven bulls and limited AI services may have unfavourable long-term effects on productivity through the degradation of the herd genotype.

Partly as a result of the decline in government services, most AI was provided to smallholders by dairy co-operatives and private producers. Unsubsidised AI is expensive relative to natural service, mainly because of the poor state of rural roads and other transport costs, and these are unlikely to change in the near future. Consequently, it is expected that natural mating will continue to predominate on smallholder farms. The organisation by farmers' co-operatives of village bull schemes using bulls of proven genetic merit may be an attractive alternative to AI. Bull schemes can be successful if bull centres are established within a reasonable distance for farmers to walk their cows for service. Associated health services will be required, however, to control breeding diseases and to minimise exposure to, for example, tick-borne diseases.

Animal recording in Kenya is undertaken by Dairy Recording Services of Kenya (DRSK), which is a farmers' organisation dominated by large-scale farmers. Few smallholders in the survey area kept performance records. To encourage smallholder participation in performance recording, DRSK needs to provide information that enables a farmer to compare the performance of his/her own herd with those of his/her community in order to stimulate competition and provide incentives to improve production. Village co-operatives may be a suitable starting point for such basic recording (Trivedi, 1998).

5. Conclusion

The breeding decisions of smallholder dairy producers in the Kenya highlands conform to producers' multiple objectives. These include the need for more milk, adaptability to local feed conditions and diseases and the provision of non-market production (e.g. manure, and the insurance, financing and social roles of cattle). Breeding policies targeting smallholder systems will be more effective when incorporating the multi-functional roles that cattle play in these systems. Recognition of this broad basis for breeding decisions is central to the formulation of effective livestock policies aimed at improving the livelihoods of smallholders and serving the interests of consumers of dairy products.

Acknowledgements

The first author was supported by a research grant from The Netherlands Foundation for the Advancement of Tropical Research-WOTRO. The authors acknowledge the support of the Smallholder Dairy (R&D) Project (SDP) of the Kenya Ministry of Agriculture and Rural Development, the Kenya Agricultural Research Institute (KARI) and the International Livestock Research Institute (ILRI) for this study. SDP was funded by the UK Department for International Development (DFID) for the benefit of developing countries.

References

Amer, P.R., Mpofu, N., Bondoc, O., 1998. Defination of breeding objectives for sustainable production systems. Proc. 6th World Congr. Genet. Appl. Livest. Prod. 28, 97-103.

Bebe, O. B., Udo, H.M.J., Thorpe, W., 2002. Development of smallholder dairy systems in the Kenya highlands. Outlook on Agric. 31, 113-120.

Bebe, O. B., Udo, H.M.J, Rowlands, G.J., Thorpe, W., 2003a. Smallholder dairy systems in the Kenya highlands: cattle population dynamics under increasing intensification. *(Livestock Production Science).*

Conelly, W.T., 1998. Colonial Era Livestock Development Policy: Introduction of improved dairy cattle in high potential farming areas of Kenya. World Development, 26, 1733-1748.

Devendra, C., 2001. Smallholder dairy production systems in developing countries: Characteristics, potential and opportunities for improvement. Review. Asian–Aust. J. Anim. Sci. 14, 104-113.

Illius, A.W., Gordon, I.J. 1991. Prediction of intake and digestion in ruminant by a model of rumen kinetics integrating animal size and plant characteristics. J. Agric. Sci. 116, 145-157.

ILRI, 2000. Handbook of livestock statistics for developing countries: Socio-economics and policy research working paper 26. International Livestock Research Institute, Nairobi, Kenya, pp 299.

Jabbar, A.M., Swallow, B.M., Rege, J.E.O., 1999. Incorporation of farmer knowledge and preferences in designing breeding and conservation strategy for domestic animals. Outlook on Agric. 28, 239-243.

Kahi, A.K., Thorpe, W., Nitter, G., Van Arendonk, J.A.M., Gall, C.F., 2000. Economic evaluation of crossbreeding for dairy production in a pasture based production system in Kenya. Livest. Prod. Sci. 65, 167-184.

Lechner-Doll, M., Rutagwenda, T., Schwartz, H.J., Schultka, W., Egelhardt, W. V., 1991. Seasonal changes of ingesta mean retention time and forestomach fluid in indigenous camels, cattle, sheep and goats grazing a thorn bush savannah in Kenya. J. Anim. Sci.. Camb. 115, 409-420.

Lekasi, J.K., Tanner, J.C., Kimani, S.K., Harris, P.J.C., 1998. Manure management in the Kenya Highlands: Practices and Potential. Kenya Agricultural Research Institute, Nairobi, Kenya. pp 24.

Matthewman, W.R., 1993. Dairying: the tropical agriculturalist. Macmillan Press Ltd, London, UK, pp 52.

Methu , J.N., Romney, D.L., Kaitho, R.J., Karuiki, J.N., 2000. Effect of abrupt and frequent changes in forage quality and the influence of patterns of concentrate feeding on the performance of dairy cattle. 3rd All Africa Conf. and 11th Egyptian Soc. Anim. Prod. Alexandria, 6-9th November, 2000. pp 47.

Methu, J.N., Owen, E., Abate, A.L., Tanner, J.C., 2001. Botanical and nutritional composition of maize stover, intakes and feed selection by dairy cattle. Livest. Prod. Sci. 71, 87-96.

Omore, A., Muriuki, H., Kenyanjui, M., Owango, M., Staal, S., 1999. The Kenyan dairy sub-sector: A rapid appraisal. Report by the MoA-KARI-ILRI Smallholder Dairy (Research and Development) Project, International Livestock Research Institute, Nairobi. pp 50.

Rege, J.E.O., 1998. Utilization of exotic germplasm for milk production in the tropics Proc. 6th World Cong. on Genet. Appl. Livest. Prod. 25, 193-200.

Romney, D., Kaitho, R., Biwott, J., Wambugu, M., Chege, L., Omore, A., Staal, S., Wanjohi, P., Thorpe, W., 2000. Technology development and field testing: access to credit to allow smallholder dairy farmers in Central Kenya to reallocate concentrates during lactation. Proc. 3rd All Africa Conf. on Animal Agriculture and 11th Conf. of the Egyptian Soc. Anim. Prod. Alexandria, Egypt from 6th –9th November 2000. pp 18.

Solano, C., Bernues, A., Rojas, F., Joaquin, N., Fernandez, W., Herrero, M., 2000. Relationship between management intensity and structural and social variables in dairy and dual-purpose systems in Santa Cruz, Bolivia. Agric. Syst. 65, 159-177.

Staal, S.J., Owango, M., Muruiki, H., Kenyanjui, M., Lukuyu, B., Njoroge, L., Njubi, D., Baltenweck, I., Musembi, F., Bwana, O., Muruiki, K., Gichungu, G., Omore A., Thorpe, W., 2001. Dairy Systems Characterisation of Greater Nairobi Milk Shed. SDP (Smallholder Dairy (R&D) Project) Research Report, Ministry of Agriculture, Kenya Agricultural Research Institute and International Livestock Research Institute, Nairobi, Kenya. pp 73.

Syrstad, O., 1996. Dairy cattle crossbreeding in the tropics: Choice of crossbreeding strategy. Trop. Anim. Hlth. Prod. 28, 223-229.

Trivedi, K.R., 1998. International Workshop on Animal Recording for Smallholders in Developing Countries. Anad, India. 20-23 October, 1997. ICAR Tech. Series No. 1., ICAR, Rome, Italy. pp 436.

Tulachan, M.P., Partap, T., Maki-Hokkonen, J., 2000. Livestock in the mountains and highlands of Asia, Africa and South America: An overview of Research and Development Issues and Challenges. In: Tulachan, P.M., Saleem, M.A.A., Maki-Hokkonen, J., Partap, T. (Eds), Contribution of livestock to mountain livelihoods: Research and Development Issues, International Centre for Integrated Mountain Development (ICIMODD), pp 3-31.

Udo, H., Cornelissen, T., 1998. Livestock in resource-poor farming systems. Outlook on Agric. 27, 237-242.

Wakhungu, W.J., 2000. Dairy cattle breeding policy for Kenyan smallholders: An evaluation based on demographic stationary state productivity model. PhD Thesis, College of Agriculture and Veterinary Sciences, University of Nairobi, Kenya. pp 164.

Zemmelink, G., Ibrahim, M.N.M., 2000. Cattle production on smallholder farms in East Java, Indonesia: II. Feeds and feeding practices. Asian – Aust. J. Anim. Sci. 13, 226-235.

CHAPTER FIVE

Smallholder dairy systems in the Kenya highlands: feeding practices and production performances under increasing intensification

B. O. Bebe[a,b,c], H.M.J. Udo[b], W. Thorpe[c]

[a]Animal Science Department, Egerton University, Box 536 Njoro, Kenya

[b]Animal Production Systems Group, Wageningen Institute of Animal Sciences, Wageningen University and Research Centre, P.O. Box 338, 6700 AH Wageningen, The Netherlands

[c]International Livestock Research Institute, P.O. Box 30709, GPO Nairobi 00100, Kenya

This chapter is to be submitted to Livestock Production Science

Smallholder dairy systems in the Kenya highlands: feeding practices and production performances under increasing intensification

Abstract

This study explored quantitative relationships between feeding practices and the performance of dairy cattle in free-, semi-zero- and zero-grazing farms, which represent increasing intensification levels. Data on feeding practices and individual cow performances were obtained in a stratified random sample cross-sectional survey of smallholder farms in the Kenya highlands between June 1996 and April 1998. Age at first calving averaged 32.4 months and lactation length averaged 456 days, resulting in average days-open of 288 days with less than 4 litres of milk per day of calving interval. The performances of the Friesian, Ayrshire or Guernsey/Jersey breeds were not significantly different. Heifers on zero-grazing farms attained age at first calving 1.7 months earlier than those on free-grazing farms. Compared to non-members, members of farmers' co-operatives fed more concentrates (Ksh 1025 per Tropical Livestock Unit (TLU) per year) to their cows, which achieved better performances. Farmers supplemented napier grass, a common basal fodder, with purchased fodder and concentrates, but purchased less feed when more crop residues were available. It was estimated that relative to each additional 1 ha/TLU of napier planted on a farm supplementary feeding was increased by Ksh 399/TLU of fodder and Ksh 5642/TLU of concentrates, whereas an additional 1 ha/TLU of maize reduced purchase of fodder by Ksh 409/TLU and purchase of concentrates by Ksh 1384/TLU. Feeding interventions to support continued intensification of these smallholder systems thus have to be considered in the context of economy of the household, which is characterised by limited cash flow and low risk bearing capacity.

Key words: *Smallholder dairying; Intensification; Feeding practices; Production performance; Kenya highlands*

1. Introduction

Lack of adequate quantity and quality of feeds is a major constraint to smallholder dairy production (Walshe *et al.,* 1991; Devendra and Sevilla, 2002). This is particularly marked in the Kenya highlands where the integration of dairying into smallholder farming has been relatively successful with smallholders intensifying their feeding practices from free-grazing to zero-grazing in response to the continuously shrinking landholdings. Intensification of smallholder dairy production systems involves the adoption of management practices and technologies to increase the output quantity and/or value from the major limiting production resources of land, capital and labour. When asked about constraints to increasing milk production levels in their herds, smallholders in the Kenya highlands ranked lack of feed as the most important followed by lack of labour, poor animal performance and lack of cash to purchase inputs (Bebe *et al.,* 2002). Their feed management practises include the gathering of forages from common properties, the growing on small plots of napier grass (*Pennistetum purpureum*) and other fodder species, the feeding of crop residues and the purchase of forages and concentrates. The availability of crop residues and napier is dependent on the use of arable land whereas the purchase of fodder and concentrates requires access to cash, labour and access to the market centres supplying feeds.

Feed availability can have a large influence on the production performance of the dairy herd as farmers intensify from free-grazing to zero-grazing. Because of pressure on land and therefore pressure for feeds in smallholder systems, a frequent recommendation is the use of small mature sized dairy breeds (Guernsey and Jersey). The larger breeds (Friesian and Ayrshire) have higher nutritional demands and have performed poorly under smallholder feeding conditions (Kahi *et al.,* 2000; Ojango, 2000; Wakhungu, 2000). In practise smallholder farmers in the Kenya highlands prefer the larger dairy breeds because these breeds potentially have higher milk yields and a higher salvage value due to their heavier bodyweight, which matches farmers' needs for cattle as means of accumulating fluid capital assets (Bebe *et al.,* 2003a). Therefore, information regarding the influence of smallholders' feeding practices on dairy production performances is needed to effectively address the research and development needs of smallholders as they intensify from free-grazing to zero-grazing. The objective of this study was therefore to explore quantitative relationships between feeding practices and production performances of cattle breeds on smallholder dairy farms representing varying intensification levels in the Kenya highlands.

2. Materials and methods

2.1. Data source and collection

A detailed description of the study sites, survey methodology and herd management for the study population is presented in Bebe *et al*. (2003b). Only a brief description is given here.

A stratified random sample cross-sectional survey of 1755 households in the Kenya highlands was conducted between June 1996 and April 1998 to characterise the smallholder dairy systems supplying the Greater Nairobi urban market. Stratification was by agro-ecological potential (for cropping and dairying) and milk market access. The agro-ecological potential (medium and high) was according to land use defined by Jaetzold and Schmidt (1983). Milk market access (low, medium and high) was defined on the basis of human population densities, local demand for milk, types of roads and the availability of milk marketing institutions. Based on the 1989 population census, the total sample size represented approximately 1% of the total number of households. Data were collected through household interviews conducted in the local language by trained enumerators using a pre-tested, structured questionnaire.

Guided by the structured questionnaire, enumerators obtained both farm-level and individual animal performance data from each of the respondents. Households with cattle practised free-, semi-zero- or zero-grazing, representing increasing levels of intensification in dairy production. Data collected at the farm-level included farm size, land allocated to growing of food crops (maize, Irish potatoes, sweet potatoes, vegetables, beans), cash crops (coffee, tea, wheat, pyrethrum) and forage crops (napier, oats, forage legumes). The respondents were asked about changes in feed types used or purchased during the year prior to the survey and feeds not used or purchased ten years previously. Other farm-level data were herd size, sources of labour (family only and hired casual or permanent labour) and estimated costs of fodder and concentrates purchases in the past year.

Individual animal data were collected from each household keeping cattle. The variables included breed; age at first calving; milk yield on the day prior to the survey; the dates of the two most recent consecutive calvings; the date of the first known service post-calving and the date of drying-off for the most-recent calvings. The *Bos taurus* cattle breeds included Friesian, Ayrshire, Guernsey and Jersey and the *Bos indicus* breeds were East African Zebu, Boran and Sahiwal. The most frequent breed on a farm was recorded as the dominant breed kept by the household. Dates of calving, service and drying-off were used to compute days-open, lactation length and milk yield per day of lactation and per day of calving interval. Days-open was defined as the period between dates of calving and the subsequent pregnancy. As a check for days-open, the dates of two most-recent calvings and the date of subsequent post-calving service were used.

2.2. *Feed resource measures*

The total land owned by a household, the land allocated to maize and the land allocated to napier were considered to reflect access to own-produced feed resources and were computed in hectares per Tropical Livestock Unit (TLU) per year. The TLU units used were 1 for bull, 0.7 for cow, 0.5 for heifer and young bull, and 0.2 for calves. Purchased fodder and concentrates were considered to reflect the level of use of external feed resources and were computed in Kenya shillings per TLU per year (Ksh/TLU/y). The estimated hectares of napier planted (ha/TLU) and the costs (Ksh/TLU/y) of fodder and concentrates purchased during the year prior to the survey were considered as feed resource measures related to intensification. Changes in feeding practices over the last ten years were captured by calculating the proportion of households that purchased a given feed during the year prior to the survey but did not ten years previously.

2.3. Statistical analysis

Farm-household was the unit of analysis, stratified by ecological potential (medium and high) and milk market access (low, medium and high) giving six strata. In order that valid statistical inferences could be made from the sample to the study population, the sampling design was specified in the model using the SURVEYREG procedure of SAS (SAS, 1999). For a stratified design, the procedure pools stratum variance estimates to compute the covariance matrix. Wald's F-test and the t-test for estimators and effects are based on the estimated covariance matrix of the regression coefficients. The general linear model equation estimated was of the form:

$$Y = b_0 + b_1X_1 + b_2X_2 + ... + b_kX_k$$

where Y is the dependent variable, b_0 is the common intercept, $b_1 \dots b_k$ are the regression coefficients of each X (independent variables) and k is the number of independent variables in the model. Grazing system practised, breed kept, income level of the household, presence of hired labour, farm size, hectares of maize and napier planted and herd size owned were tested for their effects on fodder purchased. Except for hired labour, the same variables and membership of a co-operative society and distance to the nearest market centre were tested for their effect on purchased concentrates. Age at first calving, days-open, lactation length and milk yield per day of calving interval were measures of dairy production performance. These performance parameters were hypothesised to depend upon grazing system practised, breed kept, membership of co-operative society, available maize crop residues and napier, purchased fodder and concentrates, and the herd size. To compare breeds for production performance under varying systems, descriptive statistics (SURVEYMEANS procedure of SAS, 1999) of performance parameters were obtained for each breed in the free-, semi-zero- and zero-grazing farms. Some of the households did not report data on all variables. Complete records on fodder and concentrates purchased were available from 736 households, age at first calving from 545 households, days-open from 325 households, lactation length from 720 households and milk yield per day of calving interval from 575 households.

3. Results

3.1. Feed resources

Figure 1 shows the proportion of land allocated to food crops, cash crops and forage crops by smallholder households practising free-grazing, semi-zero-grazing, zero-grazing and those growing crops only. On average, the proportion of land allocated to growing of fodder crops increased from 9 to 22% as farmers intensified their feeding management regimes from free-grazing to zero-grazing. Households growing fodder was also highest amongst those practising zero-grazing (28%; P=0.001) than amongst those practising free-grazing (19%), semi-zero-grazing (4%) or with crops only (5%). Households with smaller farms (zero-grazing and crops only) allocated a larger proportion of their land to food crops, but the proportion of land allocated to growing of cash crops was not different amongst all household categories.

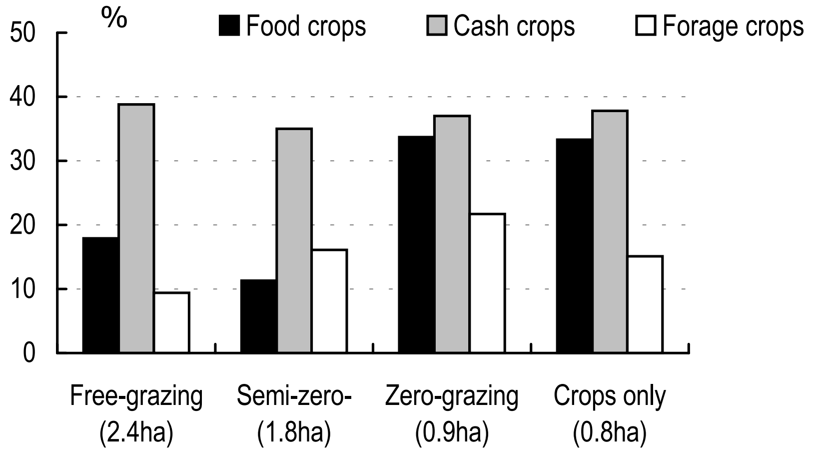

Figure 1. Proportion (%) of land allocated to food crops, cash crops and forage crops by households practising free-grazing, semi-zero-grazing, zero-grazing and growing crops only in the Kenya highlands

In free-, semi-zero- and zero-grazing farms, the average (with 95% confidence interval) hectares for each TLU of maize planted was 0.27 (0.23-0.30), 0.25 (0.20-0.30) and 0.18 (0.15-0.20), respectively. The corresponding averages for napier planted were 0.09 (0.06-0.11), 0.09 (0.05-0.12) and 0.13 (0.11-0.15), respectively. Thus, zero-grazing farms planted slightly more land in napier (1.4 times) compared to free- or semi-zero-grazing farms.

Figure 2 shows the number of households that reported feeding and buying basal and supplementary feeds during the year prior to the survey and not ten years previously. For the majority of those reporting, napier and crop residues were the major basal feeds and agro-industrial by-products formed the main supplementary feeds. Some households used poultry waste as an alternative supplement to concentrates. The changes in feeding practices over the past ten years reflect an increasing use of feed resources from outside the farms. For those reporting feeding napier or poultry wastes during the year prior to the survey and not ten years previously, a third (34%) purchased napier and over a third (38%) purchased poultry waste.

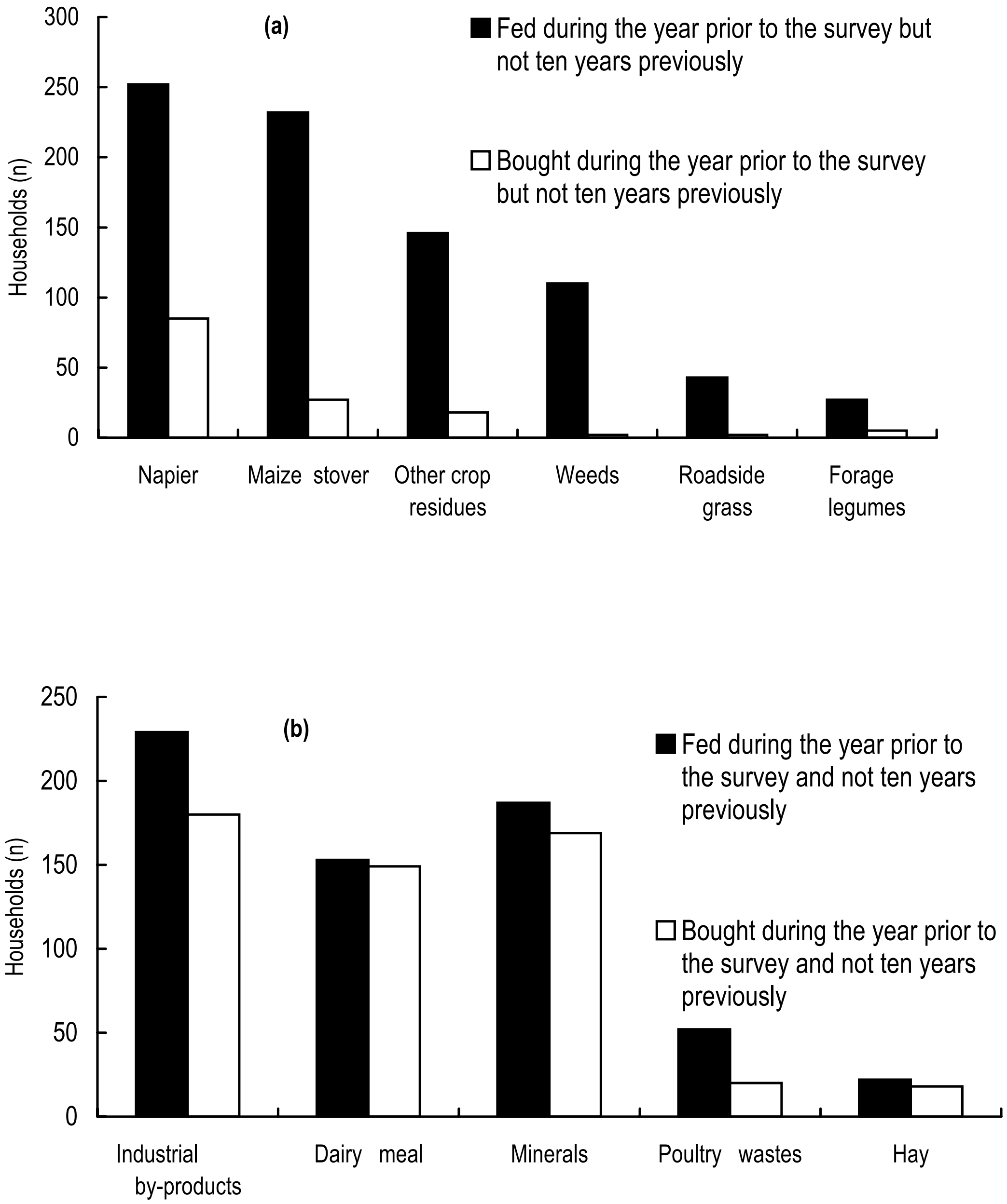

Figure 2. Number of households in the sample that reported feeding and buying the (a) basal and (b) supplementary feeds during the year prior to the survey but not ten years previously

Table 1 shows the regression estimates for fodder and concentrates purchased per TLU. Grazing system, the breed kept, maize hectares and herd size significantly influenced fodder purchased whereas area of napier planted did not. Farms where *Bos indicus* cattle dominated purchased less fodder (Ksh 580/TLU) than on those where

Guernsey/Jersey dominated (P=0.021), but the type of *Bos taurus* breed did not affect purchases of fodder and concentrates. Farms practising zero-grazing purchased more fodder for their animals (Ksh 371/TLU) than farms practising free-grazing (P=0.019). An additional 1 ha/TLU of maize reduced purchase of fodder by Ksh 409/TLU (P=0.033). Farmers who used hired labour tended to purchase more fodder (P=0.053). Purchase of fodder tended to relate negatively to farm size (P=0.083).

Farmers who were members of co-operative societies purchased Ksh 1025/TLU more concentrates than non-members (P=0.033). The purchase of concentrates per TLU increased with the increase in income levels and with the increase in hectares of planted napier; but reduced with the distance to a market centre, with the increase in farm size and with the increase in hectares of planted maize.

Table 1. Regression estimates for annual purchases of fodder and concentrates (Ksh/TLU/y) in smallholder farms in the Kenya highlands

Effect	Fodder purchased		Concentrates purchased	
	Estimate	P>|t|	Estimate	P>|t|
Intercept	697	0.009	2110	0.028
Grazing system				
Free-	ref.		ref.	
Semi-zero-	-95	0.478	-1863	0.068
Zero-	371	0.019	-407	0.689
Breed kept				
Guernsey/Jersey	ref.		ref.	
Bos indicus	-580	0.021	-369	0.589
Ayrshire	-171	0.560	3593	0.512
Friesian	-396	0.154	527	0.439
Income category (Ksh·month^{-1})				
<2500	ref.		ref.	
2500-5000	134	0.404	877	0.259
5001-10000	160	0.305	1251	0.008
>10000	276	0.237	2164	0.000
Hired labour (yes)	223	0.053	…	…
Co-operative member (yes)	…	…	1025	0.033
Distance to market centre (km)			-68	0.017
Farm size (ha/TLU/y)	-69	0.083	-80	0.023
Maize (ha/TLU/y)	-409	0.033	-1384	0.007
Napier planted (ha/TLU/y)	399	0.318	5642	0.002
Herd size (n)	25	0.040	116	0.063
Number of farms reporting	736		736	

An additional 1 ha/TLU of maize reduced the use of concentrates by Ksh 1384/TLU (P=0.007). Whereas availability of maize crop residues was negatively associated with purchase of feeds, an additional 1 ha/TLU of napier was associated with an increase of Ksh 5642/TLU of purchased concentrates (P=0.002). Farmers with larger herds tended to feed more concentrates (P=0.063) and those practising semi-zero-grazing tended to feed less concentrates compared to those practising free-grazing (P=0.068). Feeding of concentrates was, however, not related to the breed kept.

3.2. Age at first calving and days-open

Table 2 presents the factors tested for their effects on age at first calving and days-open. Age at first calving (average 32.4 months) was lower for farms feeding more concentrates (P=0.001) and tended to be lower for farms with larger herds (P=0.062). On farms practising zero-grazing age at first calving was 1.7 months lower than in those practising free-grazing (P=0.026) and farms where *Bos indicus* cattle dominated attained age at first calving 3.7 months later compared to those where Guernsey/Jersey breeds dominated (P=0.003).

Table 2. Regression estimates for age at first calving (months) and days-open (days) for dairy animals kept on smallholder farms in the Kenya highlands

Effect	Age first calving		Days-open	
	Estimate	P>|t|	Estimate	P>|t|
Intercept	32.4	0.000	289	0.000
Grazing system				
Free-	ref.		ref.	
Semi-zero-	-0.6	0.460	-38	0.2867
Zero-	-1.7	0.026	36	0.291
Breed kept				
Guernsey/Jersey	ref.		ref.	
Bos indicus	3.7	0.003	132	0.016
Ayrshire	1.3	0.126	78	0.067
Friesian	0.5	0.502	23	0.462
Co-operative member (yes)	-0.6	0.311	-33	0.217
Maize planted (ha/TLU/y)	0.3	0.737	15	0.704
Napier planted (ha/TLU/y)	-0.7	0.578	-47	0.388
Fodder purchased (Ksh/TLU/y)	-0.0003	0.769	-0.005	0.406
Concentrates (Ksh/TLU/y)	-0.0008	0.001	0.0005	0.555
Herd size (n)	-0.5	0.062	-14	0.045
Number of farms reporting	545		325	

With pair-wise comparisons, farms with Friesian dominating had earlier first calving age than those with *Bos indicus* dominating (P=0.004), but farms on which any of the *Bos taurus* breed dominated were not significantly different from the other. When individual animal breeds were considered (instead of the dominant breed on the farm), the difference in age at first calving between *Bos indicus* and *Bos taurus* breeds was much larger in free-grazing than in semi-zero- and zero-grazing farms (Figure 3). Differences between *Bos taurus* breeds were small on all farm categories.

Days-open (average 289 days) was 132 days longer for farms where *Bos indicus* cattle dominated compared to where Guernsey/Jersey breed dominated (P=0.016). Farms where Ayrshires dominated tended to have longer days-open than where Guernsey/Jersey dominated (P=0.067). On paired comparisons, days-open were shorter in farms where Friesian dominated than in those where *Bos indicus* dominated (P=0.003), but was not different between farms practising free-, semi-zero- or zero-grazing (Table 2). However, days-open was shorter in larger herds (P=0.045), but neither own-produced (as measured by areas of planted napier and maize) nor purchased feeds had significant effects on days-open (Table 2). When comparing pure breed groups for days-open, there were larger differences within grazing management regimes, but without a clear pattern for conclusive inferences (Figure 3).

3.3. Lactation length and milk yield

Table 3 shows that the average lactation length extended to 456 days. However, on average cows of members of farmers' co-operative societies had lactation lengths shorter by 107 days than those of non-members (P=0.038). No other factor had a significant effect on lactation length. Multiplying lactation length with milk yield per day of lactation (range 3.7 to 5.6 litres) gives total lactation milk yields of 2200 to 2239 litres for *Bos taurus* cattle and 1700 litres for *Bos indicus* cattle breeds.

Farms with Friesians as the dominant breed produced an extra 1 litre of milk per day of calving interval compared to those with Guernsey/Jersey dominating (P=0.047). An additional cow on the farm reduced milk yield by 0.4 litres per day, indicating that herd size and daily milk yield were negatively related (P=0.001). Breed performances in Figure 3 show that the *Bos indicus* cattle improved their milk production with the shift from free- to semi-zero and zero-grazing. The Guernsey/Jersey breed had the highest milk production in free-grazing farms. In general, the dairy breeds showed no marked differences in milk production in semi-zero- and zero-grazing farms.

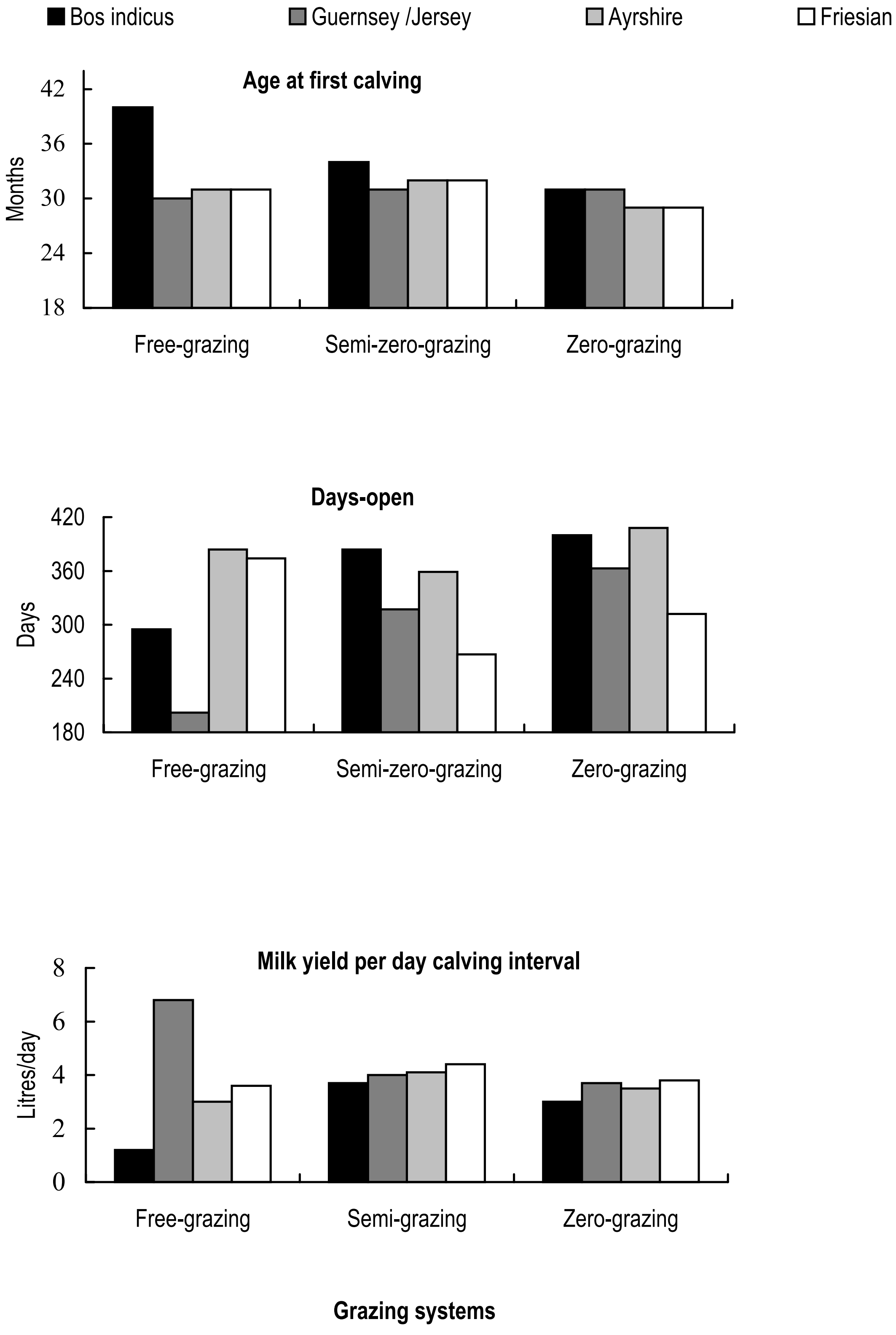

Figure 3. Mean age at first calving, days-open and milk yield per day of calving interval for cattle breeds in free-, semi-zero- and zero-grazing farms of smallholders in the Kenya highlands

Table 3. Regression estimates for lactation length (days) and milk yield (litres per day calving interval) in smallholder farms in the Kenya highlands

Effect	Lactation length		Milk yield	
	Estimate	P>|t|	Estimate	P>|t|
Intercept	456	0.000	3.7	0.000
Grazing system				
Free-	ref.		ref.	
Semi-zero-	43	0.395	-0.1	0.696
Zero-	48	0.435	0.2	0.683
Breed kept				
Guernsey/Jersey	ref.		ref.	
Bos indicus	-64	0.424	-0.7	0.151
Ayrshire	38	0.601	0.1	0.920
Friesian	30	0.659	1.0	0.047
Co-operative member (yes)	-107	0.038	0.9	0.005
Maize planted (ha/TLU/y)	63	0.374	0.1	0.924
Napier planted (ha/TLU/y)	-92	0.218	0.7	0.486
Fodder purchased (Ksh/TLU/y)	-0.001	0.930	-0.001	0.188
Concentrates (Ksh/TLU/y)	-0.002	0.797	0.0002	0.463
Herd size (n)	-10	0.399	-0.4	0.000
Number of farms reporting	720		575	

Table 4. Percentage (%) of households using only family and households using also hired labour by grazing system and breed kept

Source of labour	Grazing practised			Breed kept			
	Free-	Semi-zero-	Zero-	*Bos indicus*	Guernsey /Jersey	Ayrshire	Friesian
Family labour only	35.2	28.2	29.6	39.2	31.7	29.3	23.5
Casual labour only	36.3	48.1	53.0	35.1	53.8	52.5	50.1
Both casual and permanent labour	13.0	13.1	6.4	11.3	3.5	8.8	12.8
Permanent labour only	15.5	10.6	11.0	14.4	11.0	9.4	13.6
Number of households	227	326	434	217	157	189	424

3.4. Labour resources

Table 4 shows the distribution of labour sources for farms by grazing system and dominant breed kept. Family labour only was used by about a third of the farms and hired labour by about two-thirds. Hired labour, which was mainly on casual basis, increased with the intensification of production systems from free-grazing to zero-grazing (P=0.001) and with the change from *Bos indicus* to *Bos taurus* cattle (P=0.013).

4. Discussion

Smallholder farmers in the Kenya highlands are confronted by increasing pressure on land and therefore pressure for animal feeds. Consequently, they intensify their feeding management regimes from free-grazing to semi-zero- or zero-grazing. Intensification of feeding is through use of crop residues, and purchased forages and the greater use of planted napier fodder as basal diets, whereas agro-industrial by-products form the main supplementary feeds. Some households purchase poultry waste as an alternative cheaper source of protein instead of concentrates. Purchase of fodder is most frequently by use of hired labour to gather forages from common properties (road reserves, forests, schools). Use of hired labour increases with intensification (Table 4). Non-cattle households sell their crop residues and poultry waste to cattle-households and a few (5%) of them grow fodder for sale because of great demand for animal feeds, influenced by the change from using *Bos indicus* to *Bos taurus* breeds. In agreement with the observations of McIntire *et al.* (1992), the growing of fodder is more frequent in the areas of high market access where milk prices are higher than in areas of low and medium market access. The animal feed resource base of an individual household therefore extends to outside the farm, consistent with smallholder feeding practices observed in Asia (Zemmelink *et al.,* 1999a; Devendra and Sevilla, 2002).

Even with intensification of feeding practices, smallholders use mostly bulk feeds and not nutrient-dense feeds. Smallholders purchased less fodder and concentrates when more crop residues were available. An additional 1 ha/TLU of maize reduced the purchase of fodder by Ksh 409/TLU and the purchase of concentrates by Ksh 1384/ TLU (Table 1). In contrast, napier availability did not reduce purchase of feeds. An additional 1 ha/TLU of napier was associated with the purchase of more fodder (Ksh 399/TLU) and more concentrates (Ksh 5642/TLU). This does not imply that availability of more napier leads to the use of more concentrates; rather it reflects supplementation to offset the inadequate quantity of napier available on the farm. Another possible explanation is that larger herds grow less napier but use more hay. The reported on-farm dry matter yields of napier in the Kenya highlands average 16 tons/ha/y when using limited fertilizer (NDDP, 1994). However, in our study land allocated to napier averaged 0.13 ha/TLU in zero-grazing farms, which is much less than that recommended 0.33 ha/TLU (Muia *et al.,* 2000). Probably, farmers decide to grow food and cash crops on the same farm for subsistence and to supplement income (Figure 1).

Most smallholders use crop residues because they are cheaply available, although low in protein and very fibrous. The amounts available, however, are limited due to shrinking landholdings and the seasonality of the cropping seasons (Zemmelink *et al.,* 1999b). More low-quality feeds in the diet can help to maintain animals but cannot improve milk production and reproductive performance. Consequently, own-produced feeds had no significant influence on the production performance and larger herds had lower milk production (Table 3). Milk production and reproductive performances observed in smallholder systems of the Kenya highlands are typical to smallholder dairy systems elsewhere in Sub-Saharan Africa (Msanga *et al.,* 2000) and in Asia (Patil and Udo, 1997; Zemmelink *et al.,* 1999a). Improvement in age at first calving, days-open and milk yield only occurred with increased use of better quality supplementary feeding.

Use of better quality feeds is associated with higher incomes, shorter distance to source of supply and high farm-gate milk price that encourages additional investments. Feeding of concentrates is considered attractive when the milk/concentrates price ratio is greater than one (Walshe *et al.,* 1991). Kenya has an attractive prevailing milk/concentrates price ratio varying from 1.2 to 1.5, but regular use of concentrates by farmers is limited by cash flow, hence farmers use only limited amounts. The estimates in this study of Ksh 2110 of concentrates used in a year for each TLU indicates that farmers fed on average 0.5 kg of concentrates daily for each TLU. This is based on the prevailing cost of concentrates of about Ksh 11 per kg. With cows estimated at 0.7 TLU and comprising about 60% of the herd, it means that each cow is offered about 1 kg of concentrates per day. In practise, feeding is often opportunistic, characterised by intermittent and abrupt changes in the quantity and quality of feeds offered (Methu *et al.,* 2000). Consequently, the average lactation milk yield of dairy breeds on smallholder farms estimated at 1700 to 2240 litres is about two to three times lower than the yields obtained in the neighbouring large-scale commercial farms. Ojango and Pollott (2002) have reported an average yield of 4551 ± 1639 kg of milk in a lactation length of 300 ± 54 days in Kenyan large-scale commercial dairy herds. Compared to smallholders, large-scale commercial dairy farmers have better access to limited resources. They achieve higher production levels using better quality feeds such as total mixed rations (TMR), they follow a more consistent animal health programme and they frequently use imported semen of high genetic merit bulls.

For resource poor households, the priority objective for their cattle is to produce milk for feeding the family and then to have some marketable surplus while incurring minimal investment risks, particularly related to feeding practices (Bebe *et al.,* 2003a).

Consequently, the level of feeding is not related to expected nutritional requirements of the breed kept. Milk production levels were thus not significantly different amongst the dairy breeds (Figure 3), contrary to smallholders perceptions (Bebe *et al.,* 2003a). Smallholders did not realise higher milk yield when using the larger dairy breeds with higher potential for milk yield than when using smaller dairy breeds with lower potential for milk yield. Still, under these production conditions large dairy breeds have an advantage over smaller ones in that their heavier body weight attracts a higher market value when selling cows either for slaughter or to other farmers. This added value is critical in enabling the resource-poor households to accumulate and, when required, liquidize financial capital at times of emergency cash needs.

The long lactation lengths extending to 456 days reflect a conflict between the need to reduce reproductive wastage and the need to ensure milk supply as long as possible for feeding the family and for cash income. For cows to resume ovarian activity, they need regular supply of high energy concentrates feeds before and after calving to regain the weight above that they had at the time of calving (Balanos *et al.,* 1996; Ferguson, 1996). Being unable to ensure regular supplementary feeding, smallholders wait for cows to resume ovarian activity naturally. Consistent with this observation, a farm survey study of smallholder farms in the Kenya highlands reported that only 17% of the cows were inseminated within two months post-calving (NDDP, 1994).

In order to improve animal production performance above the levels presently attained, smallholders need adequate access to good quality feeds such as concentrates for supplementing the low-quality crop residues. One way that smallholders may have access to better quality feeds is joining a co-operative movement, through which they can obtain a regular supply of inputs on credit arrangements. Demonstrating the role of co-operatives in enabling smallholders to take investment risks, members of co-operatives fed more concentrates (Ksh 1025/TLU) and attained better dairy performances compared to non-members. Members of co-operatives are likely more committed to improving production performances because continued membership is subject to repaying the credits and services.

When aggregated at the farm level, milk yield per day of calving interval was 1 litre more where Friesians dominated compared to where Guernsey/Jersey dominated. A possible explanation for the differences at farm level is that farms where Friesians dominated tended to keep only Friesians, whereas farms where Guernsey/Jersey dominated also kept *Bos indicus* cattle. Among the *Bos indicus* breeds, Sahiwals were mainly kept in semi-zero- and zero-grazing farms, whereas in free-grazing farms more East African Zebu and Boran were kept, which possibly explains the improved milk production of the *Bos indicus* breed group with the shift from free- to zero-grazing farms. Compared to free-grazing, zero-grazing farms attained first calving 1.7 months earlier because of the dominance of *Bos taurus* breeds relative to *Bos indicus* cattle (Figure 3).

The associations between animal performance and feeding practices reported in this study are based on farmers' recall information. Respondents' memory, honesty and perceptions can influence the reliability and accuracy of such results. This could be an important cause of the large variation observed in the measures of feed availability and animal production performance. Longitudinal studies with short intervals between farm visits can improve the accuracy of the estimates compared to cross-sectional surveys. However, they are more expensive and information is usually obtained from fewer farms. A comparative study involving part of the present sample population had previously concluded that farmer-recall data gathered quickly was equally reliable as data gathered in longitudinal monitoring surveys because of the high variability of the data in these farming systems (Staal and Omore, 1998). In that study, lactation data from cross-sectional and longitudinal surveys had similar parameter estimates with comparable goodness-of-fit (R^2 0.25 vs 0.29).

5. Conclusion

Milk production and reproductive performances in smallholder dairy systems reflect low levels of feeding. Feeding practices by smallholders is characterised by use of low-quality bulk feeds with less risk in terms of investment requirements. Feeding to animal requirements is not a practice in resource driven farming systems because of cash flow limitations. Interventions to support continued intensification have to consider the overall economic situation of the household.

Acknowledgements

The first author was supported by a research grant from The Netherlands Foundation for the Advancement of Tropical Research-WOTRO. The authors acknowledge the support of the Smallholder Dairy (R&D) Project (SDP) of the Kenya Ministry of Agriculture and Rural Development, the Kenya Agricultural Research Institute (KARI) and the International Livestock Research Institute (ILRI) for this study. SDP was funded by the

UK Department for International Development (DFID) for the benefit of developing countries.

References

Balanos, J.M.; Meneses, A., Forsberg, M., 1996. Resumption of ovarian activity in zebu cows in the humid tropics: Influence of body condition and levels of certain blood components related to nutrition. Trop. Anim Hlth. Prod.28, 237-246.

Bebe, B.O., Udo, H.M.J, Thorpe, W., 2002. Development of smallholder dairy systems in the Kenya highlands. Outlook on Agric. 31, 113-120.

Bebe, B.O., Udo, H.M.J, Rowlands, G.J., Thorpe, W., 2003a. Smallholder dairy systems in the Kenya highlands: breed preferences and breeding practices (*Livestock Production Science*).

Bebe, B.O., Udo, H.M.J, Rowlands, G.J., Thorpe, W., 2003b. Smallholder dairy systems in the Kenya highlands: cattle population dynamics under increasing intensification (*Livestock Production Science*).

Devendra, C., Sevilla, C.C., 2002. Availability and use of feed resources in crop-animal systems in Asia. Agric. Syst. 71, 59-73.

Ferguson, J.D., 1996. Diet, production and reproduction in dairy cows. Anim. Feed Sci. Tech. 59, 173-184.

Jaetzold, R., Schmidt, H., 1983. Farm management Handbook of Kenya Vol.II. Part B, Central Kenya. Ministry of Agriculture, Nairobi, Kenya. pp 510-620.

Kahi, A.K., Thorpe, W., Nitter, G., Van Arendonk, J.A.M., Gall, C.F., 2000. Economic evaluation of crossbreeding for dairy production in a pasture based production system in Kenya. Livest. Prod. Sci. 65, 167-184.

McIntire, J., Bourzat, D., Pingali, P., 1992. Crop-Livestock interaction in Sub-Saharan Africa. World Bank Regional and Sectoral Studies. Washington DC.

Methu , J.N., Romney, D.L., Kaitho, R.J., Karuiki, J.N., 2000. Effect of abrupt and frequent changes in forage quality and the influence of patterns of concentrates feeding on the performance of dairy cattle. 3rd All Africa Conf. and 11th Egyptian Soc. Anim. Prod. Alexandria, 6-9th November, 2000. pp 47.

Msanga, Y.N., Bryant, M.J., Rutam, I.B., Minja, F.N., Zylstra, L., 2000. Effect of environmental factors and the proportion of Holstein blood on the milk yield and lactation lengths of crossbred dairy cattle on smallholder farms in Northeast Tanzania. Trop. Anim Hlth. Prod. 32, 23-31.

Muia, J.M.K., Tamminga, S., Mbugua, P.N., Kariuki, J.N., 2000. The nutritive value of napier grass (*Pennisetum purpureum*) and its potential for milk production with or without supplementation: A review. Trop. Sci. 40, 109-131.

NDDP, 1994. Results of Farm Survey in Murang'a district. Ministry of Agriculture, Livestock Development and Marketing, National Dairy Development Project, Hill Plaza, Nairobi.

Ojango, J.M., 2000. Performance of Holstein-Friesian cattle in Kenya and the potential for genetic improvement using international breeding values. PhD Thesis, Wye College, University of London, U.K. pp 182.

Ojango, J.M.K., Pollott, G.E., 2002. The relationship between Holstein bull breeding values for milk yield derived in both the UK and Kenya. Livest. Prod. Sci. 74, 1-12.

Patil, B.R, Udo, H.M.J., 1997. The impact of crossbred cows in mixed farming farms in Gujarat, India: milk production and feeding practices. Asian–Aust. J. Anim. 10, 253-259.

SAS, 1999. SAS Institute Inc, SAS/STAT User's Guide. SAS Institute Inc, Cary, NC, USA.

Staal, S.J., Omore, A., 1998. Use of farmer recall versus direct measurement in gathering lactation data: lessons from Kenyan smallholder dairy systems. In: BSAS/KARI Proc. Inter. Conf. Food, Lands and Livelihoods, Setting Research Agenda for Animal Science, 27-30 Januray 1998, Nairobi Kenya. pp184-185.

Wakhungu, W.J., 2000. Dairy cattle breeding policy for Kenyan smallholders: An evaluation based on demographic stationary state productivity model. PhD Thesis, College of Agriculture and Veterinary Sciences, University of Nairobi, Kenya. pp 164.

Walshe, M.J., Grindle, J., Nell, A., J., Bachmann, M., 1991. Dairy development in Sub-Saharan Africa: a study of issues and options. World Bank Tech. Paper No. 135. Africa Tech Dept Series.

Zemmelink, G., Premaratne, S., Ibrahim, M.N.M., Leegwater, P.H., 1999a. Feeding of dairy cattle in the forest-garden farms of Kandy, Sri Lanka. Trop. Anim. Hlth Prod. 31, 307-319.

Zemmelink, G., Romney, D.L., Kaitho, R.J., 1999b. Dairy farming in Kenya: Resources and nitrogen flows. In: Outcome and Perspective of Collaborative Research, 11th International Symposium on Tropical Animal Health and Production. Utrecht University, Faculty of Veterinary Medicine, The Netherlands, 5th November 1999. pp 46-50.

CHAPTER SIX

Smallholder dairy systems in the Kenya highlands: potential for producing dairy replacements under increasing intensification

B.O. Bebe[a,b,c], H.M.J. Udo[b], W. Thorpe[c]

[a]Animal Science Department, Egerton University, Box 536 Njoro, Kenya

[b]Animal Production Systems Group, Wageningen Institute of Animal Sciences, Wageningen University and Research Centre, P.O. Box 338, 6700 AH Wageningen, The Netherlands

[c]International Livestock Research Institute, P.O. Box 30709, GPO Nairobi 00100, Kenya

This chapter is to be submitted to Livestock Production Science

Smallholder dairy systems in the Kenya highlands: potential for producing dairy replacements under increasing intensification

Abstract

Smallholder dairy farmers in the Kenya highlands generally intensify their feeding management regimes from free-grazing to semi-zero- or zero-grazing, with resultant changes in the breed composition, size, structure and demographic rates of their herds. The question is whether smallholder herds can produce their own replacement stock in sufficient numbers needed to sustain the continuing shift to more intensification. A deterministic model was developed to estimate the potential production of replacement stock in representative low, medium and high intensive farming systems in the Kenya highlands. Farming households within a sub-location, the smallest administrative area in a district, were defined as the boundary of the farming system. The base situation in each farming system reflected the actual proportion of free, semi-zero- and zero-grazing farms and the size, structure and demographic rates of their herds. Model estimates at the base situation showed that all the farming systems produced replacements in sufficient numbers for maintaining and expanding the current dairy herd population, but the numbers decreased with increasing intensification. Sensitivity analyses showed that actions to effect decrease in cow mortality and then to reduce the proportion of heifers sold during the rearing period in free-grazing farms were the most promising interventions. Thus, prospects for maintaining and expanding smallholder dairying in the Kenya highlands are dependent upon the proportion of free-grazing farms maintained within the farming systems. Because increasing intensification reduced the availability of replacement stock within local areas, dairy adoption rates are projected to decline, particularly in the high intensive farming systems. It would be therefore a rational policy to promote intensification of smallholder dairying when other dairy production systems capable of producing replacement stock are functional.

***Key words**: Smallholder dairying; Intensification; Replacement stock; Kenya highlands*

1. Introduction

An insufficient supply of replacement stock is a major constraint to the development of smallholder dairy production in many developing countries (De Jong, 1996; Affi-Affat, 1998). In Kenya, public and private large-scale farms used to play an important role in producing dairy replacements for smallholder farmers (Conelly, 1998; Bebe *et al.,* 2002). A recent study of dynamics of smallholder herds in the Kenya highlands by Bebe *et al.* (2003a) has shown that nowadays smallholder farmers source dairy replacements mainly from fellow smallholders within their local farming systems and less frequently from large-scale farms because of high pricing and fear of poor adaptability. The study showed that farms practising free-grazing produce surplus replacements whereas those practising semi-zero- and zero-grazing (stall feeding), which comprise over three quarters of all smallholder dairy farms, are unable to produce sufficient dairy replacements to maintain their herds. With human population densities continuing to rise and landholdings to shrink in the Kenya highlands, free-grazing farms are shifting to semi-zero- or zero-grazing.

The intensification of smallholder farming takes place in many highland areas of Sub-Saharan Africa, Asia and South America (Jodha, 2000). The shift from free- to semi-zero- or zero-grazing may result in a need for externally produced dairy replacements and raises concern about the prospects for maintaining and expanding smallholder dairying. A deterministic model was therefore developed to assess whether there is the potential in smallholder farming systems to have self-replacing herds and to generate surplus dairy replacements for farmers aspiring to adopt dairying in the highlands and elsewhere in the country.

2. Materials and methods

2.1. Farming systems

Smallholder farming systems in the Kenya highlands representing low, medium and high levels of intensification have been described by Bebe *et al.* (2002). The farming households within a sub-location, the smallest administrative area in a district, are defined as the boundary of the farming system. Table 1 summarises the major distinguishing characteristics of the three farming systems.

Table 1. Distinguishing characteristics of low, medium and high intensive farming systems in the Kenya highlands

Characteristics	Farming system		
	Low intensive	Medium intensive	High intensive
Agro-ecological potential	High	Medium	High
Market access	Low	Medium	High
Population density (people/km^2)	206	288	583
Farm size (ha)	5.4	2.0	1.1
Stocking rate (TLU/ha)[a]	1.2	1.7	2.6
Milk production (litres/ha/day)	0.65	0.79	1.58
Proportion of milk consumed by household (%)	41	29	30
Purchased feeds (US $/year)	62	188	217
Returns to land from dairy (US $/ha)	334	343	555
Households (n)	1700	2500	1900
Households with cattle currently (%)	85	58	71
Households currently practising:			
Free-grazing farms (%)	23	32	27
Semi-zero-grazing farms (%)	72	49	8
Zero-grazing farms (%)	5	19	65
Households (%) that 10 years ago practised:			
Free-grazing farms (%)	27	53	37
Semi-zero-grazing farms (%)	67	30	25
Zero-grazing farms (%)	6	17	38

[a] TLU=1 for bull; 0.7 for cow; 0.5 for heifer and young bull; 0.2 for calves
Source: Based on Bebe *et al.*, 2002 and CBS, 2001

The low intensive farming systems are found in areas of high agro-ecological potential for cropping and dairying (Jaetzold and Schmidt, 1983), but market access is classified as low. Market access is defined on the basis of human population densities, local demand for milk, types of roads and the availability of milk marketing institutions (Staal *et al.,* 2001). The high intensive farming systems are found in areas of high agro-ecological potential with better market access. Medium intensive systems are in the medium agro-ecological potential areas with medium market access.

The relative proportions of households with free-, semi-zero- and zero-grazing farms vary with farming system. Proportionately, zero-grazing farms are more frequently found in high than in low intensive farming systems. This is related to human population densities, which are higher with the shift from low to high intensive systems. Consequently, farm and herd sizes are smaller but cattle stocking rates are higher with the shift from low to high intensive farming systems. As the size of herds decrease cows generally form a larger part of the herd and there are fewer or no replacement animals.

A characteristic pattern with the shift from low to high intensive farming systems is increased use of purchased feeds.

2.2. Model design

A dynamic deterministic model was developed to estimate the potential for producing dairy replacements in smallholder farming systems with varying intensification levels. Figure 1 shows the schematic representation of the model. The model is operated in Microsoft Excel®. Qualitative data to conceptualise the model relations and the quantitative data to quantify those relationships are based on the dynamics of smallholder dairy systems (Bebe *et al.,* 2002). Household input data are the total number of households and the proportions of free-, semi-zero- or and zero-grazing farms in each farming system. Herd input data are the size, structure and annual demographic rates of the herds for each type of farm management regime. The input values used for the base situation reflect smallholder dairying in the Kenya highlands.

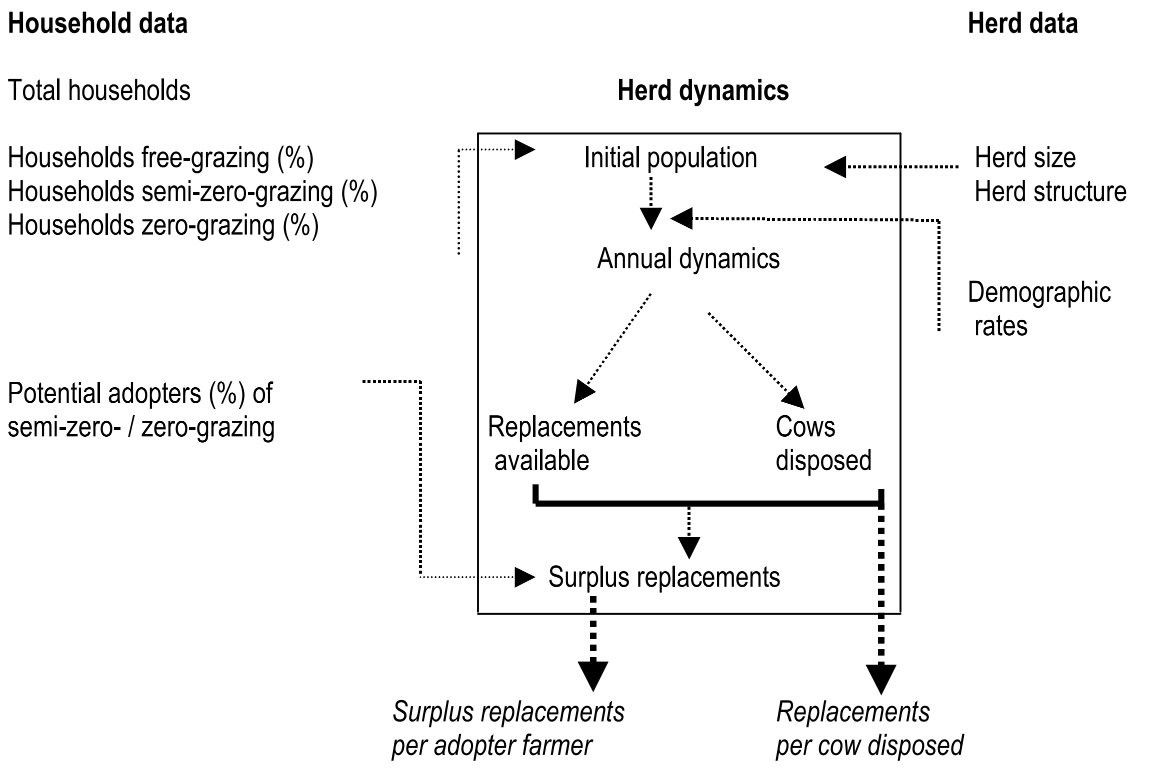

Figure 1. Schematic representation of the herd model used to project the potential for producing dairy replacements in three smallholder farming systems representing increasing intensification levels

Table 1 gives the household population, herd size and structure while Table 2 gives the cow age-structure distribution and the annual demographic parameters - calving rates, mortality rates, selling rates, buying rates - for each type of farm management regime. Simulation is performed for each farming system separately. The model calculates the initial herd population from the number of households with cattle given the size and structure of the herds. Herd projections assume that population growth only depends on female demographic rates. Males are not a limiting factor for the production of heifer replacements in smallholder systems. A herd comprises one class of heifer-calves (pre-weaned females), two classes of heifers (post-weaned females below one year and above one year until first calving) and eleven classes of cows (3 to 13 years of age).

2.2.1. Herd projections

The distribution of individual female animals over age groups in year t is given by a vector, $\mathbf{n}(t) = [n_1(t),\ldots, n_{14}(t)]$

where $n_1(t),\ldots,n_{14}(t)$ are the number of females in age group 1 to 14 in year t. This vector is linked from one year to the next by an age-transition matrix that contains the maximum likelihood estimates of annual birth rates and the survival rates for each animal class (Table 2) in projecting the population changes from year t to t+1. This population projection matrix **A** writes as:

$$\mathbf{n}(t + 1) = \mathbf{An}(t) \quad (1).$$

Survival from year t to t + 1 writes as $P_{i+1} = 1 - m - s + b$ (2)

based on Lesnoff (1999), where m is mortality rate, s is selling rate and b is buying rate associated with each animal class in a given farm type. Demographic rates apply to the population at the beginning of the year.

Table 2. Herd size, structure and demographic rates for free-, semi-zero- and zero-grazing farms in the Kenya highlands

Variables	Animal class	Farms practising		
		Free-grazing	Semi-zero-grazing	Zero-grazing
Herd size	All cattle	4.3	3.1	2.1
Herd composition	Heifer-calves	0.04	0.04	0.06
	Heifers	0.28	0.24	0.21
	Cows	0.51	0.55	0.62
Demographic rates				
Calving		0.69	0.51	0.52
	Heifer-calves	0.15	0.13	0.15
Mortality	Heifers	0.08	0.12	0.07
	Cows	0.13	0.14	0.12
	Heifer-calves	0.01	0.03	0.01
Selling	Heifers	0.07	0.09	0.15
	Cows	0.08	0.11	0.14
	Heifer-calves	0	0	0.01
Buying	Heifers	0.05	0.07	0.12
	Cows	0.02	0.04	0.09
	3 years	12.1	18.9	27.1
Cow age	4 years	12.4	16.6	14.8
distribution (%)	5 years	14.2	18.6	18.4
	6 years	16.5	13.1	13.4
	7 years	10.5	10.1	8.1
	8 years	11.3	8.6	5.8
	9 years	3.5	4.3	3.0
	10 years	9.5	4.2	5.5
	11 years	1.8	1.0	1.5
	12 years	3.2	2.1	1.2
	13 years	5.0	2.5	1.2

Source: Bebe *et al.*, 2003a.

2.2.2. Replacements needed to maintain herd size and surplus for the aspiring farmers

The number of replacement animals produced annually is calculated as females surviving to age at first breeding. This number is expressed as replacements available per cow leaving the herd, which includes all deaths and sales. Thus, this number has to be equal or greater than one (1) if the herd size is to be at least maintained. When it is below one (1), it implies that replacements outside the farming system have to be bought to maintain or expand the herd size. Any available replacements above the numbers needed to replace cows leaving the herd are surplus and are available for farmers wanting to expand their herd or who are potential adopters of dairy production. Potential adopters are defined as the sum of non-cattle-keeping households and those owning free-grazing farms presently who are most likely to adopt/or shift to semi-zero- or zero-grazing in future. Each potential adopter farmer is assumed to need one female dairy animal in order to start semi-zero- or zero-grazing dairy production. When the number of dairy stock per adopter farmer is above or equal to one (1), it implies that the available surplus replacement animals are sufficient for the aspiring farmers. The model results are presented as averages of a ten-year simulation period.

2.3. Sensitivity analyses

Sensitivity analyses evaluated the effect of the decrease in the proportion of free-grazing farms, and changes in annual calving rate, heifer-calf mortality rate, heifer selling rate and cow mortality rate on the number of replacements available for replacing cows leaving the herd and surplus for potential dairy adopter farmers. Relative to the base situation, the proportion of households annually changing from free- to semi-zero- or zero-grazing was set to vary from 1 to 5 percentage units. This was to reflect a 3 to 20% decrease in the proportion of free-grazing farms over a period of ten years estimated across the representative farming systems (Table 1) (Bebe *et al.,* 2002). The calculation was such that a decrease in numbers of free-grazing farms results in an increase of semi-zero- and zero-grazing farms. For instance, 2 percentage points decrease in free-grazing farms was accompanied with 1 percentage point increase in semi-zero- and zero-grazing farms, reflecting an equal chance of shifting to semi-zero- or zero-grazing farming. Changes of ±5 percentage units in annual demographic rates with respect to the base situation were made one at a time while keeping all other parameters at their original value. Changes in annual demographic rates were made in free-, semi-zero- or zero-grazing farms in each of the farming systems. A ±5 percentage unit annual variation in calving rates, heifer-calf mortality rates, cow mortality rates and in proportion of replacements sold during the rearing period, were considered feasible interventions on the basis of experiences with smallholder dairying reported in literature. Animal health interventions in smallholder herds in Kagera region of Tanzania reduced overall cattle mortality rate from 11.5 to 7% over a period of nine years (De Jong, 1996). The introduction of improved calf-rearing packages for smallholders in Bahati area in the Kenya highlands resulted in a 6% difference in calf mortality rate between test (49%) and control (43%) farms (Lanyasunya *et al.,* 1999).

3. Results

3.1. Basic situation

The projected number of replacements produced per cow leaving the herd in free-, semi-zero- and zero-grazing farms at the base situation was 1.40, 0.92 and 0.83, respectively. For the farming systems, the projected numbers were 1.08, 1.12 and 1.05 in the low, medium and high intensive farming systems, respectively (Table 3). This implies that free-grazing farms produced surplus dairy replacements, whereas semi-zero- and zero-grazing farms produced insufficient numbers required to maintain the existing herd size. The surplus replacements produced in free-grazing farms were sufficient for offsetting the deficits in semi-zero- and zero-grazing farms (Table 3). Consequently, all the three farming systems produced sufficient replacements needed to maintain and expand the existing herd size. The surplus replacements available were sufficient for 2, 3 and 5% of the potential adopter farmers on annual basis for a ten-year period in the high, medium and low intensive farming systems, respectively.

3.1. Decrease in the proportion of free-grazing farms

Figure 2 shows the effect of the decrease in the proportion of free-grazing farms on the production of replacements in the low, medium and high intensive farming systems. Although fewer replacements were produced as the proportion of free-grazing farms decreased, all farming systems produced sufficient numbers necessary to maintain the existing herd size even with 5 percent unit annual decrease in the proportion of free-grazing farms for a ten-year period.

Table 3. Annual average number of replacement stock produced per cow disposed and per potential dairy adopter farmer in low, medium and high intensive farming systems

Farming system	Replacements per cow leaving the herd	Surplus replacements per farmer at different proportions (%) of potential adopters				
		1%	2%	3%	4%	5%
Low intensive	1.08	4.9	2.4	1.6	1.2	1.0
Medium intensive	1.12	3.1	1.5	1.0	0.8	0.6
High intensive	1.05	2.1	1.0	0.7	0.5	0.4

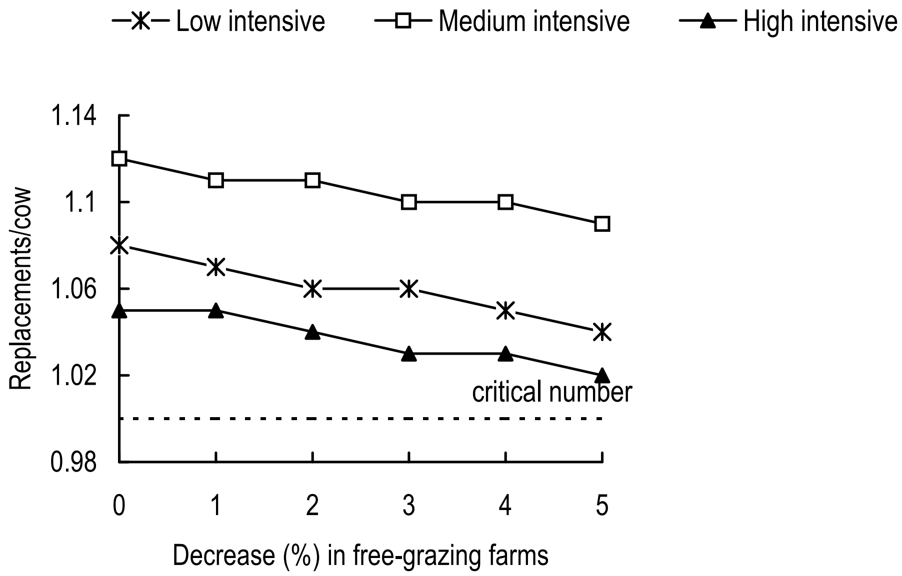

Figure 2. Effect of decrease in the proportion of free-grazing farms on the production of dairy replacements per cow leaving the herd in low, medium and high intensive farming systems

In the high intensive systems, however, a 5 percentage unit annual decrease in the proportion of free-grazing farms produced replacements only sufficient for maintaining the current herd size, none were available for potential adopter farmers (Figure 3). This was in contrast to the low and medium intensive farming systems in which a 5 percentage unit annual decrease in the proportion of free-grazing farms still produced sufficient surplus replacements for 3 and 2% adopter farmers, respectively (Figure 3). With a 2 percentage unit annual decrease in the proportion of free-grazing farms, surplus replacement animals available in the low, medium and high intensive systems were sufficient for 4, 3 and 1% adopter farmers, respectively (Figure 3). The availability of dairy replacements decreased with the decrease in proportion of free-grazing farms. The minimum proportion of free-grazing farms needed to maintain a self-replacing herd was respectively 14, 16 and 20% in the low, medium and high intensive farming systems.

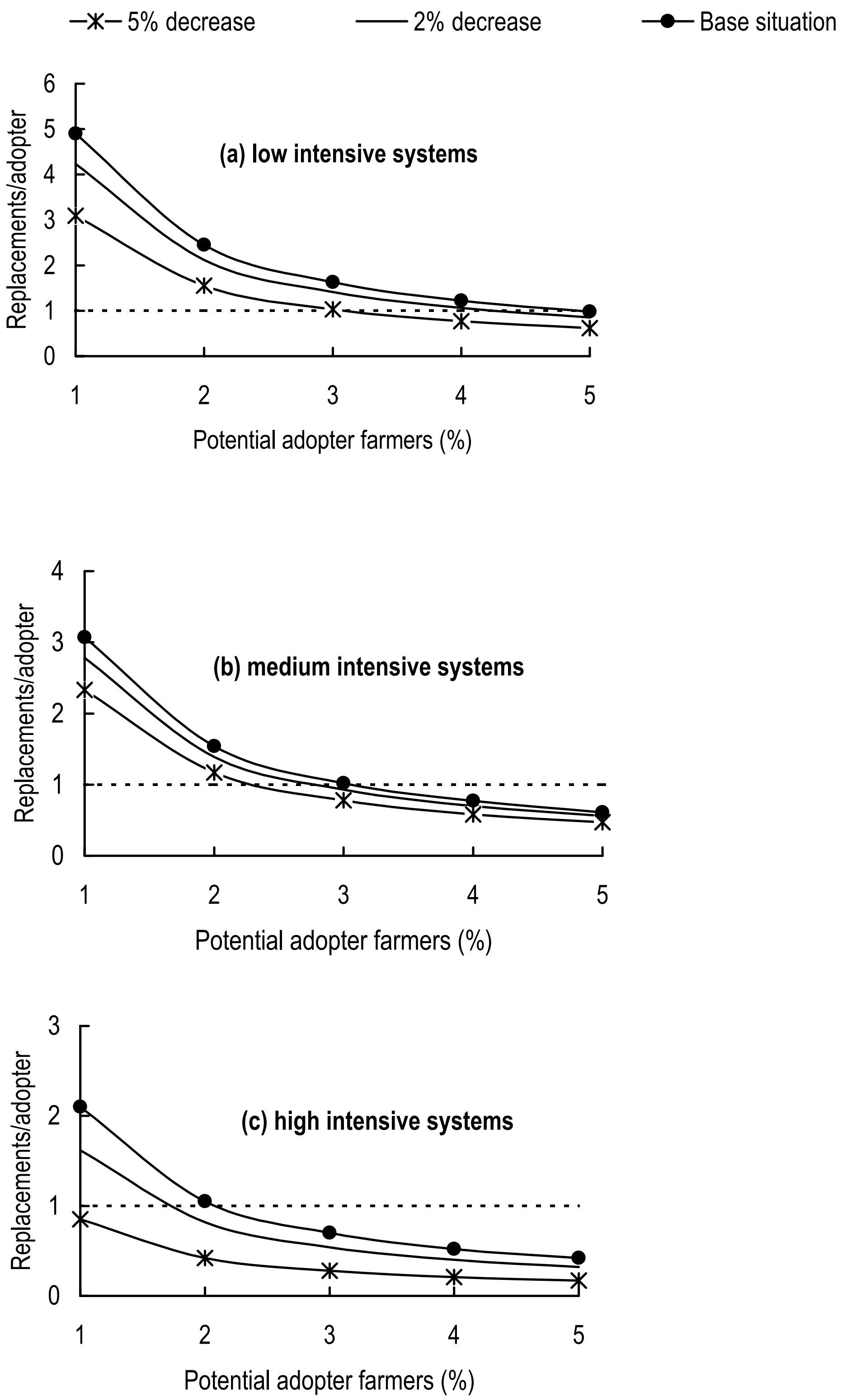

Figure 3. Effect of 2 and 5 percentage unit decrease in the proportion of free-grazing farms relative to base situation on the surplus replacements produced per adopter farmer in low, medium and high intensive farming systems

3.2. Changes in the demographic rates

Figure 4 shows the upper levels of the percentage change in the number of replacements per cow leaving the herd when ±5 percentage unit changes in annual demographic rates were made with respect to the base situation. Changes in annual demographic rates were made in free-, semi-zero- or zero-grazing farms in each of the farming systems. Percentage change in the number of replacements was consistently higher for changes made in free- than in semi-zero- or zero-grazing farms, indicating that interventions made in free-grazing farms are the most promising. Relative to the base situation, a decrease in cow mortality followed by decrease in proportion of heifers sold had the greatest percentage effect on the number of replacements produced. The effect of decreasing cow mortality ranged from 7.4 to 9.8% and the effect of decreasing the proportion of heifers sold ranged from 4.6 to 6.3%, across the farming systems. The effect of increasing calving rate or decreasing heifer-calf mortality rate was lower, ranging from 3.6 to 3.8% and 2.7 to 2.9%, respectively.

Table 4 shows the results of the evaluation of the effect of a 5 percentage unit decrease in cow mortality and proportion of heifers sold during the rearing period on the number of surplus replacements available for potential adopter farmers in each of the farming systems. The greatest change in available surplus replacements occurred when the decrease in cow mortality or proportion of heifers sold was made in free-grazing farms. Relative to the base situation, the proportion of potential adopters obtaining a dairy stock increased from 2 to 5% in high intensive systems, from 3 to 5% in medium intensive systems, whereas the available surplus stock almost doubled in the low intensive farming systems (see bold figures in Table 4). By contrast, a 5 percentage unit decrease in cow mortality or in the proportion of heifers sold in semi-zero- or zero-grazing farms did not improve the availability of dairy stock for adopter farmers relative to the base situation.

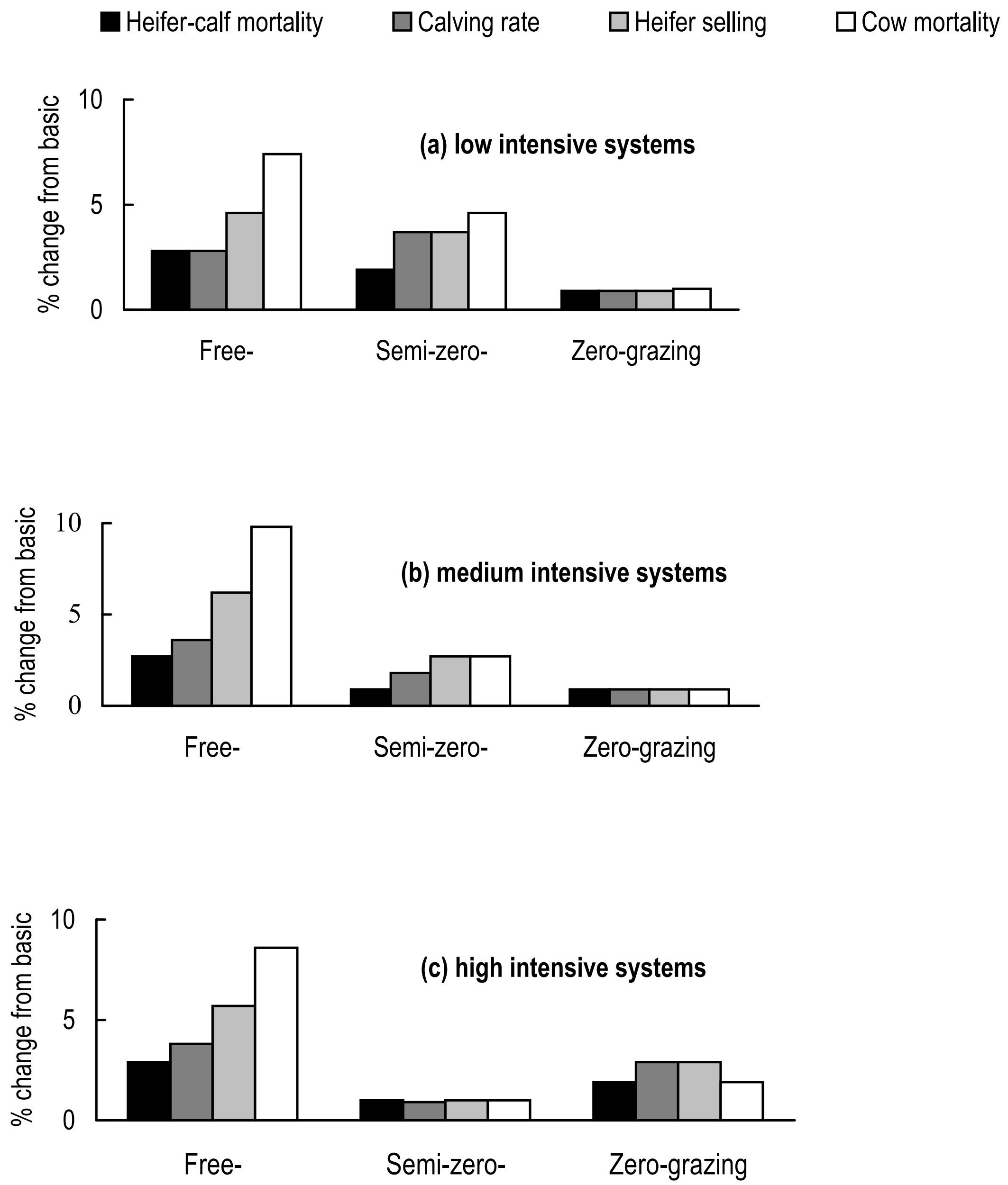

Figure 4. Upper levels of percentage (%) change relative to base situation in the number of replacements per cow leaving the herd resulting from ±5 percentage unit change in demographic rates made in free-, semi-zero- and free-grazing farms in low, medium and high intensive farming systems

Table 4. Effect of 5 percentage unit decrease in annual cow mortality and heifer selling rates on average number of replacements available for potential adopter farmers in low, medium and high intensive farming systems

Farming system	Farm where change effected	Surplus replacements per farmer at different proportions (%) of potential adopters				
		1%	2%	3%	4%	5%
				change in cow mortality rate		
	Base situation	4.9	2.4	1.6	1.2	**1.0** [a]
Low intensive	Free-grazing	10.1	5.0	3.4	2.5	**2.0** [a]
	Semi-zero-grazing	8.5	4.3	2.8	2.1	1.7
	Zero-grazing	5.0	2.5	1.7	1.2	1.0
	Base situation	3.1	1.5	**1.0** [a]	0.8	0.6
Medium intensive	Free-grazing	5.9	2.9	2.0	1.5	**1.2** [a]
	Semi-zero-grazing	4.0	2.0	1.3	1.0	0.8
	Zero-grazing	3.2	1.6	1.1	0.8	0.6
	Base situation	2.1	**1.0** [a]	0.7	0.5	0.4
High intensive	Free-grazing	5.7	2.9	1.9	1.4	**1.1** [a]
	Semi-zero-grazing	2.3	1.2	0.8	0.6	0.5
	Zero-grazing	2.8	1.4	0.9	0.7	0.6
				change in heifer selling rate		
	Base situation	4.9	2.4	1.6	1.2	**1.0** [a]
Low intensive	Free-grazing	8.6	4.3	2.9	2.1	**1.7** [a]
	Semi-zero-grazing	7.9	4.0	2.6	2.0	1.6
	Zero-grazing	5.0	2.5	1.7	1.3	1.1
	Base situation	3.1	1.5	**1.0** [a]	0.8	0.6
Medium intensive	Free-grazing	5.1	2.5	1.7	1.3	**1.0** [a]
	Semi-zero-grazing	3.9	1.9	1.3	1.0	0.8
	Zero-grazing	3.2	1.6	1.1	0.8	0.7
	Base situation	2.1	**1.0** [a]	0.7	0.5	0.4
High intensive	Free-grazing	4.7	2.3	1.7	1.3	**1.0** [a]
	Semi-zero-grazing	2.3	1.1	0.8	0.6	0.5
	Zero-grazing	3.1	1.5	1.0	0.8	0.6

[a] Critical level at which a potential adopter farmer is sure of obtaining a dairy animal

4. Discussion

Smallholder dairy farmers in the Kenya highlands generally intensify their dairy production from free-grazing to semi-zero- or zero-grazing, with resultant changes in the size, structure and demographic rates of their herds. A typical zero-grazing farm is one hectare with a herd of one to three dairy cattle, generally Friesian or Ayrshire females, which may not include a replacement heifer (Bebe *et al.,* 2003a; Bebe *et al.,* 2003b).

Many smallholder households intensify their farming systems through dairy production in order to increase the intensity of land-use and income generation. Development agencies encourage intensification as a way of meeting the increasing demand for foods of animal origin by the growing rural population and wealthier urban consumers and to provide smallholders with a sustainable pathway out of poverty through asset building (MoA, 1998; Delgado *et al.,* 2001). An important question is whether there is the potential from within the smallholder herds for producing dairy stock in sufficient numbers needed to sustain the continuing shift to more intensification. A deterministic model was used to estimate the potential production of replacement stock in representative low, medium and high intensive farming systems. Input values for the base situation reflected the prevailing levels of production performances. The model estimated a potential production of 5 to 12% of surplus dairy replacements with regard to maintaining the current herd population in the low, medium and high intensive farming systems. Consequently, on an annual basis, 2 to 5% of aspiring dairy farmers could obtain dairy foundation stock within their farming systems to start intensive dairy production under semi-zero- or zero-grazing management regimes. Proportionately, farmers obtaining dairy foundation stock decreased with the shift from low to high intensive farming systems, indicating a likely decrease in the adoption rate of dairy production in high intensive farming systems. That available replacement stock in these farming systems was sufficient for maintaining current herd size and for aspiring farmers is attributable to the valuable complementarities or stratification between free-grazing farms and semi-zero- and zero-grazing farms. The semi-zero- and zero-grazing farms, which have insufficient replacements, provide a market for the free-grazing farms, which have surplus replacements.

Because the availability of replacement animals decreased with the decrease in the proportion of free-grazing farms (Figure 2), the potential for maintaining the current herd size and continued intensification of dairy production is dependent upon the proportion of free-grazing farms maintained in the farming system. The potential production of replacements was highest in the medium intensive farming systems where the proportion of free-grazing farms was also the highest (32%) (Tables 1 and 3). The potential was lowest in the high intensive systems where the proportion of zero-grazing farms was the highest (65%) relative to those found in the low (5%) and medium

(19%) intensive farming systems (Table 1). For supplying replacements to maintain the herd or to continue intensifying, the critical minimum proportion of free-grazing farms that needed to be maintained was higher in high intensive systems (20%) than in low (14%) and medium (16%) intensive farming systems. To ensure that a certain minimum proportion of free-grazing farms are maintained within farming systems is a crucial policy issue since an estimated 80% or more of the domestic dairy herd is in smallholder farms: the majority of replacement stock has to be generated from within the smallholder herds. Smallholders cannot be expected to ensure this with human population densities continuing to rise and landholdings to shrink in the Kenya highlands. Popularising free-grazing dairy production and their important role among smallholders is one option for policy approach. The other option is for the policy to initiate some land reforms that discourage fragmentation and subdivision of farms. This can work for the medium (10 to 20 ha) to large-scale (above 20 ha) farms. These are necessary initiatives because intensification has to be accompanied by measures to supply dairy stock for the intensive farms and for the aspiring farmers.

The free-grazing farms produced more surplus replacements because more replacements are reared to breeding age, and animals leaving the herd annually through sales are lower than in semi-zero- and zero-grazing farms (Table 2). This major difference in the herd dynamics is related to changes in management practices when smallholders intensify their systems. On average, free-grazing farms are larger, their animals graze on the farmers' own land or on communal lands. These farms may keep a bull. In contrast, semi-zero or zero-grazing farms are generally smaller, they maintain smaller herds with preference for cows, which they feed partly on purchased fodder and concentrates (Bebe *et al.,* 2003c).

The most promising intervention to producing sufficient replacements for maintaining or expanding the current herd population was a decrease in cow mortality in free-grazing farms (Figure 4 and Table 4). In the Kenya highlands, involuntary losses of animals in smallholder farms are mainly due to tick-borne diseases and parasitic worm infestations, and their interactions with inadequate quantity and quality of feeds (Gitau *et al.,* 1997; Bebe *et al.,* 2003c). Despite the adoption of tick control practices by smallholder farmers in the Kenya highlands (Batz *et al.,* 1999), losses attributable to tick-borne diseases remain high. This arises from high exposure to ticks (even in zero-grazing farms through forages brought from common properties). In addition, animal health practices are implemented inconsistently (because of limited cash flow) and under-nutrition of animals is common. Interventions to lower cow mortality rates require that smallholders have adequate access to animal feeds and health services and use of cattle genotypes with better tolerance or resistance to the prevalent tick-borne diseases.

Compared to herds in free-grazing farms, those in semi-zero- and zero-grazing farms have lower calving rates and higher voluntary exits of cows and heifers (Table 2) such that a decrease in cow mortality rate alone only marginally improved the number of replacements produced. This implies that improving production of dairy replacements in semi-zero- and zero-grazing farms requires a concomitantly improved calving rate and decreased voluntary exit of potential replacement animals. This may be difficult for households without better alternative access to cash as 60 to 85% of the voluntary exits of animals are for meeting immediate cash needs of the household (Bebe *et al.,* 2003a). After decreasing cow mortality, decreasing the proportion of heifers sold during the rearing period had the greatest effect on the number of replacements produced (Figure 4 and Table 4). The rearing of replacements, however, requires cash inputs for feed, veterinary services, housing and labour. Income is only generated when the animal is sold or is lactating. Reducing the rearing costs requires increased growth rate in order to attain adequate body weight for earlier breeding. So, long-term investments are expected from the farmers (Heinrichs, 1993; Mourits *et al.,* 1999), which is difficult given the poor economic situation and the pressure smallholder households face in providing for their daily livelihood. Nevertheless, purchasing a replacement from the market is a costly option because of a general short supply of dairy stock (MoA, 1998; Bebe *et al.,* 2001). The very minimal flow of dairy stock from large-scale to smallholder farms (Bebe *et al.,* 2003a) may be partly due to unavailable surplus replacements from large-scale farms. Consequently, farmers practising semi-zero- and zero-grazing may attempt to rear their own dairy replacements in order to avoid problems of obtaining a replacement stock of the desired genotype and quality at the time when needed at an acceptable price.

The improvements obtained with a 5 percentage unit decrease in cow mortality rate and proportion of heifers sold during rearing period relative to the base situation may represent upper limits of the feasible improvements on production of replacement stock. Subsidised heifer-rearing schemes and heifer-in-trust projects to support smallholders in the rearing of dairy replacements have generally proved to be unsustainable at project and farmers' levels. Experiences with smallholders in Tanzania and Sri Lanka, for instance, showed that smallholders did not continue with the recommended management practices beyond the period of project support (De Jong, 1996; Afifi-Affat, 1998). Nevertheless, projections over time from deterministic models are a useful basis for exploring the dynamics of livestock populations under different farming systems and different interventions either for development planning or for productivity assessment (Upton, 1989; Wakhungu and Baptist, 1992; Lesnoff, 1999). The projections can be made on the basis of the number of farming households, and the size, structure and demographic rates of their herds for different farm management regimes. The model results confirmed the need for alternative sources of replacements for farms practising semi-zero- and zero-grazing farms. The results explained the current practice in which smallholders buy most (90%) of their dairy replacements from fellow smallholders within their farming systems because of the availability of surplus replacements produced on free-grazing farms (Bebe *et al.,* 2003a). Although annually 2 to 5% potential adopters could obtain dairy foundation stock, it should be noted that the proportion of adopter farmers depended upon the numbers of households in the farming system. Thus, medium intensive systems with the highest number of surplus replacements available had lower proportion of adopters compared to low intensive systems (Table 3 and Figure 3) because of more potential adopter farmers.

4. Conclusion

For smallholder farming systems in the Kenya highlands, supply of dairy replacement stock is dependent upon the proportion of free-grazing farms maintained in the system. Decrease in the proportion of free-grazing farms lead to scarcity of dairy stock, implying that adoption of dairy production by smallholders is likely to decrease in areas of high intensive farming systems where two-thirds of the farms already practise semi-zero or zero-grazing. The adoption of dairying can be expected to increase more in the low and medium systems than in high intensive systems where there is relatively lower potential for the supply of dairy stock. These low and medium intensive systems respectively correspond to areas of low and medium market access, and will need improvement in the marketing infrastructures and institutional policies to support marketed dairy production. Results of this study imply that it would be a rational policy to promote intensification of smallholder dairying when other dairy production systems capable of producing replacement stock are functional.

Acknowledgements

The first author was supported by a research grant from The Netherlands Foundation for the Advancement of Tropical Research-WOTRO. The authors acknowledge the support of the Smallholder Dairy (R&D) Project (SDP) of the Kenya Ministry of Agriculture and Rural Development, the Kenya Agricultural Research Institute (KARI) and the International Livestock Research Institute (ILRI) for this study. SDP was funded by the UK Department for International Development (DFID) for the benefit of developing countries.

References

Afifi-Affat, K.A., 1998. Heifer-in-Trust: a model for sustainable livestock development? World Anim. Rev., 91:13-20.

Batz, F.J., Peters, K.J., Janssen, W., 1999. The influence of technology characteristics on the rate and speed of adoption. Agric. Syst. 21, 121-130.

Bebe, B.O., Abdulrazak, S.A., Ogore, P.O., Ondiek, J.O., Fujihara, T., 2001. A note on risk factors for calf mortality in large-scale dairy farms in the tropics: a case study on Rift Valley area of Kenya. Asian-Aust. J. Anim. Sci. 14:855-857.

Bebe, O. B., Udo, H.M.J, Thorpe, W., 2002. Development of smallholder dairy systems in the Kenya highlands. Outlook on Agric 31:113-120.

Bebe, O. B., Udo, H.M.J, Rowlands, G.J., Thorpe, W., 2003a. Smallholder dairy systems in the Kenya highlands: cattle population dynamics under increasing intensification (*Livestock Production Science*).

Bebe, B. O., Udo, H.M.J, Rowlands, G.J., Thorpe, W., 2003b. Smallholder dairy systems in the Kenya highlands: breed preferences and breeding practices (*Livestock Production Science*).

Bebe, O. B., Udo, H.M.J, Thorpe, W., 2003c. Smallholder dairy systems in the Kenya highlands: feeding practices and production performance under increasing intensification.

C.B.S, 2001. The 1999 population and housing census Volume I. Population distribution by administrative area and urban centres. Central Bureau of Statistics, Ministry of Finance and Planning, Nairobi, Kenya.

Conelly, W.T., 1998. Colonial Era Livestock Development Policy: introduction of improved dairy cattle in high potential farming areas of Kenya. World Development. 26, 1733-1748.

De Jong, R., 1996. Dairy stock development and milk production with smallholders. PhDThesis, Department of Animal Production Systems, Wageningen Agricultural University, The Netherlands. 303 pp.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., Courbois, C., 2001. Livestock to 2020: the next food revolution. Outlook on Agric. 30, 27-29.

Gitau, G.K., Perry, B.D., Katende, J.M., McDermott, J.J., Morzaria, S.P., Young, A.S., 1997. The prevalence of serum antibodies to tick-borne infections in cattle in smallholder dairy farms in Murang'a district, Kenya: a cross-sectional study. Prev. Vet. Med. 30, 95-107.

Heinrichs, A.J., 1993. Raising dairy replacements to meet the needs of the 21st century. J. Dairy Sci. 76, 3179-3187.

Jaetzold, R., Schmidt, H., 1983. Farm management Handbook of Kenya Vol.II. Part B, Central Kenya. Ministry of Agriculture, Nairobi, Kenya. pp 510-620.

Jodha, S.N., 2000. Livestock in Mountain/Highlands production systems: Challenges and opportunities. In: Tulachan, P.M., Saleem, M.A.A., Maki- Hokkonen, J., Partap, T. (Eds), Contribution of livestock to mountain livelihoods: Research and Development Issues, International Centre for Integrated Mountain Development (ICIMODD), pp. 43-56.

Lanyasunya, T.P., Wekesa, F.W., De Jong, R., Udo H., Mukisira, E.A., Ole Sinkeet, N.S., Effects of a calf rearing package introduced to smallholder dairy farms in Bahati division, Nakuru district, Kenya. In: Proc. 6th Biennial KARI Scientific Conf. 9-13 November, 1998, Nairobi, Kenya. pp. 450- 457.

Lesnoff, M., 1999. Dynamics of a sheep population in a Sahelian area (Ndiagne district in Senegal): a periodic matrix model. Agric. Syst. 61, 207-221.

MoA, 1998. Kenya Dairy Development Policy: Towards the development of a sustainable dairy industry, Ministry of Agriculture, Nairobi, Kenya.

Mourits, M.C.M., Huirne, R.B.M., Dijkhuizen, A.A., Kristensen, A.R., Galligan, D.T., 1999. Economic optimisation of dairy heifer management decisions. Agric. Syst. 61, 17-31.

Staal, S.J., Owango, M., Muruiki, H., Kenyanjui, M., Lukuyu, B., Njoroge, L., Njubi, D., Baltenweck, I., Musembi, F., Bwana, O., Muruiki, K., Gichungu, G., Omore A., Thorpe, W., 2001. Dairy Systems Characterisation of Greater Nairobi Milk Shed. SDP (Smallholder Dairy (R&D) Project) Research Report, Ministry of Agriculture, Kenya Agricultural Research Institute and International Livestock Research Institute, Nairobi, Kenya. 73 pp.

Upton, M., 1989. Livestock productivity assessment and herd growth models. Agric. Syst. 29, 149-164.

Wakhungu, J.W., Baptist, R., 1992. Reproductive wastage and mortality components in dairying: an impact analysis method for sustained production systems. Jr. Zimbabwe Soc. Anim. Prod. 176, 45-50.

CHAPTER SEVEN

General Discussion

General Discussion

1. The motive for this study

The current development focus on intensification of livestock production through smallholder dairying is centred on two issues. One, providing for smallholders a sustainable pathway out of poverty through asset building (De Haan *et al.,* 2001). Two, improving the capacity of the developing countries to adequately meet the growing demand for foods of animal origin by their growing rural and urban populations (Delgado *et al.,* 2001). Central to achieving these objectives is how to sustain the benefits of dairying for smallholders faced with continuously shrinking landholdings, worsening soil fertility and reduced access to formerly public delivered livestock input and output services, while confronting the lack of non-agricultural job opportunities. Effective support of continued intensification requires that development agencies have a better understanding of the dynamics of intensification of smallholder dairying, which is critical to identifying and effectively addressing the research and development needs of smallholder dairy farmers. The objective of this study was therefore to quantify the consequences of the intensification of farming systems in the Kenya highlands on the dynamics of smallholder dairy herds in order to better understand the constraints to, and opportunities for, the continued intensification of smallholder agriculture through dairying.

2. Study methodology

By definition, intensification is about relative changes in input and output relations in the production systems. In order to draw conclusions about the relative changes, it is necessary to have a reference production system within a specified context (Gass and Sumberg, 1993; Wolmer, 1997). Therefore, we linked historical development perspectives with current patterns of relative changes in inputs and outputs in smallholder farms in the Kenya highlands. This target population has a long history of, and diverse potentials for, dairy development (chapter two). The target population was stratified by agro-ecological potential (medium and high) for cropping and dairying, and milk market access (low, medium and high) because these have a major influence on the development of smallholder dairy production systems in developing countries. The farming households sampled from within this stratification represented varying levels of intensification in which relative changes could be identified and quantified to gain insights into the dynamics of intensification.

Rather than collect data in a single cross-sectional survey from households where record keeping is absent, follow-up surveys were conducted to improve the reliability of the information in order to achieve both empirical breadth and depth in the results (Verschuren and Doorewaard, 1999; Noordhuizen *et al.,* 2001). The data from the stratified cross-sectional survey sample was complemented with additional information from longitudinal and targeted semi-structured interviews, which involved a randomly selected sub-sample of the cross-sectional survey.

The effects of intensification may vary at farm and at farming system levels. For instance, intensification of Dutch livestock production has led to fewer but larger farms with larger herds maintained with heavy use of imported feeds. Meanwhile the intensification phase in Kenya is different: farms are getting smaller with smaller herds, and correspondingly the number of individual holdings and the overall cattle population have increased, without significant importation of nutrients (chapter five), thereby putting pressure on local feed resources. Increasing intensification was thus studied at the level of the farm and farming systems. The shift from free- to zero-grazing represented increasing levels of intensification at the farm level and the proportion of zero-grazing farms within a defined farming area was the basis for defining the low, medium and high intensive farming systems. Results from the various models (parametric, non-parametric and simulation) applied to estimate the effects of intensification had a consistent pattern at both farm and farming system levels. The data collection methodologies and the analytical techniques used proved relevant for the research questions. Results of this study have been presented to farmers and other stakeholders including policy makers in feedback workshops, in local bulletins, in national and international conferences. These fora served to debate how best to address policy, institutional and technical constraints in the intensification of smallholder agriculture through dairying.

3. Intensification of smallholder dairying

3.1. The drivers of the intensification of smallholder dairying

A combination of factors can be associated with the intensification of smallholder agriculture through dairying in the Kenya highlands relative to the lowlands and to neighbouring countries (chapter two). Agro-ecology favourable to dairy production attracted colonial settler farmers, who developed essential infrastructures, input services and output market organisations to support their marketed dairy production. In using the local communities as source of labour force, colonial settler farmers introduced dairy husbandry technologies to smallholders. Driven by their strong tradition for cattle keeping and milk consumption, smallholders progressively adopted and modified those technologies in their production systems. At various phases of dairy development, smallholders progressively gained increased access to the use of dairy infrastructures previously only serving colonial settler farmers.

Policies of the development agencies (the government and donors) and households' objectives have influenced the subsequent intensification of smallholder agriculture through dairying. One, it was a government development policy to redistribute former large-scale farms and dairy cattle to smallholders soon after independence. Two, demographic changes effected subdivision of family land through inheritance. Three, a strong donor support for intensive smallholder dairy technologies as a source of income for resource-poor households. Four, a widespread dissemination of intensive dairy management technologies such as zero-grazing packages and artificial insemination service (AI). Five, local market opportunities for dairy presented by the traditionally milk consuming communities and the rapid growth in rural and urban populations. Six, limited creation of alternative employment in other sectors of the economy forcing government to direct development efforts to smallholder agriculture, with emphasis on dairying.

Currently, increasing intensification is closely correlated to trends in human population pressure on land, and access to, and availability of, agricultural support services (chapter two). These explain the difference in intensification levels for areas with similar (high) agro-ecological potential: low intensive systems represented by Nyandarua district and high intensive systems represented by Kiambu district (chapter two and six). Relatively, the latter district has higher human population densities, is closer to the major Nairobi urban consumption centre, has a better road network and has better access to breeding and animal health services. Consequently, the proportion of farms practising zero-grazing is highest in the high potential agro-ecological zone with better market access.

The widespread adoption of dairy production by smallholders in Kenya is a contrast to its relatively low adoption rate in neighbouring countries. These countries have had a slow development of smallholder dairy production due to a less favourable agro-ecology (higher temperatures, mono-modal rainfall and poorer soils), large areas of endemic trypanosomiosis, and, until recently, a lack of market mechanisms to encourage production of marketable milk surplus from pastoral systems. Policies and institutional environments conducive to smallholder dairying were not pursued from independence in the neighbouring countries. The lesson here is that conducive socio-economic policies are important in mediating accesses to input and output markets, to support the intensification of smallholder farming systems through the adoption of dairying.

3.2. Intensification of dairying in alleviating poverty and improving food security

Dairy production systems in Kenya can largely be classified as large or small scale, with smallholders owning over 80% of the 3 million head of the dairy cattle and producing over 70% of the total milk production and of the marketed milk (chapter two). Smallholder dairying is concentrated in the highlands, where about 60% of the smallholder households currently practise marketed dairying and 80% of them are intensive systems, either semi-zero- or zero-grazing farms (chapter three). These intensive smallholder dairy systems contribute significantly to availing an increasing per capita milk availability, estimated at an annual average of 85-90 kg of liquid milk (Nicholson *et al.,* 2001). This is four times higher than the availability in Ethiopia and Tanzania and double that of Zimbabwe.

Food security for the household is the primary objective of smallholders for keeping cattle, followed closely by income generation through marketing of surplus milk (chapter four). Intensification through dairying has enabled smallholder households to maintain more people per unit land by increasing milk production per hectare of family land and exploiting the favourable interactions between cropping and dairy (chapter two). As a proportion of total milk produced, milk retained for home consumption decreases from 0.41 to 0.30 as farmers intensify their systems (chapter two). About 25% of an estimated 625,000 smallholder households are involved in marketing of milk (Muriuki *et al.,* 2001). The small-scale milk traders buy and sell fresh raw milk at prices that are relatively more competitive for the smallholder producers and for low-income consumers compared to pasteurised packaged milk (chapter two).

Complementary to these objectives, the dairy herd plays a critical role in enabling resource-poor households to accumulate fluid capital assets, which are most frequently used for financing school fees, hospital bills and household investments (chapter three). As farmers intensify their systems, the greater is the contribution of dairying as source of income through marketing of forage and as source of casual and permanent employment (chapter five). For instance, it has been estimated that US$5 million of napier and maize fodder was traded in Kiambu District in 1996 and as source of employment, dairying generated incomes of 2-3 times the minimum daily wage (Muriuki *et al.,* 2001). Integration of dairy with crops makes important contributions to nutrient cycling, crucial in supporting crop-dairy systems through manure, which has a value equivalent to 30% of the value of milk produced, based on the observed market values for both (Lekasi *et al.,* 1998). Smallholders capture this value through increased value of crop production by applying the manure to crops, which are grown to meet subsistence needs and for cash sale.

3.3. Relative changes with intensification of smallholder dairying

The relative changes indicative of intensification were:

(i) Relative shift in management from free-grazing with larger herds to zero-grazing with smaller herds in which higher stocking rates are maintained through the feeding of crop residues supplemented with cultivated fodder and purchased feeds;

(ii) Change in herd structure with fewer heifers reared to breeding age and increased dependency on external sources of replacement animals necessary to maintain the herd population;

(iii) Greater preference for the use of dairy breeds of larger mature size and higher milk yielding potential (Friesian and Ayrshire) over breeds of smaller mature size and lower milk yielding potential (Guernsey and Jersey) and indigenous zebu cattle;

(iv) Greater importance attached to cattle genotypes with unselective feeding behaviour (especially in zero-grazing) and disease resistance (especially in free- and semi-zero-grazing);

(v) Less importance attached to East Coast fever and Anaplasmosis;

(vi) Greater importance attached to genetic improvement in the herd;

(vii) Higher reproductive wastage;

(viii) Increased milk production per unit land with the use of more purchased inputs and hired labour;

(ix) Increased production of marketable milk surplus per unit land and per farm;

(x) Greater value attached to cattle manure;

(xi) Relatively lower total benefits (sum benefits of value-added, insurance and financing benefits) per unit costs of purchased inputs, per cow and per ton of milk produced.

4. Constraints and prospects in intensifying smallholder dairying

Intensification of smallholder dairying to alleviate poverty and hunger, maintain crop production through manure and to attain self-sufficiency in foods of animal origin faces many constraints but also some opportunities. Inadequate animal nutrition is a primary technical constraint. Pressure on arable land is associated with shortage, and hence high costs, of feeds (fodder and concentrates). Shortage of dairy stock increases as more farmers intensify their farming systems. Other constraints relate to disease incidences and failure in the delivery of animal health and AI services, limited access to and high cost of credit and inadequate infrastructures (especially roads and water supplies) in some areas. These constraints and exploitable opportunities are discussed in the following sections.

4.1. Competitiveness and intensification

Development agencies supportive of intensification may be interested in relative competitiveness of dairying as intensification progresses. This is examined by quantifying the returns to a household's resources of land, labour and capital. Table 1 gives common measures of returns estimated from the longitudinal survey data (chapter two). Net recurrent cash income is cash income less purchased inputs. It represents the cash flow used by the households for paying school fees, medical treatment and purchasing household goods and farm inputs. It is lower with intensification, but it ignores that households consume a substantial proportion of their produce.

The sum of net recurrent cash income and income-in-kind (manure and household consumption included) gives the value-added, which is a measure of the total returns for the utilisation of the household's production resources. Again, this decreases with intensification. It does not however reflect the total benefits obtained by smallholders from dairy production because cattle contribute also to the household economy through their insurance and financing functions. Total benefits comprising value-added, insurance and financing roles were estimated at 1091, 1238 and 889 US$/farm/year for low, medium and high intensive systems, respectively.

Table 1. Estimated annual returns from dairy production in smallholder farms at varying intensification levels

Farming system	Value added (US$/y)[a]	Net recurrent cash income (US$/y)	Total benefits (US$/y)[a] per:			
			ha	unit cost of purchased inputs	cow	ton of milk
Low intensive (n=11)	1036	473	352.9	5.86	47.4	22.3
Medium intensive (n=11)	1165	573	364.1	3.93	44.2	20.3
High intensive (n=21)	833	360	592.7	2.60	27.8	13.0

[a]1 US$=Ksh 70
Source: Bebe *et al.*, 2002

Total benefits per hectare of land increase with intensification, resulting largely from more milk per hectare of land (590, 650 and 865 litres/ha/year in low, medium and high intensive systems, respectively). Consequently, more intensive land use can support more people per unit area of land. The total benefits derived per 1 US$ of inputs purchased, per cow (capital) and per ton of milk produced are, however, significantly lower with intensification. Intensification is therefore less competitive with the use of more purchased inputs. Still, many smallholders are intensifying through dairying, an indication that the returns are acceptable because more rewarding alternative employment opportunities are lacking while milk market remains vibrant, supported by an increasing rural and urban population with strong tradition for milk consumption (chapter two). Thus, the opportunity costs of farmers' labour are low, which contributes to acceptance of a labour-intensive dairy system (Staal, 2002). Competitiveness of smallholder dairying at varying levels of intensification will therefore depend on changes affecting the price of dairy inputs and products, and the overall level of economic development in the country.

Delgado *et al*. (2001) have argued that intensification of smallholder dairying might benefit from the continuing surge in demand for foods of animal origin being witnessed in the developing countries. The challenge for smallholders is to produce more per unit input when increasing use of external inputs. Proper macro-economic environment is a prerequisite; otherwise, smallholder dairy producers will be out-competed by large-scale producers. One, land and even water are getting scarcer. Two, there are fewer opportunities for on-farm crop and livestock integration to attain economies of scale. Three, even with intensification, multipurpose roles and subsistence objectives remain strongly pursued by smallholders. Four, smallholder households may not be able to accumulate adequate working capital to invest in the external inputs necessary to support the increased productivity required to sustain their livelihoods unless remittances are substantial. Kenya's national income per capita is currently declining due to the country's poor economic performance, resulting in fewer employment opportunities, particularly in urban areas, and lower remittances from urban employees to rural households. The macro-economic conditions thus provide a challenge for smallholder dairy systems.

4.2. Increasing stocking rates

Increasing stocking rates under semi-zero- or zero-grazing is one strategy smallholders adopt to continue keeping cattle even as human population densities continue to rise and landholdings to shrink. It is thus relevant to ask whether there are constraining factors to increasing stocking rates. Part of the answer is provided in Table 2.

Whereas average farm size is not different among households practising zero- grazing and those without cattle (crops only), the differences are larger in income levels and the use of hired labour in favour of households practising zero-grazing where high stocking rates are maintained. Compared to households without cattle, those practising zero-grazing allocate relatively a larger proportion (15 vs. 22%) of their land to fodder growing, but the proportion allocated to food and cash crops are not different (33-38%) (chapter five). Maintaining and increasing stocking rates above those in zero-grazing farms thus require the availability of sufficient income for purchasing animal feeds and for hiring labour because feed must be imported from outside the farm to sustain the high stocking rates.

Table 2. Farm size, stocking rate and income levels of various categories of households in the Kenya highlands

Households practising:	n	Farm size (ha)	Stocking rate (TLU/ha) [a]	Income level (Ksh/mo) [b]	Hired labour (%)
Free-grazing	227	2.4	1.1	2.57	65
Semi-zero-grazing	326	1.8	1.0	2.63	71
Zero-grazing	434	0.9	1.4	2.69	70
Cropping only	368	0.8	…	1.87	40
Non agricultural	400	0	…	3.02	0

[a] Tropical Livestock Unit (TLU=1 for bull; 0.7 for cow; 0.5 for heifer and young bull; 0.2 for calves)

[b] Income level (Ksh/mo): 1=<2500; 2=2500-5000; 3=5001-10000; 4=10001-20000; 5=20001-30000; 6=>30000

4.3. Access to animal feed resources

Inadequate availability of feed quantity and quality for the animals is a major constraint confronting intensification of smallholder dairying using dairy breeds when human population densities continue to rise and landholdings to shrink. In response, smallholders in the Kenya highlands have opted for keeping fewer animals with higher value output produce, but with less investment in feeding (chapter three, four and five). Thus, genotypes with less selective feeding behaviour are preferred. Further, smallholders have reduced the competition for the available feeds and their conversion to milk by reducing the proportion of heifers and bulls relative to dairy cows in the their herds. The size of the holdings, the availability of feed and affordable human labour jointly have a major influence on the herd size. A consensus among the sampled households was that, under prevailing conditions, they are limited to a ceiling of three cattle (chapter three). Further reduction in herd size to match the available feed resources is not an option unless farmers keep only one cow or move out of dairy production altogether.

For feeding their herds, smallholders have increased their own production of fodder and the purchase of feeds. The availability of napier and maize as animal feed is however limited in quantities due to land scarcity and requires supplementation. Some farmers rent land for growing fodder, but the rental charges are higher as pressure on land increases. Smallholders have to hire labour to gather forages from common properties. However, the overall increase in the number of individual households in which cattle are an integral component of the farming system is putting an increasing pressure on these common properties. The majority of the farmers feed crop residues mainly from food crops, but these are nutritiously poor, seasonally available and the quantities depend upon farm size. Conservation of crop residues, when plenty, is not attractive because the quality deteriorates further and storage facilities would be necessary. Although the nutritive value of crop residues can be effectively improved with the use of nitrogenous supplements, limited availability and lack of working capital hamper their effective utilisation by smallholders. Genetic means is one way to improve the nutritive value of crop residues without affecting the yield and quality of the grain. This may present less risk for smallholders and should be exploited by research as a priority because improved digestibility of crop residues will improve the quality. Added to this, it will be important to use cattle genotypes with a high intake capacity for roughage feeds, this can be achieved by breeding for higher voluntary dry matter intake, which is strongly related to animal performance (Blummel *et al.,* 1997; Vargas *et al.,* 2002).

Access by smallholders to quality feed resources will be necessary if they are to achieve higher milk production than the current 4 litres per day of calving interval, estimated in our study. On average, cows receive just about 1 kg of concentrate daily, which is insufficient to realise the high potential for milk production of the European dairy breeds. Constraints to adopting cereal-based diets are lack of cash for regular purchase of the feeds and the lack of surplus cereal stock for livestock feeding in Kenya (FAO, 2002) or the incentives for their importation. Importation of animal feeds is possible but the output and profit from that input needs to be that much higher to justify the additional investments. The feeding of more concentrates was influenced by whether a farmer is a member of a co-operative society, has adequate income to invest and the distance to the supply centre (chapter five). Smallholders have the option of using industrial by-products, but their availability is limited by supply and transport costs.

Smallholder households generally subsist on low incomes in cash and in kind. Consequently, they are strongly risk-aversive. Necessarily they seek improvements in productivity through interventions that incur low risk (which generally means with low gains), particularly when they are not sure of the returns to the additional investment (Batz *et al.,* 1999; Ørskov, 1999). Membership of a co-operative is one way for smallholders to obtain credit for inputs while incurring a low level of risk to their investment. Thus, strengthening of farmer co-operatives can allow more farmers to invest in better quality feeds. Because farmers need technologies offering quick returns, it has been suggested to co-operatives that they advance to farmers feeds during early lactation (Romney *et al.,* 2000). Instead of feeding limited amounts of concentrates throughout the lactation, farmers can feed larger amounts of the same total amount only over the first 12 weeks of lactation to maintain initial high yields in lactation. After that, the cow may be fed on forage diets only, in order to avoid extra costs.

4.4. Sourcing of dairy stock

Tropical dairy systems and specifically smallholder systems are generally unable to produce the number of replacement stock needed to maintain and expand their current herd size (Pearson de Vaccaro, 1990; De Jong, 1996; Afifi-Affat, 1998). This has been explained mainly by low reproductive and survival rates. Our study shows that with increasing intensification, scarcity of replacement stock results from the combined effects of low reproductive rates, low survival rates and a high proportion of voluntary exits of potential replacements (chapter three). Low reproductive and survival rates relate to inadequate availability of feeds and their interaction with diseases, particularly tick-borne and intestinal worm infestations. A high proportion of voluntary exits of potential replacements are the result of decisions to cull based on the lack of feeds and the targeting of the feeds by the smallholders to cows for milk production for feeding the family and for sale for cash income. Another contributing factor is the role of cattle as a means of accumulating fluid capital assets for the households, which is particularly critical at times of major financial stress. Meeting cash needs is a high priority to the household regardless of the herd size or reproductive status of the individual animals, consequently contributing to a high turnover of animals, particularly in zero-grazing farms (chapter three).

The number of farmers adopting dairying decreases as intensification of the farming system increases with the shift from free- to zero-grazing (Table 3). One major reason for the decease in rates of adoption is the scarcity of local supplies of replacement stock (chapter six). Scarcity of replacement stock is thus an important obstacle to the continuity of intensification of smallholder dairying in the medium to long term. The scarcity of replacement stock will lead to a big rise in costs of dairy replacements with the consequences that the poor farmers are crowded out of dairying. Abandoning dairy production will mean loss of an important source of livelihood and manure to support crop production. The sustainability of these farming systems may be reduced in the absence of the animal component, because of their dependence on manure, as use of inorganic fertilizer is limited.

Table 3. Rate of adoption of dairying by smallholders in low, medium and high intensive farming systems in the Kenya highlands

Farming system	Start of dairy adoption	Potential adopters (n)	Adopters to date (n)	Rate of adoption (%/year) [a]
Low intensive	1963	109	92	2.14
Medium intensive	1957	386	227	1.43
High intensive	1938	365	257	1.21

[a]The rate of adoption is obtained by dividing the number of current adopters by the number of potential adopters, then dividing the resultant figure by the number of years between the start of adoption and when the survey was conducted (Batz *et al.,* 1999).

Intensification of smallholder dairying has been promoted presuming outsourcing of replacement stock from large-scale dairy farms (chapter two). Our study shows that in the Kenya highlands exchange of dairy stock is generally confined within smallholder farming systems and not between large-scale and smallholder farms (chapter three). Nowadays, large-scale farms are fewer and their expansion is unlikely given the pressure on land resources in the medium and high potential agro-ecological zones.

However, the few remaining large-scale farms can still play an important role as suppliers of dairy stock, but credit facilities have to be made accessible to smallholders because they will need a lump sum of money to purchase a replacement at the market price.

Simulation results have indicated that integrating free-grazing with semi-zero- and zero-grazing farms in a farming system is important. Interventions to improve fertility and survival and rearing of dairy heifers in free-grazing farms can have a big impact on producing the number of replacement stock needed to maintain and expand the herd size (chapter six). On individual farms, rearing of replacement stock for sale involves economic decisions. Market price and their expected performance will have a major influence on the economic decisions of the farmers.

Meanwhile, dairy production will have to expand to semi-arid areas to ease pressure on the medium and high potential agro-ecological zones. Semi-zero-grazing, based on the use of Ayrshire-Sahiwal crossbreeds (considered hardy with good foraging ability) is possible in some of these areas (Muhuyi *et al.,* 2001), but rural infrastructures and water supply must be improved as well as protecting the environment from overgrazing.

4.5. Breeding and animal health services

It is clear from our studies that mortality rates are high (7-19% annually) for all animal classes, regardless of intensification levels, and that disease accounts for a high proportion (36 to 85%) of all animal exits (chapter three). The diseases regarded by smallholder respondents as the most important were East Coast fever, Anaplasmosis and intestinal worm infestations. This infers that if these losses are to be reduced significantly the access to animal health services by smallholders has to be improved. Field research shows that smallholders value these services and are not averse to paying for them, but market delivery mechanisms must be efficient (Oruko *et al.,* 2000; Ahuja and Redmond, 2001). Continued government support is thus necessary in providing the public goods of infrastructure (e.g. rural access roads) and institutions essential to improving the efficiency of the private market.

Smallholders expressed greater need for potentially high milk yielding genotypes (chapter four). However, use of AI for genetic improvement and/or for getting cows and heifers in-calf is rapidly declining following privatisation of AI services by the government in the early 1990s (Figure 1). Although farmer-co-operatives and private entrepreneurs now offer about two-thirds of all AI services to smallholders, their services are mainly confined to areas of high dairy cattle densities where opportunities for the milk market are better. Use of AI from private providers requires that smallholders have the financial means to pay for the services. In addition, evidence presented recently by Oruko *et al.* (2000) shows that private entrepreneurs cannot profitably offer AI and clinical services at the prevailing market conditions. This is likely to restrict continued growth of private service providers, although current policy advocates complete withdrawal by the government from the provision of private goods and services. Strengthening co-operative management may help ease constraints related to the accessing of AI services by smallholders in the areas where co-operatives are functioning.

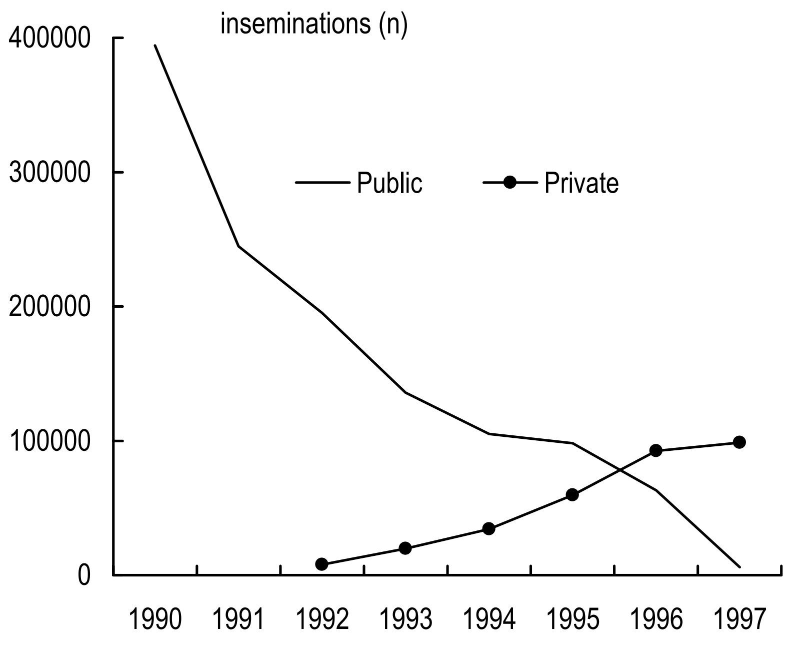

Figure 1. Number of artificial inseminations offered by public and private sectors in Kenya between 1990 and 1997 (*Source:* Oluoch-Kosura *et al.*, 2000)

It was shown in chapter four that most smallholders (over 60%) have shifted to using unproven dairy bulls, mostly of Friesian or Ayrshire breed. Smallholders share the bulls within their farming communities because only a few (20%) farmers own bulls. This practise is likely to increase inbreeding levels, and overall, reverse the previously achieved significant genetic improvement in the domestic herd. One way to correct this is to use imported semen with known breeding values as breeding values for the local bulls are not derived presently.

Bull breeding values derived in the exporting countries can be converted for use in the importing country. Ojango and Pollott (2002) have estimated the relative rate of response in Kenyan milk yield based on United Kingdom (UK) breeding values to be 44% of the rate expected in the UK. The lower response rate in Kenya is caused by genetic x environment interactions, with genetic correlation ranging from 0.49 to 0.58 between populations in Kenya and the exporting countries (Ojango and Pollot, 2002). The genetic response would be the same when the genetic correlation is above 0.75 (Vargas *et al.,* 2002).

Current recommendations on the utilisation of cattle genotypes are inconsistent with smallholders' breeding practices and breed preferences. Smallholders demonstrate a need for the use of genotypes combining greater production potential with reduced risks to diseases and less reliance on purchased feeds. This means breeding for:

(i) heavier body weight to attract a higher market value for better insurance and financing roles;

(ii) larger rumen capacity and high voluntary dry matter intake to better use poor quality roughage available locally (Blummel *et al.,* 1997; Vargas *et al.,* 2002). This also accounts for manure, which is important for the crop-livestock farmers;

(iii) better fertility and survival to improve generation of replacement animals; and disease resistance because disease incidences are high.

This desired breeding goal is not easy to achieve currently because of the lack of functional recording schemes and infrastructure to support genetic improvement. The co-operatives and breeding companies may want to consider running nucleus herds as an alternative with less reliance on the functional infrastructures.

Meanwhile more attention to improving nutrition and animal health management is recommended in order to quickly obtain returns to investments relative to genetic improvement, because it is crucial for adoption of the technology by the poor farmers. However, when importing germplasm attention has to be paid to the needs of the local production circumstances in order to minimise the inconsistencies in the breeding practices of the exporting and importing countries. This means importing germplasm only from those countries that have included in their selection index many of the traits important for the conditions in the importing country. Involving the local farming community (farmers and private sector serving them) through participatory approaches will be necessary to help to identify their needs and objectives in dairy production.

It seems necessary from now to consider the impact of intensification on animal genetic diversity in the Kenya highlands, where the cattle genetic base is narrowing on the Friesian and Ayrshire breeds (chapter four). Reduction in genetic diversity reduces the ability to respond to changing production systems and market conditions. Meanwhile the long-term solution should focus on developing local breeding programmes and improving delivery of breeding services through farmer organisations.

4.6. Credit access

Chapters two through five show that intensification necessitates increased use of purchased inputs and services such as feeds, replacement stock, breeding and health services and with these, a need for an increase in knowledge. A key issue is that the bulk of the smallholders do not have the money (working capital and cash flow) required to invest in income-enhancing innovations. In a study of credit constraints in smallholder dairy in Ethiopia and Kenya, Freeman *et al*. (1998) showed that credit has a higher potential for impact through higher input use and milk yield if targeted to liquidity-constrained farmers than otherwise.

Public credit institutions however do not have sufficient funds to meet the demand. The current annual demand for agricultural credit in Kenya is estimated at Ksh 75 billion while the supply stands at Ksh 18 to 22 billion (Kimuyu and Omiti, 2000). High demand for loans has consequently led to high interest rates, stringent collateral requirements and a bias towards non-dairy enterprises seeking short-term lending. The proportion of credit for agricultural enterprises constitutes only 10-12% of the total loan advances from both public and private institutions. Credit from co-operatives is conditional on regular milk delivery, meaning that credit is unavailable when no cow is lactating. Jabbar *et al.* (2001) have argued that enabling smallholders to purchase goods in the form, amounts and locations of their choice would encourage them to innovate and get optimum production from their smallholdings and livestock. They propose that inventory finance tied to community level input suppliers and service providers can help in getting credit to worthy and needy smallholders at lower cost than providing credit to smallholders directly. Through their long-term relationships with their customers, community level input suppliers can assess creditworthiness on the spot. In support of this, the Bangladesh poultry development model has shown that providing access to credit with small and frequent repayments can successfully reach the resource poor households (Dolberg, 2001). Reaching out to smallholders has to involve technologies, appropriate institutional arrangements and policies.

5. Concluding remarks

The intensification of smallholder dairying in the Kenya highlands has been closely related to increasing human population pressure on land, the availability of low-cost labour and a reasonable level of access to agricultural support services. It has played a very important social and economic function because it has underpinned changes in the farming systems that have sustained more intensive land use and therefore supported more people per unit area of land in smallholder households. With human population pressure continuing to rise, the continued intensification of the farming systems is inevitable, especially while alternative employment opportunities are limited either because they are not available or because household members are not competitive in those job markets. Nevertheless the contribution from the intensification of dairying towards sustaining the livelihoods of rural and peri-urban households is likely to be significant only in those areas where there is scope for intensifying feeding practices and increased use of external inputs and services. Therefore in all areas smallholders will need access to affordable working capital in order to sustain intensification through the use of purchased feeds, dairy replacement stock and breeding and animal health services. Solutions to these constraints must concurrently involve both technical and institutional innovations that may encourage greater complementarities and stratification in the dairy sub-sector.

References

Afifi-Affat, K.A., 1998. Heifer-in-Trust: a model for sustainable livestock development? World Anim. Rev. 91, 13-20.

Ahuja, V., Redmond, E.J., 2001. Livestock health and breeding services: efficiency and equity implications of privatisation. In Dairy Development in the Tropics. 12th International Symposium on Tropical Animal Health and Production. Utrecht University, Faculty of Veterinary Medicine, The Netherlands, 2nd November 2001. pp 42-46.

Batz, F.J., Peters, K.J., Janssen, W., 1999. The influence of technology characteristics on the rate and speed of adoption. Agric. Syst. 21, 121-130.

Blummel, M., Makkar, H.P.S., Chisanga, G., Mtimuni, J., Becker, K., 1997. The prediction of dry matter intake of temperate and tropical roughages from in vitro digestibility/gas-production data, and the dry matter intake of and in vitro digestibility of African roughages in relation to ruminant liveweight gain. Anim. Feed Tech. 69, 131-141.

De Haan, C., Van Veen, T.S., Brandenburg, B., Gauthier, J., Le Gall, F., Mearns, R., Simeon, M., 2001. Livestock development: implications for rural poverty, the environment and global food security. The World Bank, Washington DC, 96 pp.

De Jong, R., 1996. Dairy stock development and milk production with smallholders. PhD Thesis, Department of Animal Production Systems, Wageningen Agricultural University, The Netherlands. 303 pp.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., Courbois, C., 2001. Livestock to 2020: the next food revolution. Outlook on Agric. 30, 27-29.

Dolberg, F., 2001. A livestock development approach that contributes to poverty alleviation and widespread improvement of nutrition among the poor. IFAD workshop on Malnutrition in Developing Countries: generating capabilities for effective community action. September 19-20, 2001, Bonn, Germany.

FAO, 2002. Food Supply Situation and Crop Prospects in Sub-Saharan Africa: Global Information and Early Warning System on Food and Agriculture (GIEWS). (http:/www.fao.org/giews).

Freeman, H.A., Ehui, S. K., Jabbar, M. A., 1998. Credit constraints and smallholder dairy production in the East African highlands: application of a switching regression model. Agric. Econ. 19, 33-44.

Gass, G.M., Sumberg, J.E., 1993. Intensification of livestock production in Africa: a review of experience and issues with special reference to poverty and the environment, School of Development Studies, University of East Anglia: Overseas Development Group. 77 pp.

Jabbar, M.A., Ehui, S.K., von Kaufmann, R., 2001. Supply and demand for livestock credit in sub-Saharan Africa: lessons for designing new credit schemes. International Livestock Research Institute, Addis Ababa, Ethiopia (in press).

Kimuyu, P., Omiti, J., 2000. Institutional impediments to micro and small enterprises (MSE) access to credit in Kenya. Discussion paper 26/2000. IPAR (Institute of Policy and Research), Nairobi, Kenya. 42 pp.

Lekasi, J.K., Tanner, J.C., Kimani, S.K., Harris, P.J.C., 1998. Manure management in the Kenya Highlands: practices and potential. Kenya Agricultural Research Institute, Nairobi, Kenya, 24 pp.

Muhuyi, W.B., Mukisira, F.W., Mosi, E.A., Isika, R.O., Okore, M., Kirui, C., Makori, J., Lukibisi, F.B., 2001. Sustainability of smallholder dairy production systems in the semi-arid Rongai division of Nakuru district. In: Proc. Anim. Prod. Soc. Kenya, Annual Symposium, 7-8th March, 2001, Egerton University, Njoro, Kenya. pp 15-20.

Muriuki, H.G., Mwangi, D.M., Thorpe, W., 2001. How smallholder dairy systems in Kenya contribute to food security and poverty alleviation: results of recent collaborative studies. Paper Presentation at the 28th Tanzania Soc. Anim. Prod. Conf., Morogoro, 7th- 9th August, 2001.

Nicholson, C.; Tambi, E., Staal, S.J., Thorpe, W., 2001. Patterns of change in dairy production and consumption in developing countries from 1985 to Market-oriented Smallholder Dairy Research Working Document No. 17, ILRI, Nairobi, Kenya. 65 pp.

Noordhuizen, J.P.T.M., Frankena, K., Thrusfield, M.V., Graat, E.A.M., 2001. Application of quantitative methods in veterinary epidemiology. Wageningen Academic Publisher, Wageningen, The Netherlands, 440 pp.

Ojango, J.M.K., Pollott, G.E., 2002. The relationship between Holstein bull breeding values for milk yield derived in both the UK and Kenya. Livest. Prod. Sci. 74, 1-12.

Oluoch-Kosura, W., Okeyo, A.M., Waithaka, M.M., Okilla, E.A., 2000. The economic implications of declining artificial insemination service provision in Kenya. Proc. Dairy cattle breeding in East Africa: Sustainable artificial insemination Service, KARI HQs, Nairobi, Kenya. pp 12-13.

Ørskov, E.R., 1999. New challenges for livestock research and production in Asia. Outlook on Agric., 28, 179-185.

Oruko, O.L., Upton, M., McLeod, A., 2000. Restructuring of animal health services in Kenya: constraints, prospects and options. Dev. Policy Rev. 18, 123-138.

Pearson de Vaccaro, L., 1990. Survival of European dairy breeds and their crosses with Zebus in the tropics. Anim. Breed. Abstr. 58, 475-494.

Romney, D., Kaitho, R., Biwott, J., Wambugu, M., Chege, L., Omore, A., Staal, S., Wanjohi, P., Thorpe, W., 2000. Technology development and field testing: access to credit to allow smallholder dairy farmers in Central Kenya to reallocate concentrates during lactation. Proc. 3rd All Africa Conf. on Animal Agriculture and 11th Conf. of the Egyptian Soc. Anim. Prod. 6-9 November 2000, Alexandria, Egypt. pp. 18.

Staal, S.J., 2002. The competitiveness of smallholder dairy production: evidence from sub-Saharan africa, Asia and Latin America. In: South-south workshop on smallholder dairy production and marketing- constraints and opportunities, Anand, Gujarat, India. (http://www.ssdairy.org).

Vargas, B., Groen, A.F., Herrero, M., Van Arendonk, J.A.M., 2002. Economic values for production and functional traits in Holstein cattle of Costa Rica. Livest. Prod. Sci. 75, 101-116.

Verschuren, P., Doorewaard, H., 1999. Designing a research project. Lemma Publishers, Utrecht, The Netherlands. pp 143-184.

Wolmer, W., 1997. Crop-livestock integration: the dynamics of intensification in contrasting agro-ecological zones: a review. Institute of Development Studies, University of Sussex, UK. 29 pp.

SUMMARY

SUMMARY

Kenya is prominent among developing countries for integrating dairy into smallholder farming systems, particularly in the highlands. In these highlands and other related areas in developing countries, dairy production by smallholders is a means to improve food security, spread risks, generate income, maintain crop production with use of manure and accumulate capital assets for emergency cash needs. These benefits have the aggregate impact of potentially catalysing agricultural development, creating employment and reducing poverty, hunger and environmental degradation. However, the concern is whether smallholders will continue to benefit from dairying through continued intensification when facing the pressures of continuously shrinking landholdings, worsening soil fertility and reduced access to formerly public delivered livestock input and output services, while imported nutrients remain relatively low and non-agricultural job opportunities remain lacking.

Smallholders intensify their farming systems by integrating dairy and crops with adoption of management practices and technologies to increase the output quantity and/or value from the major limiting production resources of land, capital and labour. Intensification of smallholder dairying is characterised by the shift from free-grazing to semi-zero- or zero-grazing farming. A typical semi-zero- or zero-grazing farm is one hectare with a herd of one to three cattle of the Friesian or Ayrshire breed. Often the herds have high reproductive wastage and keep no replacement heifer. Continued intensification of crop-dairy systems is expected to effect feeding practices, herd sizes and structures, breeding and replacement decisions, and milk production and reproductive performances. The resulting dynamics of land use have implications for domestic milk production and the sustainability of crop production, hence incomes and the livelihoods of smallholder families.

The objective of this study was, therefore, to quantify the consequences of the intensification of farming systems in the Kenya highlands on the dynamics of smallholder dairy herds, in order to better understand the constraints to, and opportunities for, the continued intensification of smallholder agriculture through dairying. This understanding is critical if we are to address the research and development needs of smallholder dairy farmers and for development agencies to be effective in their support to the continued

intensification of smallholder agriculture through dairying. The following research questions were thus addressed to achieve the overall objective of the study:

(i) What are the driving forces for intensification of smallholder dairy production systems in the Kenya highlands?

(ii) What is the impact of the intensification strategies of smallholders on their ability to produce their own replacement animals required to maintain and expand the existing dairy herd in smallholder systems?

(iii) What is the rationale underlying the breed preferences and breeding practices of smallholder dairy farmers when they intensify their production systems?

(iv) What is the influence of smallholders' feeding practices on dairy production performances?

To answer the research questions, we linked historical development perspectives with current patterns of intensification of smallholder dairying in the Kenya highlands. The target population was stratified by agro-ecological potential (medium and high) for cropping and dairying, and milk market access (low, medium and high). Data collection was through a random stratified cross-sectional survey of smallholder households. Data from the cross-sectional survey sample were complemented with additional information from longitudinal and targeted semi-structured interviews, which involved a randomly selected sub-sample of the previous cross-sectional survey. The combination of survey methodologies improved the reliability of the information, resulting in both empirical breadth and depth in the results.

Dairy production is integrated with crops, with the majority (77%) of the smallholders practising semi-zero- or zero-grazing compared to free-grazing (23%). The drivers of this intensification through dairying were identified. One, it was the government development policy of redistributing former large-scale farms and dairy cattle to smallholders soon after independence. Two, demographic changes affecting subdivision of family land through inheritance. Three, strong donor support for intensive smallholder dairy technologies as a source of income for resource-poor households. Four, dissemination of intensive dairy management technologies such as zero-grazing packages and artificial insemination service (AI). Five, local market opportunities for dairy presented by the traditionally milk consuming communities and the rapid growth in rural and urban populations. Six, limited creation of alternative employment in other sectors of the economy forcing government to direct development efforts to smallholder agriculture, with emphasis on dairying. Currently, increasing intensification is closely

correlated to trends in human population pressure on land, and access to, and availability of, agricultural support services.

The consequences of intensification were quantified. Intensification was associated with relative change from use of indigenous Zebu cattle to use of Friesian and Ayrshire dairy breeds with higher potential for milk yield. Intensification was characterised by keeping smaller herds, but increased stocking rates maintained through cut-and-carry feeding, growing of fodder, feeding crop residues, and increased dependency on external sources of replacement animals, feed resources, animal health and breeding services and credit to sustain the herd population and production. Farmers attached less importance to East Coast fever and Anaplasmosis as they intensified their systems, but animal mortality rates remained high (7 to 19%) regardless of intensification levels. Through intensification, smallholders sold more milk and maintained more people per unit of land with increased returns per ha of family land. However, intensification was less competitive with increased use of external inputs and services. Total benefits comprising value-added, insurance and financing roles of cattle derived per unit cost of purchased inputs, per cow (capital) and per ton of milk produced were significantly lower with intensification. It was recommended that production practises supporting intensification have to be site-specific because intensification levels varied with agro-ecological potential for cropping and dairying and with the level of milk market access and household resources. Appropriate recommendations require a thorough understanding of farmers' objectives for keeping cattle.

Milk production for feeding the family was the most important reason for keeping cattle for households keeping *Bos indicus*, Guernsey and Jersey cattle breeds, whereas milk production for cash income was the most important reason for those keeping Friesians and Ayrshires. Attributes most preferred in the *Bos taurus* breeds were high milk and butterfat yields, heavier bodyweight, disease resistance, unselective feeding behaviour in zero-grazing farms, hardiness in semi-zero- and free-grazing farms and high market value. Breeding practices tended to favour the use of dairy breeds of larger body size with high potential for milk yield, particularly Friesians. This is inconsistent with the technical recommendations that favour the use of the smaller dairy cattle breeds, generally with lower potential for milk yield. However, the *Bos taurus* breeds were not significantly different from each other for milk production and reproductive performances. The rational underlying smallholders' breeding decisions in the Kenya highlands was based on multiple objectives: the need for more milk, adaptability to local feeding conditions and diseases and the provision of non-marketed production such as manure, insurance and financing roles of cattle

Farmers supplemented napier grass, a common basal fodder, with purchased fodder and concentrates, but purchased less feed when more crop residues were available. Compared to non-members, members of farmers' co-operatives fed more concentrates (Ksh 1025 per Tropical Livestock Unit (TLU) per year) to their cows and achieved better performances. Feeding interventions to support continued intensification of smallholder systems have to be within the context of the household's economy, which is characterised by limited cash flow and low risk bearing capacity.

A deterministic model was developed to estimate the potential production of replacement stock in representative low, medium and high intensive farming systems in the Kenya highlands. Farming households within a sub-location, the smallest administrative area in a district, were defined as the boundary of the farming system. The base situation in each farming system reflected the actual proportion of free, semi-zero- and zero-grazing farms and the size, structure and demographic rates of their herds. Model estimates at the base situation showed that all farming systems produced replacements in sufficient numbers for maintaining and expanding the current dairy herd population, but the numbers decreased with increasing intensification. Sensitivity analyses showed that actions to effect decrease in cow mortality and then to reduce the proportion of heifers sold during the rearing period in free-grazing farms were the most promising interventions. Thus, prospects for maintaining and expanding smallholder dairying in the Kenya highlands are dependent upon the proportion of free-grazing farms maintained within the farming systems. Because increasing intensification reduced the availability of replacement stock within local areas, dairy adoption rates are projected to decline, particularly in the high intensive farming systems. Thus, a rational policy would be to promote intensification of smallholder dairying when other dairy production systems capable of producing replacement stock are functional.

The intensification of smallholder dairying in the Kenya highlands has played a very important social and economic function because it has underpinned changes in the farming systems that have sustained more intensive land use and therefore supported more people per unit area of land in smallholder households. With human population pressure continuing to rise, the continued intensification of the farming systems is inevitable, especially while alternative employment opportunities are limited either because they are not available or because household members are not competitive in

those job markets. Nevertheless, the contribution from the intensification of dairying towards sustaining the livelihoods of rural and peri-urban households is likely to be significant only in those areas where there is scope for intensifying feeding practices and increased use of external inputs and services. Smallholders need access to affordable working capital in order to sustain intensification through the use of purchased feeds, dairy replacement stock and breeding and animal health services. Solutions to these constraints must concurrently involve both technical and institutional innovations that may encourage greater complementarities and stratification in the dairy sub-sector.

Samenvatting

Dynamiek van kleinschalige melkveehouderij in de Keniaanse hooglanden

Samenvatting

Melkproductie door kleinschalige boeren in de Keniaanse hooglanden en in vergelijkbare gebieden is een manier om de voedselzekerheid te vergroten, risico's te spreiden, inkomen te genereren, door het gebruik van mest de productie van voedselgewassen te behouden en het sparen van kapitaal voor geldbehoefte in geval van nood. Men is echter ongerust of kleinschalige melkveehouders baat kunnen blijven hebben van een steeds verder intensiverende melkveehouderij, terwijl ze worden geconfronteerd met de druk van steeds kleiner wordend grondbezit, het verslechteren van de bodemvruchtbaarheid en het verminderen van de toegang tot vroeger door de staat geleverde input and output diensten voor het vee. Ook de hoeveelheid geïmporteerde nutriënten blijft laag en de beroepsmogelijkheden buiten de landbouw blijven beperkt.

Kleinschalige melkveehouders in de Keniaanse hooglanden intensiveren hun bedrijfssysteem door melkvee met de productie van voedselgewassen te integreren en te verschuiven van begrazing naar beperkte of geen begrazing. Derhalve veranderen de boeren het ras, de grootte en de structuur van hun kuddes, ook veranderen de demografische kengetallen. Een typisch kleinschalig melkveebedrijf met beperkte of geen begrazing is een hectare groot met een kudde van ēēn tot drie koeien van het Holstein-Friesian of Ayrshire ras. Deze kuddes hebben vaak grote problemen met de reproductie en de boeren houden geen vaars ter vervanging.

Het doel van dit onderzoek was dan ook het kwantificeren van de gevolgen van intensivering van bedrijfssystemen in de Keniaanse hooglanden op de dynamiek van kleinschalige melkvee kuddes, zodat de beperkingen en mogelijkheden van een verdere intensivering van de kleinschalige melkveehouderij beter worden begrepen. Dit begrip is essentieel als we ons richten op de onderzoeks- en ontwikkelingsbehoefte van de kleinschalige melkveehouders en als ontwikkelingsorganisaties effectief de intensivering van de kleinschalige melkveehouderij willen ondersteunen. De volgende onderzoeksvragen zijn beantwoord om het algemene doel van het onderzoek te kunnen bereiken:

(i) Wat zijn de drijfveren voor de intensivering van de kleinschalige melkveehouderijsystemen in de Keniaanse hooglanden?

(ii) Wat is de invloed van de intensiverings-strategieën van de kleine boeren op hun mogelijkheid dieren ter vervanging te produceren, om de bestaande melkveekudde te onderhouden en te vergroten in de kleinschalige systemen?

(iii) Welke logica ligt ten grondslag aan de ras voorkeur en de fokkerijstrategieën van kleinschalige melkveehouders als ze hun productiesysteem intensiveren?

(iv) Wat is de invloed van de voerpraktijken van kleinschalige melkveehouders op hun productie?

De gegevens komen van een dwarsdoorsnede onderzoek met aanvullende informatie van diepgaande halfgestructureerde interviews, die werden afgenomen bij een willekeurig geselecteerde subgroep van het voorgaande dwarsdoorsnede onderzoek. Zes drijfveren voor de intensivering van de kleinschalige melkveehouderij zijn geïdentificeerd. Ten eerste, het beleid van de regering dat de grootschalige bedrijven en het melkvee verdeelde onder kleinschalige boeren. Ten tweede, de demografische veranderingen die de verdeling van familiegrondbezit door erfenis beïnvloedde. Ten derde, donoren die intensieve kleinschalige melkveehouderij technieken als een bron van inkomen van de arme huishoudens sterk stimuleren. Ten vierde, intensieve managementtechnieken zoals stalvoedering en kunstmatige inseminatie werden gestimuleerd. Ten vijfde, er onstonden lokale markt mogelijkheden voor melk en melkproducten door de snelle groei van de bevolking. Ten zesde, de beperkte ontwikkeling van alternatieve werkgelegenheid in andere economische sectoren dwong de regering tot ontwikkeling van de kleinschalige landbouw, met nadruk op melkproductie.

De relatieve veranderingen werden gekwantificeerd op bedrijfsniveau en op niveau van het bedrijfssysteem. Intensivering vereist een toename in het gebruik van externe middelen, met name hulpbronnen voor dieren die ter vervanging dienen, voer, diergezondheid, fokkerij-diensten en krediet om de kudde en de productie te kunnen onderhouden. Het is aanbevolen om de productie praktijken die de intensivering ondersteunen plaats specifiek te maken omdat de intensiveringsniveaus varieerden met het agro-ecologische potentieel voor voedselgewassen en melkproductie en met de toegang tot de melkmarkt en met de aanwezige productiefactoren op het bedrijf.

Vooruitzichten voor het behouden en vergroten van de kleinschalige melkveehouderij in de Keniaanse hooglanden zijn afhankelijk van de verhouding begrazings bedrijven ten opzichte van geïntensiveerde bedrijven binnen het bedrijfssysteem, omdat de begrazings bedrijven de geïntensiveerde bedrijven voorzien van dieren die ter vervanging dienen.

De logica die ten grondslag ligt aan de fokkerij beslissingen van de kleinschalige melkveeboeren is gebaseerd op de meervoudige doelen van behoefte aan meer melk, de aanpasbaarheid van het ras aan lokale voederomstandigheden en ziekten en voorwaarden van niet-commerciële rollen van vee (bruidschat, verzekering). Voeder interventies om de continue intensivering van de kleinschalige melkveehouderij te ondersteunen, moeten passen binnen de context van de economie van de huishoudens, die wordt gekarakteriseerd door een beperkte beschikbaarheid van contant geld en een klein draagvlak voor risico's. Kleinschalige melkveeboeren hebben een betaalbaar werkkapitaal nodig om de intensivering te kunnen dragen met gebruik van externe bronnen. Het intensiveren van de kleinschalige melkveehouderij heeft de basis gelegd voor de veranderingen in de bedrijfssystemen, waar ruimte is voor intensiever landgebruik. Hierdoor zijn kleinschalige huishoudens in staat om meer mensen per eenheid land te onderhouden. Oplossingen voor de beperkingen van de intensivering moeten betrekking hebben op zowel technische als institutionele innovaties die complementair zijn en die differentiatie van bedrijfsystemen in de kleinschalige melkveesector stimuleren.

Curriculum Vitae

Bockline Omedo Bebe was born on November 21, 1963 in Kisumu, Kenya. He was introduced to the art of animal husbandry at the early age of four years, first by his paternal great grandfather Ibrahim Agola, and later by two of his maternal grandfathers, Julius Otieno and Japuonj Walter Odidi. He attended several primary and high schools in Nyanza, Western and Rift Valley provinces of Kenya between 1970 and 1982. He studied for a Diploma in animal husbandry between 1983 and 1986 at Egerton University, Kenya. Between 1986 and 1989, he worked with the Ministry of Agriculture in a sheep and goats multiplication programme in Baringo district, Kenya. The Animal Science Department of Egerton University employed him in 1989 as senior technician in sheep and goat management. A year later he qualified for a staff development programme and joined the same University for a BSc in Animal Production, which he completed in 1994, then a MSc in animal science between 1996-1997 at Wageningen Agricultural University in The Netherlands. His MSc thesis was entitled *Consequences of reducing reproductive wastage in intensive smallholder dairying systems in Kiambu district, Kenya*.

After his MSc, he re-joined the same Animal Science Department as an assistant lecturer, mainly teaching courses on ruminant livestock management. He was awarded in 1999 a fellowship by The Netherlands Foundation for the Advancement of Tropical Research (WOTRO) to study the dynamics of smallholder dairy herds in the Kenya highlands. This study was done in collaboration with the International Livestock Research Institute (ILRI -Nairobi) with the support of Smallholder Dairy (R&D) Project (SDP) of the Kenya Ministry of Agriculture and Rural Development, the Kenya Agricultural Research Institute (KARI) and ILRI.

List of related publications

Bebe, B.O., Abdulrazak, S.A., Ogore, P.O., Ondiek, J.O., Fujihara, T., 2001. A note on risk factors for calf mortality in large-scale dairy farms in the tropics: A case study on rift valley area of Kenya. Asian – Aust. J. Anim, 14:855-857.

Bebe, B.O., Udo, J.H.M. and Thorpe, W., 2002. Rationale for dairy breeding decisions by smallholder dairy farmers. Paper presented at the 53rd European Association for Animal Production, 1-4 September, 2002, Cairo, Egypt. pp 154.

Bebe, B.O., Udo, J.H.M. and Thorpe, W., 2000. Disposal and replacement policies in Kenya's smallholder dairy herds. Paper presented at the 3rd All Africa Conference on Animal Agriculture and 11th Conference of the Egyptian Society of Animal Production, 6-9 November, 2000, Alexandria, Egypt.

Bebe, B.O, Mulinge, W., Thorpe, W. and Udo, H.M.J. 2000. Breed preferences and breeding practices in smallholder dairy systems of central highlands of Kenya. The 7th KARI Biennial Scientific Conference, 13-17 November, 2000, KARI Headquarters, Nairobi, Kenya.

Bebe, B.O, Udo, H.M.J., Jalvingh, A.W. 1998. Is it beneficial to inseminate cows early after calving in smallholder dairy herds? The 6th KARI Biennial Scientific Conference, 9-13 November, 1998, KARI Headquarters, Nairobi, Kenya. pp 158-162.

Bebe, B.O., Thorpe, W., Owango, M. and Muruiki, H.G.,. 1999. Replacement heifer generation in smallholder dairy herds in the central highlands of Kenya. In: Proceedings of the Animal Production Society of Kenya Symposium held at Naivasha, Kenya, 11th to 12 March, 1999. pp 3-9.

Bebe, B.O.., 1998. Herd dynamics of smallholder dairy in Kiambu Distrit: Assessing implications for the supply of heifer replacements. Smallholder Dairy (R&D) Project. MoA/KARI/ILRI Collaborative Research Report, ILRI, Nairobi, Kenya. pp. 20.

Bebe, B.O., 2001. Important decisions to obtaining quality heifer replacements in smallholder farms. In: Breeding elite sires for higher productivity to alleviate poverty. Central Artificial Insemination Service Magazine. pp. 31-32.

Bebe, B.O., 2000 . Dairy breeding practices in smallholder herds. In: Elite sires for the year 2000 and beyond. Central Artificial Insemination Service Magazine. pp. 26-27.

Bebe, B.O. 2000. Dairy herd structures and rearing of replacement heifers on smallholder farms in the Kenya highlands. Kilimo News, A quarterly Newsletter of the Ministry of Agriculture and Rural Development, Kenya. January-March, 2000. pp 22-23.