Potential farmer demand for a dairy genomic assay technology

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Acronyms and abbreviations

AI	Artificial Insemination
ADGG	African Dairy Genetic Gains
AVCD	Accelerated value chain development
BIB	Better informed breeding decisions
DNA	Deoxyribonucleic acid
DGEA	Dairy Genetics East Africa project
HSP	Higher sales price for an animal with the certificate and
IDM	Increased demand for mating
ILRI	International Livestock Research Institute
KALRO	Kenya Agricultural & Livestock Research Organisation
SDP/KDDP	Kenya Dairy Development Programme
WTP	Willingness to pay
USAID	United States Agency for International Development

Abstract

Cross-bred dairy cattle have become the mainstay of smallholder dairy development across many countries in sub-Saharan Africa and Asia, particularly in favourable environmental settings such as the East African highlands. Due to a long history of mostly indiscriminate cross-breeding, the genetic makeup of most of these cattle is typically only roughly known by the cattle keepers. This lack of information affects producers' ability to make breeding decisions, constrains cattle buyers from being able to predict performance, and hinders sellers of breeding animals to demand higher prices based on greater genetic potential.

A genetic assay technology was developed by the African Dairy Genetic Gains (ADGG) project, which can determine the genetic makeup of a sampled dairy animal and make that information available to the owner, at a relatively low cost. A survey was conducted in western Kenya to evaluate the potential interest in this technology. Some 300 smallholder dairy farmers as well as 50 cattle traders, were interviewed to gauge their reasons for potential interest, as well as willingness to pay to use the technology. Some farmers were owners of village bulls, used for servicing cows in their communities. Comparisons were made between farmers in 'traditional dairy' areas, where there was a longer history of dairy development, and 'emerging dairy' areas.

The results show a generally high level of interest across all subgroups of smallholder dairy farmers in traditional as well as in the emerging areas. The main reasons for this high level of interest can be broadly grouped into financial reasons and need for better-informed breeding decisions. Among the financial reasons, owners of village bulls view the assay and the accompanying certificate as a marketing instrument that will help them in their breeding business. For all producers, the use of the assay was seen as potentially leading to higher sales prices for animals, as an assurance to buyers of the quality of the animal. More information to make better breeding decisions is the other main reason for the interest in the assay. A significant number of respondents believed that increasing exotic proportion in a cross-bred cow would lead to increased milk yield. In general respondents were eager to know more about good breeding practices but had only limited ideas to what extent the additional information provided through the assay would help them in that respect. Most traders were indifferent to the technology, although those that were interested recognized the potential value in increasing demand or sales price in the cattle they were trading.

In general, it can be concluded that the genomic assay could find a market and a group of potential adopters, depending on the cost and logistics of access and implementation. Once successfully piloted, it could be part of a comprehensive program of education and training for smallholders on a wide range of topics emphasizing the three main pillars of any livestock activity, namely breeding, feeding and health.

1 Background

In many parts of Africa and Asia, particularly in temperate climates such as tropical highlands, colonialists introduced 'exotic' European breeds of cattle to achieve higher levels of milk production than was available from the local cattle. To increase their survivability in the context of harsh temperatures, significant disease challenges and poor-quality feed, the common practice was developed in many countries to cross-breed these exotic cattle with the local breeds, which were better adapted to the local settings. Currently, this happens ideally via artificial insemination (AI) using semen of exotic bulls either produced and delivered by the national cattle breeding institutions or imported from private animal genetics companies. Using AI reduces the risk of disease transmission associated with natural mating, and assures better choice of and control of breed type. Alternatively, locally-kept bulls, which can accurately detect heat in cows, are employed to provide natural service, either opportunistically by farmers raising cross-bred bulls for sale to butchers, or by farmers keeping breeding bulls mainly to serve their cows, but also providing this service to other farmers in the neighbourhood, in general against a moderate fee. These 'village bulls' were either bought as young stock from commercial farmers (in this case they are very often pure exotic-breed bulls) or they are offspring of cows believed to be 'well-performing' within the localities. For a number of reasons, among them the unreliability and sometimes unavailability of AI service, as well as cost, Baltenweck et al. (2004) found that slightly more than 80% of breeding is done through natural service, in spite of the fact that just over 50% of producers indicated a preference for AI for greater milk productivity.

Due to many decades of both controlled (via AI) and uncontrolled cross-breeding, there are now millions of cross-bred dairy cattle in Africa, about which, since there are generally few records kept, little may be known regarding the ratio of local versus exotic breed composition of specific cattle and the various breeds involved in the crosses. This constrains continued breed improvement since breeders are not able to easily know the animal's traits so as to select those which suit their objectives. It also constrains the livelihoods and businesses of smallholder dairy farmers, since they cannot easily know the milk production potential of the heifers they buy.

The African Dairy Genetic Gains (ADGG) project developed a genetic assay that can determine the breed composition of a dairy animal based on a single sample of its hair or blood. Using the latest technological advances, the test assays an animal's genotype at hundreds of thousands of locations across the genome. The genetic information can be used to estimate with high accuracy the percentage of the animal's ancestry that is of exotic breed origin (Bos taurus) versus the percentage that is from a local zebu breed. It can, with somewhat lower accuracy determine which particular exotic breeds are represented (e.g. Holstein vs. Ayrshire vs Jersey). In addition to breed composition, when related animals are sampled, an animal's parents can be identified, allowing pedigrees to be determined. The initial version of the genetic assay was expensive (approximately USD200 per sample). A much simpler and cheaper assay, based on a few hundred genetic markers, has now been developed by the project, which provides an accurate estimate of exotic versus zebu ancestry and can assign parentage with high accuracy. It does not, however, discriminate between different exotic breeds in the ancestry of an animal.

This simpler technology requires only that a hair sample, including hair roots, is pulled from the tail of a cow/bull to be used as the source of deoxyribonucleic acid (DNA) for the genetic assay analysis. It is estimated by the ADGG

management that the simpler assay can be made available for the equivalent of approximately USD10 including the logistic expenses of getting the sample from the cow to the lab and after analysis, transmitting the result in the form of a certificate back to the farmer.

During early discussions with the ADGG management the following types of potential benefits of this genomic assay from the perspective of the smallholder dairy farmers were hypothesized, which would likely drive demand for the assay technology:

- Knowing the genetic makeup of their cows allows farmers to make better-informed breeding decisions so that progeny are best matched to the production environment in which they are raised.
- Whenever a dairy animal is being sold and purchased, a certificate proving the genetic composition might increase the value of the animal. This is most likely to be true for heifers because farmers will focus more on achieved milk yield when buying cows that are already in production.
- In case the owner of a 'village bull' has a certificate of genetic makeup, this might increase the demand for service by that bull.

In order to validate these hypotheses or at least determine generally the level of potential interest by dairy system actors in the genetic assay technology, a set of surveys was designed and conducted. This report presents the results of these surveys.

A healthy and well-managed cross-bred cow (credit: ILRI/Christoph Weber).

2 Methodology

2.1 Selection of the survey area

Although Kenya is at present not included in the ADGG program, it was selected for the survey site for the following reasons:

- Compared to the two present ADGG countries, Ethiopia and Tanzania, the dairy sector in Kenya is significantly more developed, which has some advantages. With some area-specific differences, dairy development in Ethiopia and Tanzania is likely to occur along a similar pathway to that in Kenya. The current smallholder dairy system in Kenya thus offers an opportunity to assess dairy technology demand, which is likely to also develop in the neighbouring countries.
- In Kenya there is a somewhat pronounced regional differentiation of the smallholder dairy sector between the 'traditional dairy areas' like the central region (Kiambu, Nandi, Bomet and Uasin Gishu counties) and the 'emerging dairy areas' like western Kenya and the Upper Eastern region around Meru. The traditional dairy areas were in part developed during the colonial period by settler farmers, so have a long history of commercially oriented dairy development and still comprises a few large-scale commercial farms, although most are small- to medium-sized farms. In the 'emerging dairy' areas further west, smallholder dairying has developed in recent decades post-independence. These differentiated dairy areas allow a comparison of the demand for technology by relatively more and less advanced dairy producers.

For logistical reasons, several counties from western Kenya in the 'emerging dairy areas' that were adjacent to counties in central Kenya representing 'traditional dairy areas' were selected for the survey. As we will see below there is also a significant trade of dairy cattle between these areas and inside the survey area, with relatively high-grade cattle from the traditional dairy areas providing stock to the emerging dairy areas. In western Kenya, Busia, Kakamega and Vihiga counties were selected in the emerging dairy area while Nandi and Bomet were in the traditional dairy areas.

The emerging areas are characterized by small landholders and primarily zero-grazing dairy production systems, whereby animals are stall fed with cut fodder and crop residues. Farmers source cross-bred replacement animals from the traditional dairy areas where high-grade heifers are available through traders or agents from the livestock department. In these areas, calving intervals are longer due to poor heat detection and animal husbandry among often relatively inexperienced farmers. Milk sales are typically to informal traders or retailers in towns.

The traditional areas reflect higher levels of dairy development, as well as larger land holdings. Production systems are semi-intensive in nature, with cattle kept in paddocks, so they are not exclusively stall fed. High-grade bulls are kept by some farmers, living in paddocks with cows. Milk marketing is more formalized, with sales going to cooperatives, commercial processors or large traders.

The level of cross-breeding is likely to play a significant role during all commercial transactions involving dairy cattle intended for production or breeding (culled animals for slaughter are likely to be priced largely according to body

condition and weight). As indicated, farmers in the emerging dairy areas often sourced cattle from the traditional areas. Therefore, livestock markets were included in the survey as well, particularly livestock markets where dairy cattle are sold and purchased during the regular market days. On this basis, the weekly livestock markets in Serem (Vihiga/Nandi) and Bomet were included in the survey.

2.2 Definition of subgroups

During a brainstorming session among a group of experienced International Livestock Research Institute (ILRI) field researchers, discussion was held as to what subgroups of smallholder dairy farmers might exist that would have a potential interest in the genomic assay described above.

Given the general lack of official pedigree certification and performance recording among smallholder farmers, the benefit for a farmer of having a certificate that documents a cow's genetic makeup would likely occur during animal sales and purchases. There are farmers in the traditional dairy areas who regularly breed heifers for sale, for additional income, given that they do not need all their on-farm-bred youngstock to maintain their dairy herd at the typically small scale suitable to their resource constraints. This subgroup was designated the 'breeders' and exists predominantly in the traditional dairy areas.

Correspondingly, in the emerging dairy areas we have 'new' smallholder dairy farmers who buy heifers or cows to expand their herds of cross-bred dairy cows, rather than rely only on the longer process of raising home-bred young stock. These farmers are also likely to be interested in certification of the genetic makeup of the cattle they buy.

Farmers are likely to want to know the genetic makeup of their cows to make better informed breeding decisions. If a farmer for example has a good experience with cross-bred cows, which are 75% exotic and 25% indigenous breed and wants to maintain that level of exotic blood in the herd, they would prefer a bull with the same makeup. At present they would depend only on a phenotypic assessment of their cows as well as of potential bulls for servicing, which may not be accurate. The genomic assay can provide this basic information. Such farmers form another group who are 'smallholders who are likely to want better informed breeding decisions.'

Another potential group of clients for the genomic assay is expected to be owners of village bulls that are used to service cows among surrounding farmers for a small fee. A certificate confirming the genetic makeup of the bull (for example, 75% exotic genes) might increase the demand for the service and possibly the price. In most of the traditional dairy areas artificial insemination (AI) services are available from public or private providers, so an alternative to village bulls exists, but AI is generally less available in the emerging dairy areas. Whether owners of bulls in traditional and emerging dairy areas rate the benefit of the genomic assay differently may be revealing.

As shown in Table 1, these subgroups are not represented equally across the two different dairy areas chosen for the survey. Breeders, who sell dairy cattle are found mainly in the traditional dairy areas where there is long experience in cattle breeding. New dairy farmers, who buy dairy cattle, are found mostly in the emerging dairy areas. Smallholders who want better breeding decisions, village bull owners and traders of dairy cattle are found in both regions.

A young village bull (Ayrshire) supplied by the AVCD project (credit: ILRI/Christoph Weber).

Table 1: Subgroups present (X) in the traditional and the emerging areas

	Traditional dairy area (Nandi and Bomet counties)	Emerging dairy area (Busia, Kakamega and Vihiga counties)
Owners of village bulls	X	X
Breeders, who sell dairy cattle	X	
New dairy farmers, who buy dairy cattle		X
Smallholders who want better informed breeding decisions	X	X
Traders on livestock markets	X (Bomet)	X (Serem)

2.3 The questionnaire

The objective of the questionnaire (see Annex) was to obtain basic characteristics of the respondent's dairy and cattle breeding activities, farmer objectives, and to determine the degree of potential respondent interest in the genetic assay, for which type of animals and for what reasons. Sufficient explanation was given to the respondents including some principles of animal breeding to clarify the relevance of the genomic assay in the context of a smallholder dairy farm. The initial questions enabled the enumerator to categorize the respondent into one of the six subgroups.

Willingness to pay (WTP)

One of the objectives of the survey was to find out what price the respondents were willing to potentially pay for the genomic assay including the certificate. We assessed the WTP directly by an open question during the survey. Many studies have shown that the various WTP approaches can generate inaccurate results for various psychological and technical reasons. The inaccuracy tends to increase if the product or service in question is unknown to the respondent,

as it was the case in the survey. Nevertheless, carefully framed WTP enquiry is a simple and fast method to assess an approximate price range for a product or service (Breidert, Hahsler and Reutterer 2006).

2.4 Selection of respondents

The survey started with a one-day training of the five enumerators on the ILRI campus. During this training the enumerators received a list of smallholder dairy farmers in Busia and Vihiga counties in the emerging dairy area, that were supported by the Accelerated Value Chain Development (AVCD) project a United States Agency for International Development (USAID)-funded program supporting dairy value chain development. These farmers received purebred exotic (Ayrshire) bulls at subsidized rates to be used as village bulls, since dairy farming was relatively new in the area, availability of AI was limited and only very few exotic bulls were available. The enumerators contacted the owners of village bulls from the lists and arranged interviews. Village bull owners also provided contacts with smallholders from the other two subgroups present in the emerging dairy area (new farmers and those wanting better informed breeding decisions). The same approach of contact with village bull owners then 'snowballing' to other farmers was used also in Vihiga County. In Kakamega, where AVCD does not operate, lists of dairy farmers were obtained from the Kakamega Dairy Farmers Cooperative. In Nandi and Bomet counties, in the traditional dairy areas, contact farmer lists were obtained from the ADGG's precursor project, the Dairy Genetics East Africa (DGEA) project.

As a result of this process, the selection of respondents was not in any way randomized, but can be confidently expected to represent typical dairy farmers in the target areas.

2.5 Interviews

In the morning the team (five enumerators and the ILRI researchers/authors) met and the mode of travel for each enumerator to their area for the interviews of the day was organized. The researchers accompanied one of the enumerators on a rotational basis each day. The interview sessions varied between 30 and 45 minutes mainly depending on the explanation of the breeding principle and the genomic assay. Over time each enumerator developed their own way of explaining it either using bean and maize seeds representing local and exotic breeds or doing some simple calculations on paper. In general, the respondents were interested in these explanations and eager to engage. At the end of the day the team met again to discuss any issues of the day's work and prepare for the following day.

In the emerging dairy area, the team sought to interview at least 16 respondents in each of the three counties from each of the relevant subgroups. In the traditional dairy area, 25 respondents from each of the three relevant subgroups per county were interviewed in each of the two counties. The numbers of respondents in each subgroup and county are provided in Table 2.

Farmers were interested to get involved (credit: ILRI/Christoph Weber).

Table 2: Respondents per county and subgroup

	Emerging dairy area				Traditional dairy area		
	Busia	Kakamega	Vihiga	Total	Nandi	Bomet	Total
Owners of village bulls	18	14	15	47	20	25	45
Breeders, who sell dairy cattle					26	23	49
New dairy farmers, who buy dairy cattle	17	15	15	47			
Smallholders who want better informed breeding decisions	20	23	15	58	29	27	56
Traders			25	25		25	25
Total	55	52	70		75	100	
Total per area				177			175
Grand total							352

3 Results

3.1 Herd size and herd composition

A detailed overview of the average herd size per farm as well as the average herd composition in the various subgroups is given in Table 3. The distinction between local and exotic cattle has been made solely on phenotypic appearance, with the latter category mostly made up of cross-breeds that have a significant and visible degree of exotic genes.

In the traditional dairy area, given the more advanced nature of dairy development, the focus is on dairy cattle breeds for milk production, so neither local bulls nor local castrated males are kept in any of the three subgroups. In these areas, donkeys are generally used for traction such as pulling carts, so there is also no demand for local bullocks.

In the emerging dairy areas, some of the owners of village (exotic) bulls also keep at least one bull of local breed. These local bulls normally accompany the local herd when grazing and might serve other farmer's cows as well, but in such cases no fee is charged by the owner. Local bullocks are kept in the emerging dairy area, mostly at least one pair, used for cultivation and transport. Some exotic bullocks (castrated males) are kept in the emerging areas, most likely as a by-product of dairy farming and reared for beef production since they grow quickly, if the farmer has adequate access to green fodder, roughages such as maize straw, or grazing land.

As with local males, very few local female cattle as well as local youngstock and local calves are kept any longer in the traditional dairy area. In the traditional dairy area, the average number of exotic dairy cows varies between 2.3 and 3.3 cows per smallholder farm. As expected the numbers of exotic dairy cows in the emerging areas is lower, between 0.9 and 1.5 per farm on average, with the most found among the smallholders who want better breeding decisions subgroup. The share of productive animals, i.e. adult females, is rather low even in the traditional dairy area and varies between 28% and 39% of the total herd. In the emerging dairy area, the share of exotic cows in the herd was somewhat lower and varied between 10% and 27%. These numbers are somewhat less than those found in a study of 400 farms in western Kenya in which 36.4% of the average herd were lactating cows, which together with dry cows comprised 50% of the herds which were on average adult females (Omondi and Njehia 2014). It is possible that since the survey lists were obtained from dairy development project, that the farmers selected were among the more resource poor, thus had smaller herds than the overall regional average.

Cross-bred cow with her newborn calf (credit: ILRI/Christoph Weber).

Table 3: Average farm herd size and composition per subgroup

Subgroup	Bulls		Castrated males		Cows		Youngstock 1 – 3 years		Calves below 1 year		Total cattle		Grand total
	Local	Exotic	Local	Exotic	Local	Exotic	Local	Exotic	Local	Exotic	Local	Exotic	
Owners of bulls in traditional area	0	1.2	0	2.7	<0.1	3.3	0.1	2.5	0.1	2.0	0.2	11.7	11.9
Owners of bulls in emerging area *	0.7	0.9	1.8	0	1.2	0.9	1.0	1.1	0.5	0.7	5.2	3.5	8.7
Breeders, who sell dairy animals (traditional areas)	0	1.5	0	1.0	0	3.0	<0.1	2.6	0	1.9	<0.1	10.0	10.0
New dairy farmers, who buy dairy cattle (emerging areas)	0.2	0.8	2.0	1.0	0.8	1.0	0.5	1.1	0.4	1.0	3.8	4.8	8.6
Better informed breeding, traditional area	0	0	0	0	0.1	2.3	0	2.0	<0.1	1.5	0.1	5.9	6.0
Better informed breeding, emerging area	2.3	0	0	0	0.8	1.5	0.5	1.4	0.3	1.2	1.5	4.1	5.7

* Five respondents in this subgroup kept local and exotic bulls

3.2 Sales and purchases of cattle

In all subgroups and in all categories, cattle sales exceed purchases on average, as reported by respondents during the previous two years (Table 4). The likely reasons for this is that of course herds on dairy farms grow with each calving needed to produce the next lactation cycle, and that farmers manage herd sizes and composition to most effectively use the limited feed and labour resources available and to meet their objectives. Thus, cows are normally sold for slaughter after their productive life, and most of the replacement heifers may be bred on-farm rather than purchased. Additionally, most male cattle are sold while young, besides those kept to be raised for meat. Owners of village bulls may sometimes need to buy a replacement bull to mitigate inbreeding and improve the genetic makeup of the herd. Out of the 18 bulls purchased during the past two years 16 (89%) have been bought by owners of village bulls.

The proportion of cattle sold is higher in the traditional areas than in the emerging dairy areas, notably among breeders, as is to be expected, and which is likely to reflect the fact that such areas are a source of heifers for the market. They sell more cattle than they buy, and more than a third of all cattle sold are heifers, the category of cattle most likely to be in demand for herd growth and breeding stock. Bullocks are neither sold nor bought frequently. Calves up to one year of age are also infrequently sold or purchased and those which are, are mostly males (Table 4). Somewhat more young males are sold than females, most noticeably by breeders. Slightly more bulls are purchased in the emerging dairy area than in the traditional area, where supply may be adequate, and AI is more readily available.

The results show that the farmer strategy for increasing herd size relies on buying-in a cow followed by buying-in heifers (75 cows and 60 heifers were reported to have been purchased and 60 heifers). An advantage of buying a cow is the ability to better evaluate the likely milk yield. The breeders in the traditional area sell not only cows, but also bulls and youngstock of both sexes: in total they sell more than six times the number of animals they purchase (193:30)! The most numerous category of cattle they sell are heifers followed by male youngstock and cows (Table 4).

The new smallholder dairy farmers in the emerging areas mainly buy cows and heifers; this is the only subgroup where the number of female cattle bought are almost the same as the number of female adults sold. (27:28).

Table 4: Cattle sales and purchases during the previous two years, per subgroup (and average per farm)

	Bulls		Castrates		Cows		Male young stock		Female young stock		Male calves		Female calves		Total cattle		Sales : purchase ratio	% of heifers of all cattle sold
	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P		
Bull owners in traditional area	26 (0.8)	3 (0.2)	4 (0.2)	0 (0)	23 (0.7)	7 (0.5)	23 (0.5)	2 (0.2)	13 (0.5)	10 (0.8)	1 (0)	0 (0)	0 (0)	0 (0)	90 (2.8)	22 (1.7)	4.1 (1.8)	18.9
Bull owners in emerging area	22 (0.5)	13 (0.5)	1 (<0.1)	0 (0)	25 (0.6)	9 (0.3)	13 (0.3)	3 (0.1)	10 (0.3)	8 (0.3)	3 (<0.1)	4 (0.1)	7 (0.1)	0 (0)	81 (1.9)	37 (1.4)	2.2 (1.5)	17.6
Breeders who sell cows	16 (0.3)	0 (0)	4 (0.2)	0 (0)	34 (1)	16 (1.3)	64 (1.5)	1 (0.1)	67 (1.8)	13 (1.1)	6 (0.4)	0 (0)	2 (0)	0 (0)	193 (5.1)	30 (2.5)	6.4 (1.9)	34.4
New farmers who buy cattle	10 (0.2)	1 (<0.1)	0 (0)	0 (0)	15 (0.3)	12 (0.5)	21 (0.3)	4 (0.2)	13 (0.2)	15 (0.6)	6 (0.1)	0 (0)	2 (0.1)	1 (<0.1)	67 (1.1)	33 (1.3)	2.1 (0.9)	17.2
Better informed breeding, traditional area	7 (0.1)	0 (0)	1 (<0.1)	1 (<0.1)	31 (0.6)	18 (0.7)	23 (0.4)	3 (0.1)	13 (0.2)	9 (0.4)	4 (0.1)	0 (0)	0 (0)	2 (0.1)	79 (1.5)	33 (1.3)	2.4 (1.3)	16.2
Better informed breeding, emerging area	7 (0.1)	1 (<0.1)	1 (<0.1)	0 (0)	24 (1.0)	13 (0.6)	18 (0.2)	7 (0.3)	15 (0.1)	5 (0.2)	3 (0)	2 (0.1)	2 (0)	2 (0.1)	70 (1.4)	30 (1.3)	2.4 (1.2)	6.7
Totals	88	18	11	1	152	75	162	20	131	60	23	6	13	5	580	185	3.1	

S = Sales, P = Purchases

As can be seen from Table 4 there is considerable exchange of dairy cattle to and from the smallholder farms, an indication that sale of animals is part of the business model, and may match seasonal resource constraints and household cash needs, and that purchasing stock is a means to potentially improve the genetic makeup and performance of the herd, which is relevant of course to the genetic assay technology.

3.3 Production level and market orientation

The general market orientation of dairy farms may be regarded as relatively high, with more than two third of all respondents selling part of the milk produced on their farm; on average half of all milk produced is sold. For comparison, earlier work by Waithaka et al. (2002) in western Kenya found that on average, 33% of dairy households sold milk. Since milk is an important part of the Kenyan diet, the remainder is consumed within the household and community.

Looking at the various subgroups in terms of production level and market orientation, the results are clear: In the traditional areas in all three subgroups the production level is higher and the share of milk sold is higher as well. (Table 5). Smallholder dairy farmers in the traditional areas sell on average 57% of the milk they produce, whereas in the emerging area this figure is 44%. Moreover, the absolute number of farmers selling milk per subgroup is also higher in the traditional area. This is matched by higher milk yields in the traditional dairy area, reflecting longer history of dairy development, experience, genetic makeup of cattle, and access to inputs and services.

Among the subgroups in the traditional area, the breeders, who can be described as the most advanced dairy farmers, have the highest milk yields and sell the greatest proportion of milk. Compared to many international standards however, the production level even in this group of the most professional and most experienced farmers is quite low with an average of the best cow of all respondents in the subgroup at peak lactation of 9.1 l/day. Another indicator for the low production level is the fact that only 21 smallholders of all 302 respondents had at least one 'high-yielding cow' (giving at peak lactation a minimum of 15 l/day).

Table 5: Milk production level and market orientation

	Milk yield of best cow during peak lactation (l/day)	Number of farmers with a cow giving 15 l/day and more	Average milk yield of best cow of all respondents (l/day)	Share of milk sold in % of all milk produced	Respondents who sell milk in the subgroup (total number of respondents)
Bull owners in traditional area	20	2	8.34	53	36 (45)
Bull owners in emerging area	10	0	4.67	41	19 (47)
Breeders, who sell cows, traditional area	23	6	9.1	60	43 (49)
New farmers, who buy cattle, emerging area	18	2	6.05	41	25 (47)
Better informed breeding, traditional area	23	4	8.67	57	51 (56)
Better informed breeding, emerging area	26	7	7.66	49	43 (58)
Total		21	7.42	50	217 (302)

3.4 Breeding methods

When breeding their cows, farmers can choose whether to use natural mating with a bull or to use AI, which is to some extent available in all areas. Availability of high-grade bulls may also be variable, particularly in emerging areas. It should be kept in mind that farmers may have differing objectives when seeking to have their cows served. Some may simply want to generate another lactation to continue milk production, and so may have limited interest in the genetic makeup of the resulting calf. Others may aim to raise replacement heifers or to sell heifers, in which case the source of genetics may be important.

In the traditional dairy areas, which have demonstrably greater market orientation, the share of use of AI is higher than in the emerging area (31% versus 21%) – Table 6. Even in the traditional area, however, only a minority of farmers reported using AI in the last two years, even among the breeders (36% report using AI). The lowest use of AI is in the subgroup of bull owners in the emerging area, as would be expected, given they have their own means of servicing their cows.

Overall, the use of AI is remarkably low across both areas, given the large investment in dairy development over the years. For comparison, a study in western Kenya in 2002 found that nearby 80% of surveyed households reported using AI in the previous 12 months from either government or non-governmental organization/cooperative sources (Waithaka et al. 2002). Various sources report ongoing problems with AI services, including high cost, but in particular poor reliability and frequent failed inseminations.

Enumerator and farmers in a discussion (credit: ILRI/Christoph Weber)

Table 6: Reported breeding method used (as per cent of all breeding events during the past two years)

	Own bull	Other bull	AI	
Bull owners in traditional area	58	20	22	100
Bull owners in emerging area	51	39	10	100
Breeders who sell cows, traditional area	7	57	36	100
New farmers who buy cattle, emerging area	12	66	22	100
Better informed breeding in traditional area	4	60	36	100
Better informed breeding in emerging area	4	64	32	100
Traditional areas (subgroups 1,3,5)	23	46	31	100
Emerging areas (subgroups 2,4,6)	22	57	21	100

Respondents provided reasons for their preference of a particular breeding method. The main reasons in favour of natural service focused around

- Lower price
- Easier access
- More reliable/higher success rate

Main reasons in favour of AI were

- Better quality of calves (although this was also sometimes mentioned as a reason for natural service)
- No transmission of diseases

3.5 Main reasons in favour of natural service

Cost of breeding services

In Western countries the AI costs normally vary between the equivalent of 40 to 75 litres of milk (Bane and Hultnäs1974) and assuming an average price per litre of milk of KSh35, the price for AI in Kenya also is in that range (KSh1,400–2,625). However, given that milk yields are much lower in Kenya, the relative cost of AI per unit milk produced is much higher than in the West. Natural service using village bulls is likely to be a fraction of the cost. AI is also more expensive due to the cost of 'repeat' service in the case of a failed insemination, which is less likely (and less costly) in the case of natural service.

It is generally accepted that after the privatization of veterinary and AI services in Kenya in the 1990's the AI distribution systems collapsed and prices for services increased considerably, so that the use of AI in areas still serviced by AI most likely also declined. Some suggest that privatization also led to a lower quality and poor performance of the AI service (Karanja 2003), but no clear evidence is provided. What has changed in the AI system is the mode of delivery. Unlike the current situation, where AI technicians directly ride to the farmers herds/cows when reached to on phone, before privatization in the 1990s, AI technicians were doing 'runs', i.e. driving regular routes along which farmers could bring their cows to roadside cattle crushes which were placed at a distance of approximately 1.5 km from each other.

What is less clear is whether the reintroduction of subsidies for AI in a country – e.g. in Rwanda around 2008 (ILRI, 2011) or in various counties in Kenya, the latest case being Kiambu, where the governor announced free AI services in February 2019 (Korir 2019) – will have a long-lasting and sustainable effect on the use of AI services.

More reliable/higher success rate

It is well-known that the village bull is better in heat detection than the farmer. Particularly in zero-grazing systems and even in the emerging dairy areas quite a few cows are individually tethered near homesteads, and not kept in a group of cattle, rendering heat detection more difficult. Moreover, signs of heat are not so pronounced if the cow is underfed, which is again not uncommon. Poor heat detection can increase the cost of AI, if the insemination is not accurately timed, increasing inseminator transport costs. Some farmers fear that AI with exotic semen will produce big calves, leading to difficult calving and even mortalities.

Often single cows are tethered near the house and then heat detection is not easy, especially when the cow is underfed (credit: ILRI/Christoph Weber).

There is not much research work published on the performance of the AI service in Kenya. Kinyua (2016) and Ngetich (2010) state that conception rates on two government farms (1 veterinary farm, 1 Kenya Agricultural & Livestock Research Organisation [KALRO] research farm) were 1.9 and 2.74 inseminations per pregnancy, which for a large farm with qualified staff and no transport nor communication problems is not impressive. Conception rates among smallholder farmers in rural area can only be lower.

3.6 Main reasons in favour of AI

Better quality of calves

As mentioned above, some farmers believe that natural service by a village bull gives better calves, but it was not entirely clear what a respondent meant by 'better calf'. The term may refer to the genetic quality of the calf, which the farmer may regard as better suited to the environment, or the size of the calf. It may also refer to the sex of the calf. Some farmers were found to believe that use of AI led to more male than female calves (Staal and Kaguongo 2003). Some sources claim that there are indications of a considerable level of inbreeding in both breeding systems (SDP/KDDP, 2004).

For farmers who have the objective of producing high-quality calves, rather than just producing another lactation, the attractiveness of AI is reflected in its somewhat greater use among the breeders in the traditional dairy areas. The acceptance and use of AI increases with farmer experience and market orientation – expressed by milk sales as well as by sales of breeding stock of smallholders.

Reduced transmission of diseases

The processing of semen eliminates the risk of sexually transmitted diseases, albeit the skill of the inseminator may influence other risks. No reliable figures were identified to assess the risk of spreading of sexually transmitted or other contagious diseases by using a village bull, but they certainly exist.

3.7 Conclusions – breeding decisions

The fact that even in the traditional dairy areas more than 60% of all reported breeding events were by use of a bull, despite some degree of existing AI service available, may be a result of a mix of factors, including differing farmer objectives for servicing cows, perceptions of reliability, cost, accessibility and degree of market and performance orientation. In a recent multi-country study (Mwanga et al. 2019) results showed that users of AI kept records more frequently, purchased more animal feeds and hired more and better paid workers than their colleagues using village bulls. That suggests that AI, as expected, is more frequently adopted by farmers who also adopt other modern practices and are performance oriented.

4 The genomic assay

4.1 Interest in the genomic assay

The majority of respondents expressed interest in the genomic assay and the certificate documenting the result, and this holds true across all subgroups of the survey with the exception of the traders. Whereas in the six subgroups of smallholder dairy farmers the interest in the genomic assay varied between 90% and 96%, only 21 (42%) of the 50 traders interviewed showed interest (Table 7).

With the relatively small number of respondents in each subgroup it is not possible to interpret a difference between 90% and 96% interest in the genomic assay between the various subgroups. It is, however, worth noting that the most business-oriented subgroup, the breeders in the traditional area, who sell a considerable number of heifers, are not more interested in the assay and the accompanying certificate than the other subgroups.

Responses as to the amount which respondents are willing to pay (WTP) for the genomic assay and the certificate, the traders indicated they are prepared to pay the most (KSh 665), whereas the breeders indicated the lowest amount, KSh 368. These WTP results do not seem to conform to the levels of interest expressed in the technology, particularly in the case of traders, who expressed the least interest.

Table 7: Interest of farmers of the various subgroups in the genomic assay and their willingness to pay

	Are you interested in the assay including the certificate?		Total numbers of respondents in the subgroup	How much would you pay for the assay (KSh)?
	Yes	No		
Bull owners in traditional area	43 (96%)	2	45	480
Bull owners in emerging area	45 (96%)	2	47	477
Breeders who sell cows, traditional area	44 (90%)	5	49	368
New farmers who buy cattle, emerging area	43 (91%)	4	47	575
Better informed breeding in traditional area	53 (95%)	3	56	597
Better informed breeding in emerging area	54 (93%)	4	58	425
Traders	21 (42%)	29	50	665
Total	303 (86%)	49	352	Average 512

4.2 Main reasons for interest in the genomic assay

Respondents were asked why they were interested in the genomic assay and the certificate and could give one or more reasons for their interest, and for which animal (Table 8). The choices for interest indicated in the questionnaire were for a) better informed breeding decisions, b) high sales price of animal, and c) greater demand for mating services (only in the case of male). Respondents could also indicate other reasons, which were recorded. The resulting reasons for interest in the technology were a mixture of these pre-formulated options and freely formulated answers. Since some of the open question responses were similar to the pre-formulated options, we formed clusters of similar reasons among the responses:

Cluster 1: The assay as a basis for better informed breeding decisions

The respondents who mentioned explicitly 'Better informed breeding' as their reason for interest were 125 while 23 respondents mentioned 'I want to know the genetic make-up of my cattle' as a reason. Both reasons indicate a desire to have better information for decision-making, albeit for possibly different objective. A few respondents provided a more detailed reason such as 'If I know the cross-breeding level of my cow, it is easy to know it from her calf as well' or ' If I know the level of cross-breeding, it will help me to avoid lowering the level of exotic blood'.

Cluster 2: The assay is advantageous for financial/business reasons

In this cluster, two main reasons were combined and given by 97 respondents: bull owners envisaged an increased demand for service by their bull or farmers expected a better price when selling young stock, because the certificate would provide additional information for the buyers. Four (4) more respondents indicated that the certificate would be helpful in general when buying or selling cattle.

Cluster 3: 'The more exotic, the more milk the cow will produce'

Twenty-seven (27) respondents clearly expressed their opinion that the certificate would tell them exactly the ratio of exotic and local breeds of a cow and therefore they would also know the milk yield of that cow.

Cluster 4: The genomic assay as an additional management tool

Twenty-four (24) respondents saw the genomic assay as an additional tool to improve their overall management or for some specific management issues such as animal health, feeding, record keeping or decisions on culling of cattle.

Cluster 5: The genomic assay as a modern technology increasing the social status of the farmer

Seven (7) respondents indicated that they are interested in the genomic assay because they are a village elder, a progressive farmer or want to be pioneers in livestock development.

Cluster 6: Unspecific/other reasons

Five (5) respondents gave unspecific reasons for their interest in the assay.

Serem livestock market in Vihiga County: A broad variety of cattle are on offer (credit: ILRI/Christoph Weber)

Some animals from Serem market end up in the nearby slaughter slab (credit: ILRI/Christoph Weber) .

Table 8: Reasons for interest in the genomic assay and the certificate by subgroups and type of animal

	Type of animal				
Subgroup	Bull	Cow(s)	Heifer(s)	Young bull/male calf	Total
Bull owners in traditional area	27 resp/52 reasons	24 resp/32 reasons	12 resp/16 reasons	10 resp/11 reasons	73 resp/111 reasons
	1 BIB 19	1 BIB 24	1 BIB 10	1 BIB 6	1 BIB 59
	2 HSP 16	2 HSP 8	2 HSP 6	2 HSP 4	2 HSP 34
	3 IDM 17			3 IDM 1	3 IDM 18
Bull owners in emerging area	36 resp/63 reasons	13 resp/15 reasons	15 resp/18 reasons	4 resp/7 reasons	68 resp/103 reasons
	1 BIB 21	1 BIB 11	1 BIB 14	1 BIB 6	1 BIB 52
	2 HSP 17	2 HSP 4	2 HSP 4	3 IDM 1	2 HSP 25
	3 IDM 25				3 IDM 26
Breeders who sell cows, traditional area	1 resp/2 reasons	29 resp/36 reasons	19 resp/27 reasons	14 resp/19 reasons	63 resp/84 reasons
	2 HSP 1	1 BIB 26	1 BIB 15	1 BIB 9	1 BIB 50
	3 IDM 1	2 HSP 10	2 HSP 12	2 HSP 8	2 HSP 31
				3 IDM 2	3 IDM 3
New farmers who buy cattle, emerging area	3 resp/4 reasons	24 resp/29 reasons	14 resp/16 reasons	7 resp/14 reasons	48 resp/63 reasons
	1 BIB 2	1 BIB 21	1 BIB 11	1 BIB 5	1 BIB 39
	2 HSP 1	2 HSP 8	2 HSP 5	2 HSP 5	2 HSP 19
	3 IDM 1			3 IDM 4	3 IDM 5
Better informed breeding in traditional area	No respondents	48 resp/58 reasons	18 resp/27 reasons	4 resp/6 reasons	70 resp/91 reasons
		1 BIB 44	1 BIB 11	1 BIB 1	1 BIB 63
		2 HSP 14	2 HSP 9	2 HSP 4	2 HSP 27
				3 IDM 1	3 IDM 1
Better informed breeding in emerging area	2 resp/3 reasons	44 resp/53 reasons	20 resp/31 reasons	12 resp/18 reasons	78 resp/105 reasons
	1 BIB 1	1 BIB 40	1 BIB 19	1 BIB 11	1 BIB 71
	2 HSP 1	2 HSP 13	2 HSP 12	2 HSP 6	2 HSP 32
	3 IDM 1			IDM 1	3 IDM 2
Total	69 resp/124 reasons	182 resp/223 reasons	98 resp/135 reasons	51 resp/75 reasons	400 resp/557 reasons
	1 BIB 43	1 BIB 166	1 BIB 87	1 BIB 36	1 BIB 334
	2 HSP 36	2 HSP 57	2 HSP 48	2 HSP 27	2 HSP 168
	3 IDM 45			3 IDM 10	IDM 55

Note: Respondents, were free to give more than one reason. The three reasons proposed in the questionnaire were 1. Better informed breeding decisions BIB, 2. Higher sales price for an animal with the certificate HSP and 3. Increased demand for mating IDM (the most frequent reason given is in bold letters).

4.2.1 Main reasons for the interest in the genomic assay according to type of animal

After respondents indicated their general level of interest in the genomic assay and their reasons, they were then asked in more detail their reasons for the categories of cattle in their herd (bulls, cows, heifers, young males). The responses (Table 8) are generally in line with the overall reasons given, but provide a more differentiated picture.

Bull

Smallholders owning a bull (there were only six respondents from other subgroups than the two 'bull owner' subgroups) had interest in the genomic assay because they envisage a higher demand for their bull for serving cows against payment. So, the bull owners consider the certificate as a marketing instrument, especially if the expected 'higher sales price' (reason 2, HSP) is combined with the expected increased demand for the bull service.

Cow(s)

For cows, the major reason for the interest in the assay and the certificate is in better breeding decisions (166) , followed by higher sales price (for animals) (57). 10 of 29 breeders indicated higher sales price as a reason. As expected the majority of the two subgroups labelled as seeking better informed breeding chose that as a response (84) vs higher sales price (207).

Heifer(s)

For heifers, again better breeding decisions was the most frequent response (87), but a significant number of respondents indicated higher sales price for the animal (48). The interest in sales price was particularly strong among breeders, 12 of 19 of whom indicated that reason for interest.

Young bull/male calf

A young bull/male calf, except when intended as to replace a bull in the herd, is likely to be sold. Therefore, financial reasons, either an expected higher price at sale or better marketing of the bull for service, are important reasons for the genomic assay and equally important as the additional information for breeding decisions. However, the large number of responses (36 from 51) indicated interest in better breeding decisions, suggesting that at least some farmers are raising males as bull replacements.

4.2.2 The traders and their interests in the genomic assay

Traders were interviewed in two livestock markets during market day.

- Bomet/Kapkwen livestock market, which is situated about four kilometers outside Bomet town, holds market day on Tuesdays. It is estimated that approximately 1,000 cattle are sold here on a normal market day (Mibei 2013).
- Serem livestock market is a market split between two locations: On Fridays there is the Serem livestock market in Nandi County and one day later, on Saturdays, the livestock market is in Serem, Vihiga County. Quite a number of traders buy cattle on Friday on the Nandi side and sell them the following Saturday in Vihiga. The team interviewed traders on a Saturday on the market in Serem, Vihiga county.

Serem livestock market, a number of cross-bred cattle being assessed by market actors (credit: ILRI/Christoph Weber).

Although all traders were interviewed in their role as traders, a considerable number were also keeping cattle at home and in some cases their opinion differed between their roles as cattle trader and cattle owner. In Kenyan livestock markets there is a class of middlemen generally called 'brokers'. Unlike traders, they normally do not own the livestock being traded, but mediate between buyers and sellers. During the interviews we could not differentiate between traders and brokers.

As shown in Table 7 traders are the only subgroup in the survey in which the majority of respondents (58%) expressed no interest in the genomic assay and the certificate. Since the respondents have been interviewed in their role as traders and brokers only, it is assumed that they viewed the genomic assay from this perspective and considered the effect the assay and the certificate might have on their business activities.

Most traders indicated interest in the technology based on a potential increase in the sales price of the animal, or similarly indicated that the assay will be a proof of (better) quality of cattle for sale and a better quality will lead to better prices and higher margins. Some traders were concerned that the certification would create precedent, which may make it difficult in future to sell animals without certificates since potential buyers might assume that the animal is of inferior quality. Some traders thought that because cattle with a certificate may be more expensive, it may mean they will be more difficult to sell and eventually the margins for trader might shrink. Buyers may not understand or appreciate the certificate, since they are mainly buying according to phenotypic appearance of the animal. A small number of traders were only buying cull cattle to sell to butchers and for them, the assay and the certificate has no influence on value.

5 Conclusion

There is a high level of expressed interest in the genomic assay across all subgroups of smallholder dairy farmers in traditional as well as in the emerging dairy areas. The main reasons for this high-level of interest can be broadly grouped into financial reasons and better-informed breeding decisions.

The financial reasons focus around two different issues: Owners of village bulls see the assay and the certificate, in addition to informing breeding decisions, as a marketing instrument which will help them in their breeding business. A second financial reason frequently stated for all categories of cattle, is a potential higher sales price for animals, in the expectation that the assay and the accompanying certificate might contribute to an overall impression of good animal quality and modernization of the sellers' business.

More information to make better breeding decisions is the other main reason for the interest in the assay. Most respondents were very engaged in the explanation of the assay and showed an interest in the topic. A significant number of respondents believed that increasing exotic proportion in a cross-bred cow automatically would lead to increased milk yield, although we know that other factors such as feeding and animal health play a large role. Given the limited resources of most smallholder farmers, the milk yield potential of higher-grade animals is unlikely to be achieved.

In general respondents were eager to know more about good breeding practices, but had only limited ideas to what extent the additional information provided through the assay would help them in that aspect. This limitation may be reflected in the fact that there were few differences across the six subgroups as far as the general interest in the genomic assay and the reasons for that interest are concerned. The interest of breeders was not higher than in all the other subgroups. At the same time, respondents did provide rational explanations for their reasons across the various categories of cattle. Making better breeding decisions was the primary reason across all groups, although some, such as breeders and bull-owners anticipated value in higher sales prices for their animals, or increasing demand for their bull services.

Most traders were indifferent, although those that were interested recognized the potential value in increasing demand or sales price in the cattle they were trading. Some expressed concerns with the precedent that regular use of such certificates might set and the implications in the future.

It should be repeated that surveys on the interest in and the willingness to pay for a product, which was unknown to the respondents, tend to yield inaccurate results, as found in other surveys on related topics as well (Khainga, Obare and Nyangena 2018). These results suggest that there is an interest in the genomic assay and smallholders are also willing to pay for this service, but the exact figures should be treated with some caution. In general, it can be concluded that the genomic assay could find a market and group of potential adopters, depending on the cost and logistics of access and implementation. Once successfully piloted, it could be part of a comprehensive program of education and training for smallholders on a wide range of topics emphasizing the three main pillars of any livestock activity, namely breeding, feeding and health.

So many difficult questions (credit ILRI/Christoph Weber).

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Annex: Survey questionnaire

Market survey ADGG, genetic assay

A farmer-specific categorization into one of the 6 subgroups is first conducted using a few basic questions on dairy business objectives and practices. Once categorized, the main characteristics per farmer interviewed should be limited and focused on the basics like number of dairy cattle, production level, breeding method(s) and a 'verification' of the assumption for the subgroup (does he own a bull, is he selling or buying dairy cattle).

Code of subgroup:

Farmers details

Name

Mobile number

Village

Ward

Sub-county

County

GPS co-ordinates

Cattle herd

	Local	Cross-bred/Exotic
Bulls/castrated males		
Cows		
Youngstock 1–3 years		
Calves below 1 year		

Milk production and marketing

How many litres of milk did your best cow produce yesterday?

At peak production?

When did this cow have her last calf?

Of all the milk you produce, what is the share you sell?

Breeding methods

Over the past two years, what were the share of the various breeding sources?

Own bull	Other bull	AI	Total
			100%

Why do you prefer your favourite method?

Cattle sales and purchases

Over the last 2 years how many cattle have you sold or purchased?

	Bulls/castrated males	Cows	Youngstock	Calves
Sold				
Purchased				

Now the genetic assay, the sampling method and the certificate will be explained including the context (cross-bred versus purebred, degree of cross-breeding etc.). The farmer will have the chance to ask questions regarding the topic.

Now one/several questions from the enumerator will follow:

Let's assume you have a good cow and you know this cow has 75% cross-bred and 25% local blood. What type of bull do you need to stay on that level of cross-breeding (75 : 25) ?

Once the enumerator is reasonably sure that the farmer has properly understood the 'product' (which is taking the hair sample, having it analysed and receiving a certificate), the enumerator now asks questions again:

Are you interested in such a certificate stating the level of cross-breeding?

No Why not

Yes Why

For which type of animal would you be interested and for which reason(s) ?

[tick all applicable]	interest	reasons		
My present bull		Better informed breeding	Higher sales price	Increased demand for mating
My present cow(s)		Better informed breeding	Higher sales price	
My present heifer(s)		Better informed breeding	Higher sales price	
My young bull/male calf		Better informed breeding	Higher sales price	Increased demand for mating

In case the farmer gives another/additional reason, state it here

In case you buy a dairy animal, would you be more interested in an animal which has such a certificate and be ready to pay a higher price?

No why not

Yes why

How much would you be ready to pay for the genetic assay including the certificate ?

After the farmers has given a figure the enumerator should talk/discuss a bit on how the farmer came to that amount (literature recommends the direct question if an unknown product and the willingness to pay is being assessed).

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