Animal Genetic Resources, 2016, 58, 1–12. © Food and Agriculture Organization of the United Nations, 2015
doi:10.1017/S2078633615000326

Indigenous cattle breeds and factors enhancing their variation, potential challenges of intensification and threats to genetic diversity in Uganda

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Summary
Indigenous cattle support approximately 26.1 percent of Ugandan families through provision of food and income in addition to the supply of socio-cultural wealth and security. Cattle keepers have developed and maintained variations of indigenous cattle phenotypes and genotypes suited to their agro-ecological zones through traditional management practices and socio-cultural aspects. The Ankole (*Bos taurus indicus*), East African shorthorn Zebu (*Bos indicus*) and their crossbred cattle constitute the main indigenous breeds, adding up to 93.3 percent of the Ugandan herd. With intensions to increase productivity, state policies encourage livestock farmers to upgrade local genotypes towards high yielding exotic dairy cattle. This if not appropriately planned is likely to result into loss of local genetic diversity, well endowed with resilience to local climatic conditions, endemic diseases and feed resource constraints. Here in, we review literature related to indigenous cattle in Uganda including how diverse landscapes, local management practices and socio-cultural aspects have enriched patterns of indigenous cattle variations. Then we highlight potential challenges of intensive management, increased selection for higher productivity and threats to genetic diversity of indigenous cattle populations. Since indigenous cattle vary with landscapes and socio-cultural values, have taken decades to establish, efforts to save them through genetic diversity studies, conservation and farmers sensitization should be undertaken immediately.

Keywords: *Agro-pastoral and pastoral, Ankole, East African shorthorn zebu, genetic variation, intensification, Uganda*

Résumé
Les bovins indigènes se soutiennent environ 26.1% des familles ougandaises par la fourniture de nourriture et de revenus, en plus de la fourniture de la richesse et de la sécurité socio-culturelle. Les éleveurs de bovins ont développé et maintenu variations de phénotypes et les génotypes de bovins indigènes adaptées à leurs zones agro-écologiques (ZAE) grâce à des pratiques de gestion traditionnelles et les aspects socio – culturels. Le Ankole (Bos taurus indicus), shorthorn Afrique de l'Est Zébu (EASZ) (Bos indicus) et leurs hybrides constituent les principales races de bovins indigènes, en ajoutant jusqu'à 93.3% du troupeau ougandaise. Avec intensions pour augmenter la productivité, les politiques de l'Etat encouragent les éleveurs à améliorer génotypes locaux vers les bovins élevés laitiers exotiques rendement. Cette si pas prévu de manière appropriée est susceptible d'entraîner dans la perte de la diversité génétique locale, bien dotée en la résilience aux conditions climatiques locales, les maladies endémiques et les contraintes de ressources d'alimentation. Ici, dans, nous passons en revue la littérature liée aux bovins indigènes en Ouganda, y compris la façon dont divers paysages, pratiques de gestion locales et les aspects socio- culturels ont renforcé types de variations de bovins indigènes. Ensuite, nous mettons en évidence les défis potentiels de la gestion intensive, une sélection accrue pour une meilleure productivité et des menaces à la diversité génétique des populations de bovins indigènes. Depuis les bovins indigènes varient avec des paysages et des valeurs socio-culturelles, ont pris des décennies à établir, les efforts pour les sauver à travers des études de la diversité génétique, la conservation et la sensibilisation des agriculteurs doivent être prises immédiatement.

Mots-clés: *Ankole, la variation génétique, gardiens de bovins indigènes, agro-pastorale et pastorale, Zébu shorthorn Afrique de l'Est, Ouganda*

Resumen
El ganado bovino autóctono sostiene a, aproximadamente, el 26.1 por ciento de las familias ugandesas mediante el abastecimiento en alimentos y el aporte de ingresos, además de por su importancia sociocultural en términos de riqueza y seguridad. Los criadores de ganado bovino autóctono han desarrollado y mantenido variaciones en el fenotipo y en el genotipo del ganado, que se adecúan a sus zonas agroecológicas, por medio de las prácticas tradicionales de manejo y por influencia de aspectos socioculturales. El ganado Ankole (*Bos taurus indicus*), el Cebú de Cuernos Cortos del Este de África (EASZ por sus siglas en inglés, *Bos indicus*) y sus cruces

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constituyen las principales razas autóctonas, llegando a representar hasta el 93.3 por ciento de la cabaña ugandesa. Con la intención de incrementar la productividad, las políticas estatales animan a los ganaderos a mejorar los genotipos locales con la vista puesta en el ganado lechero exótico de alta producción. Esto, si no se planifica adecuadamente, puede fácilmente llevar a una pérdida de la diversidad genética local, bien dotada de resistencia a las condiciones climáticas locales, a las enfermedades endémicas y a las limitaciones en la alimentación. En este artículo, revisamos la documentación existente sobre el ganado bovino autóctono de Uganda, incluido cómo diferentes entornos, prácticas locales de manejo y aspectos socioculturales han generado patrones de variación en el ganado bovino autóctono. A continuación, hacemos hincapié en los desafíos que pueden derivar del manejo intensivo, de una mayor selección para incrementar la productividad y de las amenazas a la diversidad genética de las poblaciones bovinas autóctonas. Dado que han sido necesarias décadas para que surgieran en el ganado bovino autóctono las variaciones debidas al entorno y a los valores socioculturales, los esfuerzos necesarios para preservarlas deben iniciarse cuanto antes (estudios de diversidad genética, proyectos de conservación y la sensibilización de los ganaderos).

Palabras clave: *Ankole, agropastoral y pastoral, Cebú de Cuernos Cortos del Este de África, variación genética, intensificación, Uganda*

Submitted 13 June 2015; accepted 22 September 2015

Background

At least 26.1 percent of Uganda's rural households derive their livelihoods from indigenous cattle (MAAIF *et al.*, 2010) which constitutes 93.3 percent of the national herd. However, 1.2 million rural households from cattle keeping areas in Uganda have been reported to experience food insecurity (IRIN, 2013). Globally, a rapid human population growth rate, increased urbanization and escalating consumer preferences occurring in most parts of the developing world is a serious threat to food security (Thornton, 2010). Food insecurity is more evident among the rural poor households who are mainly engaged in smallholder crop-livestock farming systems (Delgado *et al.*, 1999; Delgado, 2003). Smallholder farming systems have been perceived as less likely to satisfy the demand for foods of animal origin set to dramatically increase (MAAIF, 2013). In order to arrest this situation, a High Level Panel of Experts on Food Security and Nutrition (HLPE, 2013) has argued that increased capitalization of smallholder livestock enterprise systems could provide a dependable conduit out of poverty and food insecurity for nearly one billion people in sub-Saharan Africa. Since about 26.1 percent of the Uganda's households derive most of their livelihood from indigenous cattle (MAAIF *et al.*, 2010), government and local non-government organizations (NGOs) perceive increased capitalization of smallholder livestock farming systems as a springboard for poverty reduction (Baltenweck *et al.*, 2007). As a result current national livestock policies encourage smallholder livestock farmers to cross-breed their indigenous cattle towards the more specialized high yielding exotic breeds in a bid to increase productivity (Taberlet *et al.*, 2008). This is being done without conservation plans of the indigenous genetic resources which manifests as variation of the indigenous cattle adapted to the different landscapes (Taberlet *et al.*, 2008). Indigenous cattle are well endowed with adaptive traits to endemic diseases, fragile climatic conditions and poor feed resources (Hanotte, Dessie and Kemp, 2010; Hoffmann, 2010) and the current cross-breeding practices may result into an irreversible loss of genetic variation (Taberlet *et al.*, 2008). Indeed, scientists have already warned that this loss spells disaster for Africa's food security and livestock genetic pool for the next generation (Seré *et al.*, 2008; Hanotte, Dessie and Kemp, 2010). Before more losses are realized, there is a need to study in a landscape approach the current genetic variation among the indigenous breeds and how geographic and socio-cultural factors have influenced these patterns of variations (Joost *et al.*, 2007; Pariset *et al.*, 2009; Schwartz *et al.*, 2009). In this study we review literature concerning indigenous cattle in Uganda with the aim of establishing how management factors, socio-cultural values and landscapes influence variations among local indigenous cattle genotypes. Finally we have highlighted the consequences of intensive management systems, selection for increased productivity traits and the threats to indigenous cattle diversity in Uganda.

Review methodology

A search of peer-reviewed studies on indigenous cattle breed diversity was conducted from comprehensive databases including Google Scholar, PubMed, Science Direct, Swetswise and CAB direct. The search was extended to available theses, conference proceedings, project reports etc. The search was restricted to English language articles. Keywords were standardized across the databases to produce comparable searches and these were: Ankole; genetic variation; indigenous cattle keepers; agro-pastoral and pastoral; East African shorthorn zebu; Uganda. References of all relevant articles were also searched to identify articles that could have been missed in the search. A total of 430 records were retrieved. All records were imported in to Microsoft Excel, and articles

http://dx.doi.org/10.1017/S2078633615000326

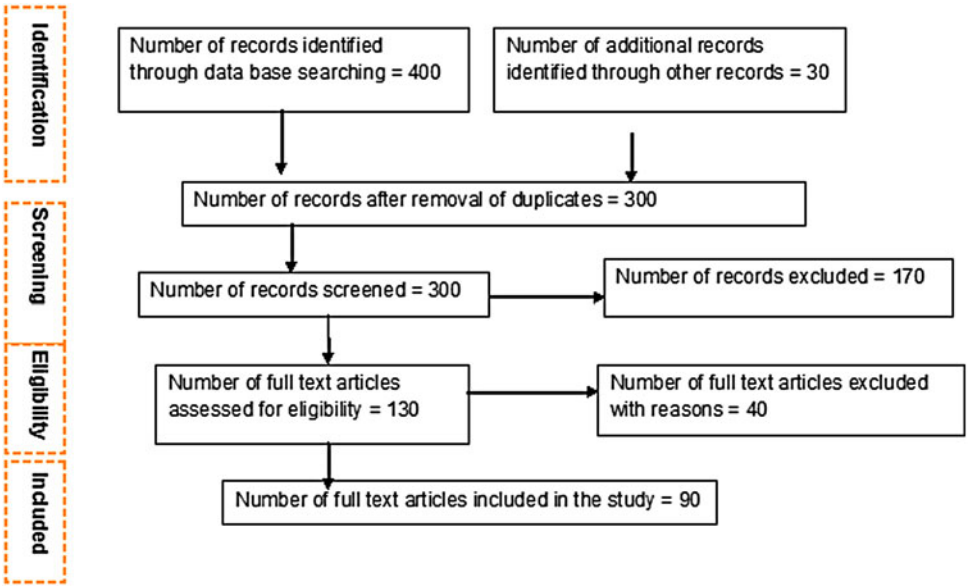

Figure 1. A flow chart of the methodology used to identify and review literature on Indigenous cattle breeds and factors enhancing their variation, potential challenges of intensification and threats to genetic diversity in Uganda (Adopted from PRISMA flow diagram (Moher et al. 2009).

presenting duplicate titles/findings were removed to obtain 300 records. Further screening was done by title and abstract focusing on studies reporting on indigenous cattle breeds and factors enhancing their variation, potential challenges of intensification and threats to genetic diversity in Uganda and countries with similar situations yielding 130 text articles published as of May 2015. Additional screening of the articles then identified the most relevant ones for Uganda yielding 90 articles which were used in this review. Figure 1 shows a flow chart of the methodology used to identify and review literature used in this report (Moher *et al*., 2009).

Indigenous cattle breeds in Uganda

Uganda has a total of 10.64 million indigenous cattle, representing 93.3 percent of the national herd of 11.4 million (MAAIF/UBOS, 2010). The Ankole and East African shorthorn Zebu (EASZ) constitute the main traditional cattle breeds in Uganda. Other breeds are variants and intermediates of the two including Nganda, Nkedi, Kyoga, Nyoro and Kigezi (Rege and Tawah, 1999). Although indigenous cattle have been faulted for low productivity and reproductive performances, they still remain popular in Uganda because of their adaptive traits to the local underprivileged conditions (Balikowa, 2011). Below is a brief description of the indigenous cattle breeds.

The Ankole cattle

The Ankole cattle have been naturalized in Uganda having been imported from North-eastern Africa about 600 years ago (Rege, 1999) by the Hamitic (Bantu) pastoralists. In addition to Uganda, Ankole cattle are found in Burundi, Democratic Republic of Congo (DRC), northern Tanzania and Rwanda. In Uganda, the Ankole cattle are mainly present in the western and south-western rangelands but also some parts of central Uganda (Okello and Sabiti, 2006; Ndumu *et al*., 2008).They are part of the Sanga linage of cattle which probably evolved in Ethiopia as a product of interbreeding between the original longhorn non-humped cattle with the cervico-thoracic humped zebu cattle (Rege and Tawah, 1999; Rege, 1999; Kugonza *et al*., 2012). Having evolved within Africa, the Ankole cattle constitute an indispensible Animal Genetic Resource (AnGR). They are reared by the pastoral and agro-pastoral farming communities in a typical subsistence traditional farming system, thus constituting an indispensable and unique AnGR well adapted to the local tropical conditions. They are characterized by a medium to large body frame with a small cervico-thoracic hump, large, long and curved white horns. The coat colour is mainly red, fawn, brown and often spotted with white. Several ecotypes have emerged as a result of different indigenous cattle keeping communities who benefit a supply of food and income for recurrent needs, risk aversion, accumulation of cultural wealth and prestige (Wurzinger *et al*., 2006).

The EASZ cattle

The EASZ cattle (*Bos indicus*) were introduced into the East African region by the Arab traders through the East African coast from Western Asia (Payne, 1990; Rege, 1999). Several variations of Shorthorn Zebu cattle are reared in the eastern and southern Africa, all commonly referred to as the "East African Zebu". However, based on their sizes and conformation, two main populations of Shorthorn Zebu are recognized and these are "the large"

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and "small" groups (Rege, 1999). The large Zebu types traditionally inhabit the marginal lands of northern Kenya, north-eastern Uganda, southern Sudan, southern Ethiopia and western Somalia. The small East African Zebu cattle have a smaller and more compact body as compared with the large Zebu. They are more common in the much wetter habitats and manifest greater variations in size and conformation. However, both the small and large Zebu types are believed to be of common lineage. Mwacharo *et al*. (2006) have attributed the variations in size to have resulted from adaptive response to the prevailing natural environment.

Variation among cattle populations, its origins and importance

Only two cattle domestication centres, the Fertile Crescent at the border of Iran, Iraq and Turkey, and the Indus valley of today's Pakistan (Bradley *et al*., 1996; Freeman *et al*., 2006) have been fully documented. The progenitor of modern cattle is the extinct wild auroch (*Bos primigenius*) (Ajmone-Marsan, Garcia and Lenstra, 2010) which lived as two subspecies in the Fertile Crescent and the Indus Valley which have given rise to a vast variation present in cattle populations today. Enormous variations arose after subsequent dispersal of cattle over different continents and adaptation to various environments (Ajmone-Marsan, Garcia and Lenstra, 2010).

This wide variety of characteristics evolved more or less naturally over a few thousands of years, but has recently been rapid leading to the development of well defined, specialized and genetically isolated breeds (Ajmone-Marsan, Garcia and Lenstra, 2010). Cattle variations based on geographical, ecological or cultural isolations with heritable characteristics such as colour markings, unique morphologies and differences in yields have resulted into the modern distinct breeds (FAO, 2003, 2007). Felius *et al*. (2014) have noted that the natural distribution of *B. taurus* and *indicus* is successfully restricted to regions with similar climatic conditions to those of the earlier domestication centres in the Fertile Crescent and the Indus Valley, respectively.

Wilson (2009) has described fitness traits of tropical indigenous livestock that may equally apply to cattle which give them comparative advantage to survive in the tropics better than the temperate breeds. They are: – a lower metabolic rate that produces less heat; reduced panting but more ready sweating that preserves energy; a feed intake which is less affected by high ambient temperatures; a higher ability to survive on lower quality feed; higher digestibility and efficiency of feed conversion; lower water requirement; a greater ability to retain feed and water in the large intestine and better resistance to ticks, insects and some diseases. Indeed these qualities are present among indigenous cattle populations of Uganda with different variations.

Today, several breeds have emerged as a result of interbreeding related indicine and taurine cattle. This tends to occur in localities without distinct boundaries as is the case of Ankole-Zebu crosses giving rise to unique variations of the two such as the Nganda and Nyoro cattle in central Uganda. Variation has not emerged to be studied at a later time as a basis for classification of cattle, genetic diversity and adaptation. Studying the factors which enhance indigenous cattle variation in contrasting landscapes could provide a baseline for landscape genomic research and conservation approaches thus establishing the gene pool for next generation livestock farming.

Traditional management systems and their influence on indigenous cattle variation

Traditional management systems by either opening grazing and/or tethering on communal pastures are the mainstay of traditional cattle management practices in East Africa (Muhereza and Ossiya, 2004). These systems form a continuum between agro-pastoralism and pastoralism in Uganda (Nalule, 2010; Balikowa, 2011). Livestock farming communities select breeding sires and dams with specific traits to enhance resilience to the challenges of pastoralism and agro-pastoralism in their localities. This selective breeding enhances cattle population adaptive traits to extremes of either system with tendencies to develop variations (Franktin and Mearns, 2003). For example, in the semi-arid region of north eastern Uganda, the climatic conditions vary from arid to semi-arid with seasonal availability of pasture and water (Loquang and Köehler-Rollefson, 2005; Nalule, 2010), to which traditional Karamojong shorthorn zebu cattle are well adapted. Similar although less severe conditions apply to the Bahima pastoral communities in the South-western pastoral rangelands of Uganda (Kugonza *et al*., 2012). Indigenous cattle provide the most suitable means of exploiting marginal lands with scarce resources and sustainable pastoral livelihoods (Hoffmann, 2011). The farmers' selection criteria of breeding cattle under this system would opt for resilience traits observed in parent stock associated with strong well-developed musculature to enable long distance movement in search for pastures and water (FAO, 2007). While in the agro-pastoral areas of the Lake Victoria Crescent agro-ecological zone (AEZ) where cattle are mainly tethered, selection will target docile cattle to enable frequent handling. Such selection is likely to result into locally adapted variations of indigenous cattle. Presently, local farmers' choices greatly influence patterns of genetic variation which has not yet been fully studied, similar to the morphometric variation lately documented (Kabi *et al*., 2015).

The role of socio-cultural practices in indigenous cattle variations

Cattle keeping communities in Uganda have deliberately bred cattle as a socio-cultural prestige in addition to

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being a primary source of livelihood to households (Kugonza *et al*., 2011). Several indigenous breeds are connected to a specific ethnic group or community, which is often reflected in the breed names such as the Nganda and Ankole cattle (Kohler-Rollefson, 2003; Krätli, 2008). Different cattle keeping communities deliberately breed cattle to develop favoured unique variations (FAO, 2007, 2009). This practice has been observed among the Ankole cattle communities where unique morphological features such as the shape of horns and colour markings (Ndumu *et al*., 2008; Kugonza *et al*., 2012) create a sense of ownership while meeting the traditional desires of the communities. Some of these practices were initiated by the pre-colonial monarchies for gifts and presents to beloved ones or ceremonies and festivities (Ndumu *et al*., 2008). As a result cattle populations in Uganda have been named according to tribal communities such as the Teso zebu for the Itesot speaking community and Nyoro cattle for the Banyoro speaking communities. This accounts for great variation among indigenous cattle populations within the country.

The traditional cattle keepers from the West Nile region, North-eastern and South-eastern Uganda keep the EASZ cattle. The specific features of the EASZ cattle such as size and shape of horns, multiple colourations, body size are carefully selected for by kraal leader through utilization of specific sires and dams (Loquang and Köehler-Rollefson, 2005; Nalule, 2010). These too account for significant variations among cattle populations. The Karamojong Zebu cattle, Nkedi Zebu, Lango Zebu and the Nganda Zebu are the common varieties belonging to the various cattle keeping communities in Uganda.

The role of landscape features to variations among indigenous cattle populations

Uganda is endowed with unique physical features such lakes, rivers, highlands and rift valleys. These features provide exclusion barriers within geographical and ecological locations dividing indigenous cattle inhabitants into several subpopulations. Breeding of cattle within the same localities have definitely concentrated specific features (productivity, resilience and adaptive) which vary from one locality to another as could be influenced by the landscape as previously described by Grimaud *et al*. (2007). Pastoral communities select breeding cattle with attributes to withstand challenges created by landscapes, this is common in semi-arid region of Karamoja where cattle have to trek long distances in search of pastures and water (FAO, 2007; Nalule, 2010). In the South-western rangeland cattle will utilize pastures on the higher altitudes during the wet seasons and are moved to the lower altitude valleys in the dry seasons. This requires adaptation to seasonal movements between the different altitudes. This local adaptation could potentially create significant variations between the cattle in the rangelands, plateaus and highlands.

The role of adaptation to endemic diseases

Cattle keeping communities in rural areas may not have access to adequate modern disease control and veterinary services. For example, Gradé, Tabuti and Van Damme (2009) note that cattle present in the semi-arid regions do not access adequate veterinary services. In such situations cattle get adapted to seasonal movement away from areas with high disease risks created by insect vectors emergence during the rainy seasons and will return when the dry season sets in. However, minimal continuous exposure to specific diseases such as East coast fever will result into exhibition of non-clinical disease conditions loosely related to endemic stability within a population as lately described (Kabi *et al*., 2014). Such practices will result into indigenous cattle genotypes yet to be described that vary with different disease challenges and control practices (Carval and Ferrier, 2010). Several studies have indicated that indigenous cattle can endure and be sustainably productive in the presence of disease challenges, a phenomenon referred to as tolerance or resilience to disease (Baker and Gray, 2004; Bishop, 2012) and endemic stability (Jonsson *et al*., 2012) to infection. In pastoral areas of Uganda, the humid climatic conditions favour proliferation of vectors creating an endemic disease presence (Otim *et al*., 2004; Ocaido *et al*., 2005; Moloo, Kutuza and Borehan, 2006). The continuous exposure of endemic diseases such as tick borne diseases among indigenous cattle populations has led to the development of tick borne disease tolerant traits (Jonsson *et al*., 2012). However, these unique traits (such as endemic stability among indigenous cattle) may be lost due to stringent tick control measures being imposed on indigenous cattle in order to protect exotic naïve breeds imported in Uganda since the former are regarded as source of infection (Okello-Onen *et al*., 1998). Disease outbreaks among populations with low genetic variation have been reported to result into high morbidity and mortality rates as is the case with exotic genotypes compared with genetically diverse livestock populations (Mirkena *et al*., 2010; Danchin-Burge *et al*., 2012).

Based on the above factors of variation, an appropriate cattle population would require most of these traits, such as adaptation to local physical landscape, nutritional and management environments; acceptability to local communities' socio-cultural needs; resistance to the endemic diseases of the area; good reproductive and growth performance; and adequate yields of meat, milk, draught power related to the prevailing management system. Similar qualities have also been alluded to by Wilson (2009). However, it is worth noting that adaptive traits may not be positively correlated to increased productivity as shown by unfavourable genetic correlation between milk yield and the incidence of ketosis, ovarian cyst, mastitis and lameness. This means that continued selection for higher milk yield will increase incidence rates for these production diseases and reduce the well-being of dairy cows (Ingvartsen, Dewhurst and Friggens, 2003).

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Generally, the critical factor for increased productivity in farm animals is the availability of insufficient resources for adequately coping with environmental stresses and disease pathogen challenges (Rauw, 2009). This indirectly assigns limits to further increase in productivity of livestock in the tropics where endemic disease challenges are quite high.

The potential challenges of intensification of smallholder livestock farming systems

Increasing quality of farm inputs and services

Improvement of rural household incomes is part of Uganda's obligations to the Millennium Development Goals initiatives (MAAIF *et al*., 2010). In view of the circumstances that most of the rural households derive much of their livelihoods from smallholder livestock farming systems. Policy makers and other stakeholders envisage the commercialization of livestock production as one of the favourable option, both to meet the increasing demand for livestock products in addition to contributing to poverty reduction among households (Otte and Upton, 2005; MAAIF *et al*., 2010; Udo *et al*., 2011). This policy and practice will most likely lead to intensive cattle management systems. However, intensification demands increased use of purchased high quality inputs and services, such as feed supplements, replacement stock, breeding and veterinary health services (Bebe *et al*., 2003; Otte and Upton, 2005; Udo *et al*., 2011). This means that in practical terms more investment will be needed and it is the affluent livestock farmers who may have the capacity to benefit from the increased demands for livestock products. This paints a dark cloud over the benefits of intensification of smallholder livestock farming systems especially among the majority of the rural poor. Cooperatives for bulk milk marketing and purchase of inputs, and modern management skills will be needed urgently. This calls for revitalization of farmers' credit and cooperative saving schemes which were abolished during privatization of public enterprises in Uganda to assist small scale farmers with procurement of farm inputs, value addition and marketing of milk and its products.

Intensified selection of cattle

After livestock were domesticated, selection criteria mostly targeted phenotypic behavioural traits such as calmness in cattle for non-problematic handling and beautiful colour patterns (Oltenacu and Broom, 2010; Taberlet *et al*., 2011) in addition to productivity traits to provide better livelihoods among households. However, in the last 40 to 60 years, interest has mainly shifted to genetic improvement of productivity traits, including milk yield and beef in cattle (Oltenacu and Broom, 2010). Consequently milk productivity has tremendously increased in various farming systems within the tropics over the recent decades as observed by Galukande *et al*. (2013). However, this has to be accompanied with intensive management practices, without which the maintenance of increased productivity remains quite challenging to rural smallholder livestock farmers. In other regions, high productivity has been accompanied by challenges such as reduced capacity to reproduce, increased incidence of metabolic disorders and declining longevity in modern dairy cows (Van Raden, 2004; Oltenacu and Algers, 2005). Lameness is a common welfare challenge for dairy cows in the UK (Webster, 2000; Amory *et al*., 2008) which is usually complicated by loss of weight, poor feed intake, lowered milk production and higher risks of reduced fertility, mastitis and eventually culling (Weaver, 2000). The incidence of metabolic disorders and production ailments tends to occur whenever high yielding cows are unable to satisfy the high metabolic requirements of maintenance, pregnancy and lactation (Rauw *et al*., 1998). For example severe forms of hypocalcaemia or hypomagnesaemia occur when the cows run short of calcium and magnesium in circulation, respectively (Rauw *et al*., 1998). Other diseases such as ketosis and fat liver syndrome occur due to above normal energy demands (Webster, 2000). Without specialized veterinary attention and manufactured nutritional farm inputs, huge losses will usually result. Intense selection for high milk yield has also been linked to high infertility levels (Webster, 2000). Increased milk yield is genetically correlated to longer calving intervals, more days to first service and lowered chances of conception at first service. The resultant infertility is the main reason for culling in dairy cows (Whitaker, Kelly and Smith, 2000). Nørgaard, Lind and Agger (1999) conclude that a higher level of physiological stress due to higher milk yield and concentrate consumption has led to increased mortality in dairy cows. Intensified selection for increased productivity without fitness is now being discouraged in developed countries due to welfare reasons (Oltenacu and Broom, 2010).

Selective breeding for increased productivity in tropical countries like Uganda must be accompanied with agro-ecological fitness to counter metabolic, unsustainable feed resources and endemic diseases challenges as suggested by Eisler *et al*. (2014). Intensive selective breeding for increased productivity in Uganda can be successful if well planned to counter the negative effects which usually occur at extremely high levels of productivity of cross-bred cattle. In India for example the Sunandini synthetic cattle breed has been developed through a well-organized cross-breeding programme between the Jersey, Brown Swiss and Friesian and the local cows of Kerala state, with the involvement of local farmers' interests resulting into high milk production (Chacko, 2005). The Australian Friesian Sahiwal is another popular synthetic breed with 50:50 Sahiwal:Friesian developed and maintained by the Queensland government in Australia for more than 30 years before being privatized. Among other traits, this breed is known to have good tick resistance, milk yield

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traits and well adapted to tropical grazing pastures (Stephens, 2006).

Threats to indigenous cattle diversity in Uganda

In general, several authors have accepted the fact that AnGR is on the decline due to several factors acting as threats to the latter (Eisler *et al*., 2014). For example Bett *et al*. (2013) have noted that the Ankole and Nganda cattle genotypes have become gradually threatened due to cross-breeding with exotic dairy breeds. Likewise the Nkedi and Lugbara zebu linage could be disappearing due to breed substitution with Ankole and Karamajong, respectively. The Kigezi breed could be threatened due to the high human population pressure in its homeland of south western highlands, increased cross-breeding with the more productive exotic genotypes and suitable environmental conditions (Bett *et al*., 2013).

The use of exotic germplasm, changes in production systems, because of socio-economic factors, natural disasters (drought, famine, disease epidemics, civil strife/war) and exploitation of rangeland resources have been cited as the major causes of genetic erosion (Rege and Gibson, 2003; Gibson *et al*., 2006; Taberlet *et al*., 2008) however, these are common in the rest of the world but also occur in Uganda.

Changes in producer preference due to socio-economic and policy factors

The increasing demand for foods of animal origin and improvement in income levels have tempted livestock farmers and policy makers towards the utilization of specialized high yielding breeds (Delgado, 2003). In Uganda, smallholder cattle farmers have been encouraged to replace their indigenous cattle with high yielding exotic breeds (Grimaud *et al*., 2007; Balikowa, 2011). This is a widespread consequence of the need to increase productivity, although it is latently accompanied with narrowing of within-breed genetic variation (Kantanen *et al*., 2015). This is a big threat to indigenous cattle genetic diversity among agro-pastoral and pastoral farmers. Regions where this practice was previously promoted have reported loss of genetic variation (Kantanen *et al*., 2015). In Europe for example, 200 breeds of indigenous cattle have been replaced only by 20. This is undesirable in the current uncertain times of climate change.

Introduction of exotic germplasm

Use of exotic germplasm has been the approach in the desire to increase productivity in the tropics. Several initiative such as cattle zero-grazing and semi-intensive cattle farming with increased upgrading towards the more productive exotic cattle have been popularized in tropics including Uganda (Galukande *et al*., 2013). The use of artificial insemination, embryo transfer and exotic village bull schemes have been used at various stages as tools to support the introduction of exotic germplasm especially in cattle since 1960 (Galukande *et al*., 2013). In Uganda, these practices have been mainly amplified by local NGOs and other developmental community based organizations targeting smallholder cattle farmers with the objective of increasing milk productivity (Balikowa, 2011). Unfair competition from vigorously promoted commercial European breeds (Rege and Gibson, 2003) even where such genotypes are inappropriate (King *et al*., 2006; Hanotte, Dessie and Kemp, 2010) have been observed. No comprehensive national breeding program has been established to produce cattle that would easily get adapted to the local disease conditions, usually resulting into high mortality rates among improved dairy cattle (Bebe *et al*., 2003; Bayemi *et al*., 2005; Galukande *et al*., 2013). Despite the successes associated with cross-breeding, the practice has faced challenges such as limitations of skilled techniques (inadequate heat detection), mismatches between genotypes and production system where environmental conditions cause stress affecting heat detection, intermittent funding of programmes, lack of appropriate supportive policies and limited involvement of farmers in the design of the interventions. Unplanned use of exotic germplasm will most likely lead to loss of the much cherished indigenous cattle traits including endemic disease tolerance, adaptation to poor quality pasture and high environmental temperatures (Taberlet *et al*., 2008). Improved dairy cattle are more vulnerable to local diseases and parasites particularly tick-borne diseases, internal helminths and trypanosomosis (Magona, Walubengo and Kabi, 2011), whose effective control requires substantial investments.

Changes in production systems

Indigenous cattle are managed by open grazing on communal rangelands, involving mobility in search of pastures and water in resource-scarce and highly variable marginal areas to enable human habitation and subsistence (Krätli *et al*., 2013). This is implemented in the form of sophisticated herd movements and grazing strategies to save forage for critical periods for sustainable utilization. However, successive colonial and post-independence government policies have always advocated for the settlement of pastoralists to enhance governance and political control (Inselman, 2003; AU-IBAR, 2012) faulting pastoralism as backwards and wasteful. In certain circumstances, increased population growth has *in addition* limited the availability of land available for pastoral nomadic movement, forcing pastoralists to *revert to* settled agriculture (Grimaud *et al*., 2007). The above have resulted into reduced mobility of pastoralists and their livestock, but may hasten loss of indigenous AnGR since local farmers are further enticed to indiscriminately cross-breed their cattle.

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Breakdown of traditional and cultural leadership as a consequence of disaster

Livestock keeping communities have for long established traditional and cultural leadership institutions in order to ensure long-standing sustainable pasture management, water supply and AnGR (Rathore and Kohler-Rollefson, 2002; Homann, Dalle and Rischkowsky, 2004; Nalule, 2010). Due to continued conflicts and civil wars, community leaders are not able to enforce these leadership roles which would enable them to sustainably utilize scarce natural resources in the region (Nalule, 2010; Stites, Fries and Akabwai, 2011; AU-IBAR, 2012). The council of Jie and Dodoth ethnic elders of Karamoja region have previously planned for the sustainable use of grazing pastures and water for livestock. Lack of comprehensive livestock management system due to the breakdown of traditional leadership as a continuous civil strife has resulted into degradation of rangeland resources which supplies livestock feeds thus threatening AnGR (Nalule, 2010).

Exploitation of natural resources within pastoral areas

Exploitation of oil and minerals in the Albertine region of Western savannah grassland zone and the Northeastern Drylands zone, respectively, will definitely interfere with the natural ecosystem of wildlife and plants (Kityo, 2011). Indigenous cattle which benefit from this ecosystem will lose access to feed and water resources. This is a threat to AnGR in the region.

Discussion and conclusion

Variations of indigenous cattle populations have augmented their agro-ecological fitness in Uganda while supporting several cattle keeping communities through provision of household livelihoods. This paper reviewed literature to establish how traditional management factors, contrasting landscapes and socio-cultural practices have influenced indigenous cattle variations. Additionally, challenges associated with intensive management initiatives, increased selection for higher productivity and associated threats to indigenous cattle diversity were elucidated.

From the review of available literature, indigenous cattle breeds including the Ankole and EASZ in Uganda have been regionally structured until recently when cattle trade and restocking plans have led to widespread dispersal of the two main breeds. Several indigenous cattle intermediate populations of the Ankole and EASZ occur patronized by other cattle keeping communities (Balikowa, 2011; Kabi *et al.*, 2015). The Ankole have been naturalized in the southwestern and western regions, while the EASZ have been mainly reared in the eastern, northern and west Nile regions. This breed distribution structure could be attributed to points of entry and settlements of immigrant cattle keepers and promotion by the pre-colonial traditional leadership in Uganda (Hanotte *et al.*, 2000). Ankole cattle that are present in Uganda, DRC, Rwanda, Burundi and western Tanzania could have arisen from livestock movements that followed Bantu immigration from the Niger-Cameroon region, along the Atlantic coast, or through the rainforest basin into the African Great Lakes region (Hanotte *et al.*, 2000). While the EASZ cattle that are believed to have moved inland following their introduction at the east African coast by Arab traders. The Zebu cattle spread was further enhanced by local pastoral communities and their natural resistance to the Rinderpest epidemic of the late nineteenth century (Epstein, 1971). Traditional management practices (selective breeding and grazing patterns), different landscapes, socio-cultural needs and endemic disease challenges have overtime enhanced indigenous cattle breed adaptation to their localities. The adaptations to diverse AEZs take the form of variations in body sizes and levels of productivity (Kugonza *et al.*, 2011), morphometric traits variations (Kabi *et al.*, 2015) and resilience to endemic diseases (Magona, Walubengo and Kabi, 2011; Kabi *et al.*, 2014). Currently, intensive cattle management policies are being popularized for increased productivity and prospective poverty alleviation (MAAIF, 2013). Developing countries mostly rely on cross-breeding towards the industrial livestock genotypes as a standard approach to the improvement of livestock production more especially for dairy cattle productivity. Several authors allude to the fact that at a higher level of cross-bred cattle, local animal genetic resources are lost (Thomas *et al.*, 2002; Udo *et al.*, 2011; Galukande *et al.*, 2013). Thus the call for national conservation plans of indigenous livestock resources to act as a source for future generation livestock farming. Additionally, several case-studies by Bebe *et al.* (2003) and Udo *et al.* (2011), reported that intensification demands increased use of purchased inputs and services, including feeds, replacement stock, breeding and veterinary health services, credit facilities, producer organizations and market access for both inputs and outputs, and an increase in livestock management skills.

Udo *et al.* (2011), further noted that the less financially privileged farm households may exhibit less interest in investing their scarce resources and efforts in more intensive livestock systems. The socio-cultural and capital asset roles will remain important for these households. Furthermore, without robust development policies that deliberately consider the opportunities and threats likely to be met by mixed crop-livestock farming systems, these households are likely to miss out from the increased market opportunities for livestock intensification initiatives. Commercial industrial breeds of interest must only be promoted with adequate guidance in suitable ecologies and under appropriate management, while retaining the adaptive traits among indigenous cattle breeds. It is also worthy understanding that the modern breeding techniques such as artificial insemination, embryo transfer, cryopreservation

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and cloning from which industrial breeds are benefitted for wide popularization may also contribute immensely to the conservation and promotion of local breeds.

Awareness of the value of indigenous cattle genetic variations has now attracted lots of attention and can no longer be overlooked with respect to the different landscapes of Uganda. Indigenous cattle breeds adapted to contrasting landscapes and ecosystems need to be conserved since they constitute an important genetic source for next generation farming. Conservation efforts should be well planned to enable maintenance of within breed and between breed variations with consideration of their agro-ecological habitats. Within-breed variation is critical for the genetic adaptation of a population to changes in the production and economic environment and for averting inbreeding problems. With regard to the increasing demand of foods of animal origin, stakeholder must create policies that will enable the poor to obtain a share in the expanding market for livestock products. The policies include introduction of savings and credit schemes, removal of market barriers to trade in traditional livestock products and improvement of social services to rural farming communities.

Acknowledgements

We thank the Next generation methods to preserve farm animal biodiversity (NEXTGEN) project and the Eastern Africa Agricultural Productivity Project (EAAPP) for providing the logistics for this study.

Statement of interest

The authors have no conflict of interest to declare.

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http://dx.doi.org/10.1017/S2078633615000326