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Review: The diversity of local cattle in Indonesia and the efforts to develop superior indigenous cattle breeds

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Abstract. *Sutarno, Setyawan AD. 2016. The diversity of local cattle in Indonesia and the efforts to develop superior indigenous cattle breeds. Biodiversitas 16: 275-295.* Cattle breeding are regarded indigenous to Indonesia. In the country, there are three types of cattle breeds: zebu (*Bos indicus*), Bali cattle (*Bos javanicus*), and taurine (*Bos taurus*). These breeds are farmed for their meat, milk, leather, and their power for agricultural work. Zebu was introduced by the Indians in the beginning of the first century. Bali cattle are indigenous breeds that have been domesticated from wild bantengs (*Bos javanicus*) in Java and Bali for hundreds of years. Several breeds of taurine were imported in early eighteenth century to be used as dairy cattle. Zebu and taurine are the major cattle breeds of the world; whereas in Indonesia, the major cattle breeds are Bali cattle, Ongole crossbred, and Madura cattle, which is a crossbred of the former two. Primary breeding between species in the genus *Bos* will result in sterile male and fertile female offspring. However, secondary breeding with a crossbred female will result in fertile offspring. In Indonesia, there are several local cattle breeds of zebu that have adapted to the local condition, for example Ongole crossbred, Aceh cattle, Pesisir cattle, Sumba Ongole, and, the less commonly found, Galekan cattle of Trenggalek. In addition, there are many hybrids between zebu and Bali cattle such as Madura cattle, Jabres cattle of Brebes, Rancah cattle of Ciamis, and Rambon cattle of Bondowoso, Banyuwangi, and the surrounding areas. A crossbreeding of zebu and taurine produces Grati dairy cattle. In 1970s, an Artificial Insemination program was conducted in a large scale using male cattle and semen from several breeds of zebu (Brahman, Brahman Cross) and taurine (particularly Simmental, Limousin, Holstein Friesians). The program resulted in more complex genetic mixes. Crossbreeding conducted directly in the field causes a concern since it may threaten the purity of the native species and decrease the cattle's potential for adaptation, reproduction, and productivity. It is better to conduct crossbreeding programs privately in research centers or corporate/large farmers, of which the result can be distributed to smaller farms. "Ongolization" program that was introduced in the early twentieth century should be a lesson to learn, because it had led to the extinction of Javanese cattle, while the produced offspring, the Ongole Crossbred, are considered unsatisfactory so that they still have to be crossbred with other species of cattle, particularly taurine.

Keywords: Bali cattle, crossbreeding, local cattle, taurine, zebu

INTRODUCTION

A cattle breeding is closely related to the religion, culture, and civilization of the people of Indonesia. There is no certain record on the history of cattle as livestock in Indonesia. However, it is predicted that cattle has been raised and bred for a very long time throughout the archipelago. On the inscription of the Kingdom of Kutai found in Muara Kaman, near Mahakam River, East Kalimantan from the fourth century, it is inscribed that Mulawarman, the king of Kutai, had generously given alms of 20,000 cows to Brahmin priests (Vogel 1918; Poerbatjaraka 1952). The Tugu inscription of Tarumanegara Kingdom that was found in North Jakarta from the fifth century mentioned that the King Purnawarma of Tarumanegara awarded 1,000 cows to Brahmin priests as a gratitude for the completion of the construction of a canal (Kern 1910; Poerbatjaraka 1952). The Dinaya inscription found in Malang, East Java from 760 AD stated that Gajayana, the king of Kanjuruhan (an escapee from the kingdom of Kalingga in Central Java), gave cows and other gifts to Brahmin priests (Bosch 1915/16; de Casparis 1941) (Figure 1). Considering the large number of cows given, it can be assumed that people had started breeding cattle during the period, although some historians doubt it (Poesponegoro and Notosusanto 2010). In Linggasutan Inscription (929 AD) from the period of King MPu Sindok of Medang, found in Malang, East Java, it is mentioned that types of animals that are taxed commodities in the market, where the minimum threshold of taxable cattle is 40 heads. Several other inscriptions show that the cow has an important position and so many are farmed, there is even an effort for the conversion of protected forest into grazing land (Poesponegoro and Notosusanto 2010).

The domestication of cattle is believed to have been introduced by traders from Kalinga Kingdom of India (now Odisha, Eastern India) since the first century and even before. In the first century, the people of Kalinga had traveled to Sri Lanka, Burma (Myanmar), Nicobar Islands, Malay Peninsula, Sumatra, Java, Bali, Borneo, mainland Southeast Asia, and China. In the next several centuries, a lot of large Indianized kingdoms were established in these states (Coedès 1968; Wheatley 1975; Keyes 1995; Lukas 2001). In the belief of Hinduism, cow is a sacred animal

because it is the *vahanas* or vehicles of Hindu gods. Therefore, most Hindu temples are adorned with cow reliefs and sculptures (Bhattacharya 1977; Jha 2002). In Indonesia, sculptures of *Nandi* (bull) that are almost seen in Shiva Hindu temples are mostly precisely sculpted, indicating that the sculptor had seen an actual cow. Examples of accurate and proportional nandi sculptures were found in Prambanan temple from 850 AD (Ariswara 1994). Nandi is also found in other Hindu temples, especially in Central Java, Yogyakarta and East Java, as well as in West Java (Cangkuang Temple)(Arifah 2013), South Sumatra (Bumiayu Temple) (Bottenberg 2010), Jambi (Muara Jambi) (Adam 1921), and South Kalimantan (Laras Temple). In Borobudur, a Buddhist temple, there is a carved relief of two cows ploughing a farm on the temple walls in the area of Kamadhatu (the base). The reliefs in Kamadhatu represent the daily life during the period of time in which the temple was built (Soekmono 1976). The images of cow in these temples are characterized by a hump on their shoulders, indicating that they are of the species of zebu (*Bos indicus*) from India. This type of cow is also known as the Javanese cattle, of which the offspring are called Ongole Crossbred (Peranakan Ongole) or Bengali (Benggala) cattle. However, in Sukuh temple, one of the last temples which were built during the era of Hinduism in Java from 14th century AD, there is a carved relief of a humpless cow (Asmadi et al. 2004; PNRI 2014). This is supposed to be the first record of the existence of Bali cattle (*Bos javanicus*) in Indonesia (Figure 2). Based on this timeline, Bali cattle may have been domesticated during the Majapahit Kingdom (1293 to around 1500), based in East Java.

The review aims to discuss the diversity of indigenous cattle in Indonesia that have adapted to the local climate and condition including the feed, the influence of foreign cattle genes on the quality of the native cattle, and the conservation efforts. This manuscript is complementary to Sutarno and Setyawan (2015).

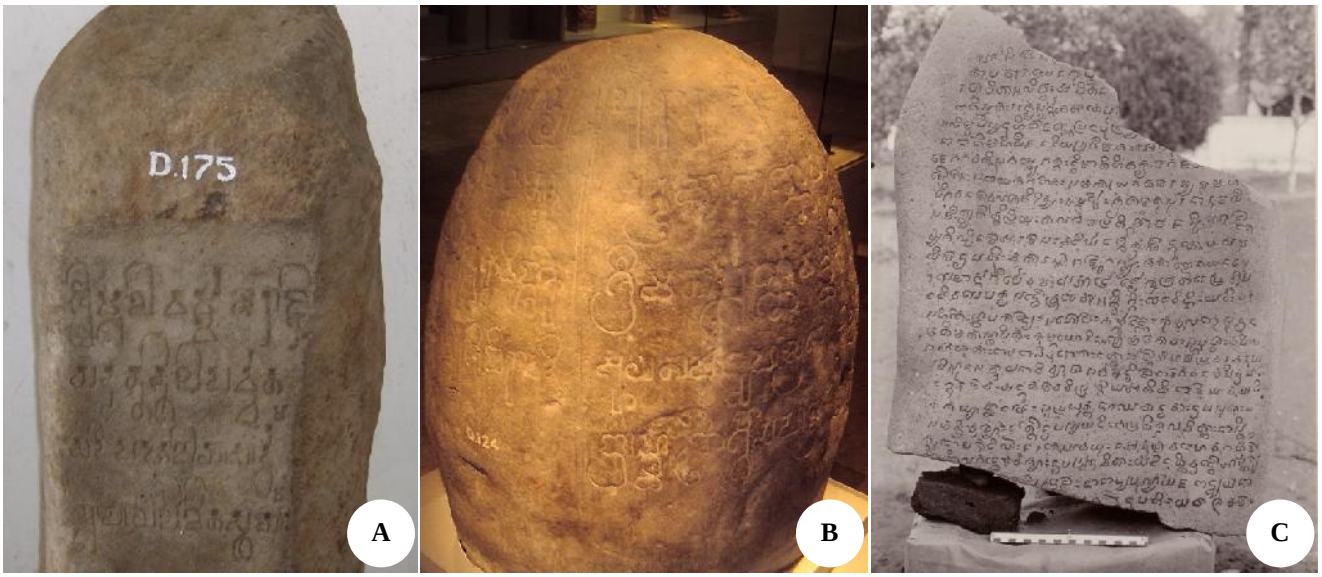


Figure 1. Stelae as the initial records of the presence of cattle in Indonesia. A. Muara Kaman stela, Kutai, East Kalimantan. B. Tugu stela, North Jakarta. C. Dinaya stela, Kanjuruhan, Malang, East Java. (from many sources)

Figure 2. Cow sculpture and ornaments on temples as the initial records of the presence of cattle in Indonesia. A. Nandi sculpture in Prambanan temple, Klaten (Zebu cattle). B. Carved relief of cows ploughing farm on the wall of Borobudur temple, Magelang (Zebu cattle). C. Bas relief of a humpless cow (Bali cattle) in Sukuh temple, Karanganyar. All locations are in Central Java Province, Indonesia. (from many sources)

CATTLE DOMESTICATION WORLDWIDE

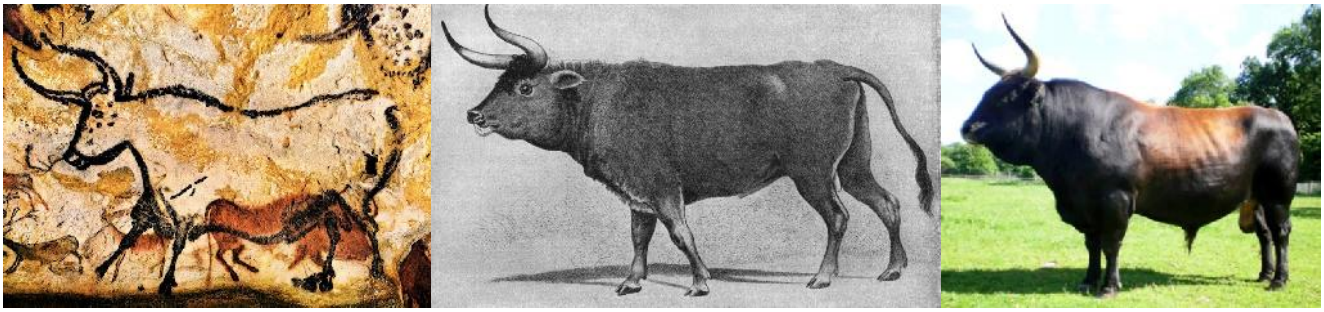
Throughout the history of human civilization, many types of cows have been domesticated (Lenstra et al. 1999, 2014), however, only taurine (*Bos taurus*) and zebu (*Bos indicus*) become the major cattle breeds of the world. Both types can be distinguished easily by the hump—zebu cattle are humped and taurine cattle are humpless. Both zebu and taurine descended from the wild Indian aurochs (*Bos primigenius*) that inhabited Asia, Europe, and North Africa at the end of the last glacial period (12,000 BP) (Felius et al. 2014) (Figure 3). Since the last species of aurochs died in Poland in 1627 (Rokosz 1995), the Europeans tried to preserve the existing species of taurine and zebu. Even though the wild aurochs are widely distributed around the world, the descendants, taurine and zebu cattle, are believed to be originated from two regions only.

Archaeological data indicates that taurine cattle were first domesticated between 10,300-10,800 BP in the western part of the border between Syria and Turkey (Helmer et al. 2005; Vigne 2011). Fossil remains of wild and domestic taurine cattle from that era were discovered in the region (Barker 1985; Zeder et al. 2006). It is estimated that around 80 female aurochs were the maternal ancestors of almost all present day taurine cattle (Van Vuure 2001). In other hand, Indus Valley, a desert ecoregion of southern Pakistan, is believed to be the center of origin of zebu domestication dating back to 8,000 BP (Ajmone-Marsan et al. 2010; Chen et al. 2010). Fossil remains of zebu cattle from that era were found in Mehrgarh, a proto-historic cultural site in Balochistan in the southwestern region of Pakistan (Jarrige et al. 2006). Based on the origin of domestication, the present day taurine cattle mostly live in sub-tropical regions, with Europe, North America, and Australia as the main producers. Zebu cattle have spread into tropical regions with the highest population being found in India, Africa, and Brazil. Both taurine and zebu have hundreds to thousands of breeds including crossbreds and hybrids.

Various attempts of cattle domestication are also found in Asia (Ho et al. 2008; Achilli et al. 2009). People in Tibet and its surrounding regions have domesticated yaks (*Bos grunnies*) that are able to adapt to highlands (Qiu et al. 2012) since around 4500 BP (Payne and Hodges 1997). The gayal or mithun (*Bos frontalis*) were domesticated from the gaur (*Bos gaurus*) or the Indian bison (Uzzaman et al. 2014) on the northeastern border of India, Bangladesh, and Myanmar (Mason 1988; Payne and Hodges 1997). In Indonesia, Bali cattle was domesticated from wild banteng (*Bos javanicus javanicus*) since around 5000 BP (Payne and Hodges 1997), and has become the most populous cattle after taurine and zebu cattle. Hybridization of these three breeds; yaks, gayal or mithun and Bali cattle, with taurine and zebu has produced many breeds with complex and unique mixtures that contribute to the diversity of cattle worldwide (Felius et al. 2014). Kouprey (*Bos sauveli*), a wild cattle that are found in Indo-china is a hybrid between local banteng (*Bos javanicus birmanicus*) and zebu (Hassanin and Ropiquet 2007) (Figure 4 and 5).

DIVERSITY AND DISTRIBUTION OF CATTLE IN INDONESIA

Bali cattle are an indigenous breed with the widest distribution and largest number of population in Indonesia. There are several other local cattle breeds in Indonesia, which are the direct descendants of the Indian zebu as well as crossbred between zebu and the Bali cattle (either directly or through the Madura cattle). Local breeds that are categorized as zebu are for example Pesisir cattle of West Sumatra, Aceh cattle of Aceh, and Sumba Ongole of the Sumba Island. In addition to the Madura cattle, other breeds that are intermediate between zebu and Bali cattle include the Jabres cattle of Brebes, the Rancah cattle of Ciamis and the surrounding areas, the Rambon cattle of Bondowoso and the surrounding areas, and the almost extinct Galekan of Trenggalek. Indonesia also has a crossbred between zebu and taurine, which is the Grati cattle or more popularly known as the Indonesian Holstein Friesians, an intermediate between a male Holstein Friesians and a female Ongole Crossbred.



A **B** **C**

Figure 3. Cattle domestication worldwide. A. Figure of aurochs on the wall of Lascaux cave, France (Ruspoli 1983), B. Aurochs by Charles Hamilton Smith (Pyle 1995), C. Tauros, one of the descendants of the extinct aurochs (Parkvall 2010)

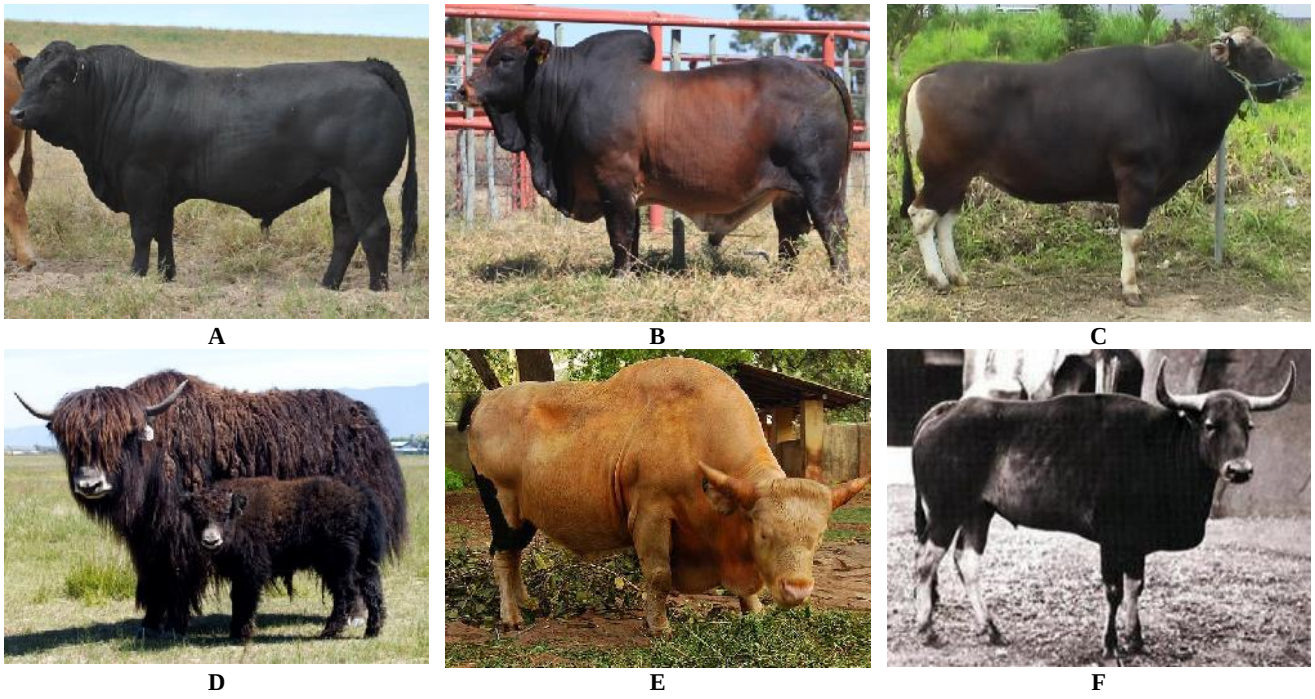


Figure 4. Cattle diversity in the world. A. European taurine cattle, B. Indian zebu cattle, C. Indonesian local Bali cattle, D. Tibetan yak, E. Northeast Indian gayal (gaur), F. Cambodian kouprey. (from many sources)

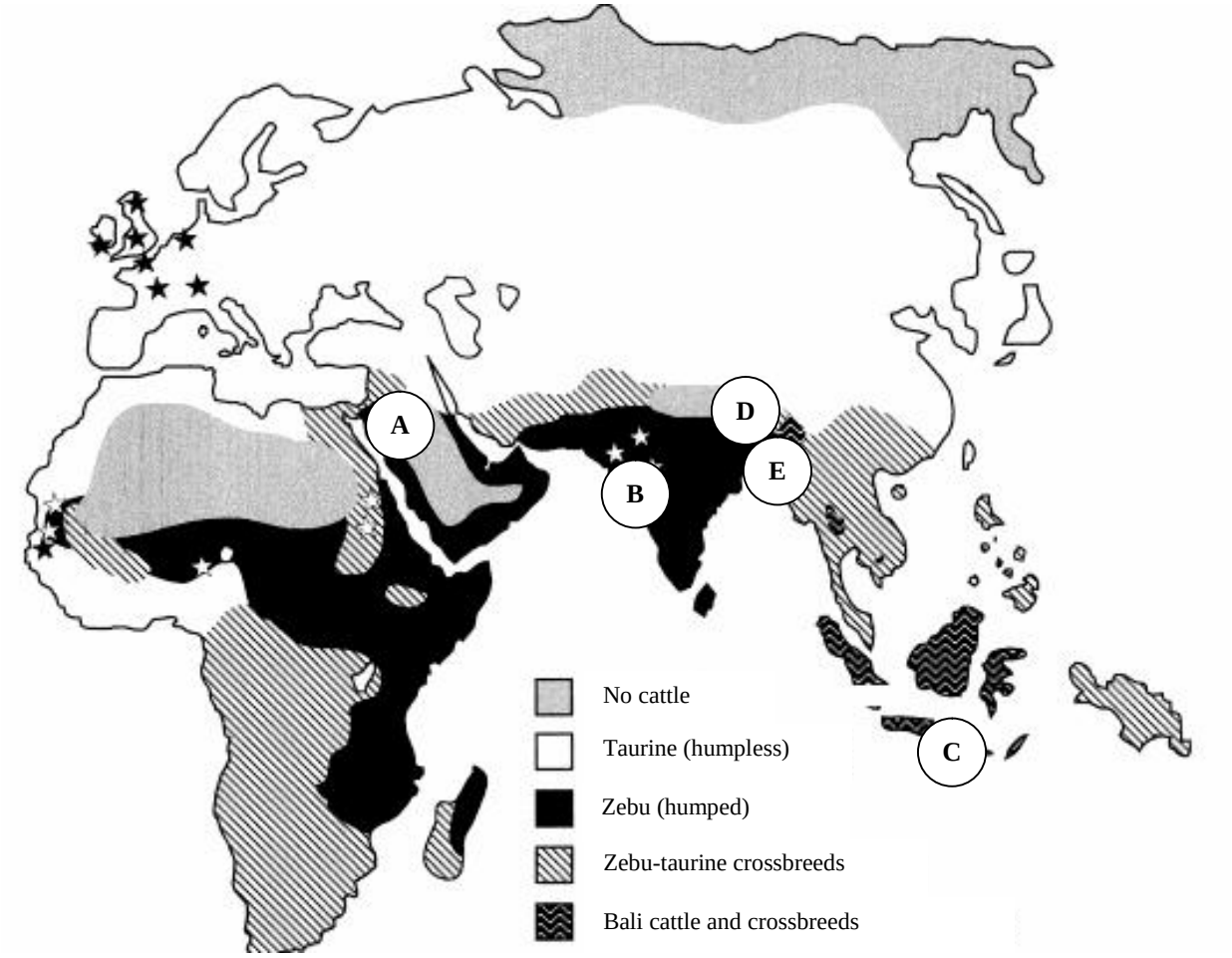


Figure 5. Distribution and domestication of cattle worldwide. Site domestication of A. Taurine in Mesopotamia, B. Zebu in Indus valley, C. Bali Cattle in Java or Bali, D. Yak in Tibetan Plateau, E. Gayal in northeast India and Bangladesh (Felius et al. 2014)

Bali cattle

Bali cattle are raised in all parts of the country except in Central Java, West Java, and in some other regions in which a lot of goat (*Capra hircus*) farms are found because goats can transmit the malignant catarrhal disease, a serious, often fatal, disease that affects many species of young Bali cattle. In Central Java and West Java, Ongole is the more dominant raised breed of cattle. This breed is descents of zebu that were imported from India a long time ago (Javanese cattle) and other zebu from various origins that were imported in a later period (particularly Ongole and Sumba Ongole). They have been introduced to and have adapted with the local climate for a long time, therefore they are considered indigenous to Indonesia. Ongole Crossbred (OC) cattle are the second most essential breed after the Bali cattle. Another indigenous breed is the Madura cattle, the crossbred of Bali cattle and zebu cattle (Javanese cattle or Sinhala cattle), that was first crossbred about 1500 years ago. In South Sulawesi, people started crossbreeding Ongole cattle in 1890.

The distribution of Bali cattle to all parts of Indonesia has been done for a long time. In 1912, Bali cattle were brought to Timor Island. In 1920-1940, Bali cattle were distributed again to Timor, this time also to Lombok, South Sulawesi, and South Kalimantan (Omerling 1957; Hardjosubroto 2004). A transmigration program peaked in 1970-1980, which relocated farmers in Java, Bali, West Nusa Tenggara, and East Nusa Tenggara to other islands with smaller number of population, especially Sumatra, Kalimantan, Sulawesi, and Papua. The program unexpectedly became a means of distributing Bali cattle throughout Indonesia because during the program Bali cattle were also moved to be bred and used as working animals. Bali cattle have relatively better productivity and endurance in their pure genetic condition without being crossed. Madura cattle are the outcome of successful crossbreeding between Bali cattle and zebu; however their distribution is only limited to Madura Island and few regions in eastern East Java. In 1908, crossbreeding between Java cattle and male Bali cattle in East Java was initiated again, but was halted in 1921 due to the high death rate of Bali cattle and their offspring. Natural crossbreeding occurred in Trenggalek, Brebes, and Ciamis, however, the population number were limited and the productivity kept decreasing.

Zebu cattle

Before being substituted with the Ongole Crossbred, there had been attempts to breed Javanese cattle descending from the Indian zebu which was brought by traders during the period of Hindu and Islam kingdoms. These attempts were fully supported by the government that initiated a program to distribute a large number of male Javanese cattle to all areas in Java in 1905-1911. These cattle were distributed to regions in Central Java, East Java, and West Java to improve their quality. However, this program was stopped due to resistance from farmers who wanted stronger and bigger cattle for farm working; the characteristics that are owned by male cattle of other zebu breeds.

A century before, in 1806 and 1812, some breeds of Indian zebu (Mysore, Ongole, Hissar, Gujarat, and Gir) were brought by traders to East Java to be crossbred with Javanese cattle in order to produce good-quality offspring. The introduction of zebu was done again from 1878 before it was banned in 1897 due to the threat of rinder pest disease. In late nineteenth century, owners of big plantations in East Sumatra imported the Hissar breed of zebu as working cattle. In 1889, the local government of South Kedu castrated male Javanese cattle in a large scale, and only allowed female cattle to mate with zebu. Until today, Kebumen is one of the biggest producers of Ongole Crossbred calves in Indonesia. The same thing was done in Magetan, East Java, in 1890.

In 1905, the government allowed to import zebu, particularly the Hissar breed. Two years later, the government started to import Mysore cattle but it was not successful due to a relatively high death rate. In 1909, three zebu breeds—Ongole, Gujarat, and Hissar were imported from India. They were distributed to Java, Sumba, and Sumatra, where they successfully bred. In 1909-1911, considering that the Ongole developed most ideally in Java, the government imported a large number of Ongole, which were then, quarantined in Sumba Island together with the Gujarat cattle that were imported earlier. These breeds bred very impressively, producing the Sumba Ongole (SO) cattle. In 1915-1929, the SO cattle were distributed to Java through a program called "Ongolization", in which male Javanese cattle were castrated and the female were mated with male SO. The program led to the extinction of the remaining Javanese cattle and the creation of a new species, the Ongole Crossbred (CO). In 1920-1940, the Ongole Crossbred was distributed from Java to Sumbawa Island, Sulawesi, West Kalimantan, and Sumatra.

Madura cattle

Development and distribution of Madura cattle have also been conducted since a long time ago. In 1891-1892, the local government of Pasuruan established a program to crossbreed Javanese cattle and Madura cattle. The program was conducted one more time in a larger scale in 1905, but was terminated in 1921 because it did not meet the expectation. In 1920-1940, Madura cattle were distribute to Flores and East Kalimantan; however, the breed was later substituted with Bali cattle that were brought later because the quality of Bali cattle was considered much better (Omerling 1957; Hardjosubroto 2004). In 1957, there was an attempt to improve the generic quality of Madura cattle by crossing them with the Red Danish dairy cattle. However, the offsprings were not very high in demand. In addition, in the last few decades, Madura cattle have been crossed with Simmental cattle, producing more popular offspring that are highly demanded by farmers particularly in Sumenep and the surroundings.

Taurine cattle

In Indonesia, the distribution of taurine cattle (*Bos taurus*) is more limited because they need highland and cool temperature to live and breed; so the more commonly raised breed are those that survive better in warm climate.

In Papua, there are many wide highland pastures, but limited infrastructure becomes a problem in developing cattle farms. Most taurine cattle in Indonesia are of Holstein Friesians breed, which are mostly raised in Java for their milk. In addition, in West Sumatra highlands, people raise Simmental taurine cattle in small scale. Recently, the number of crossbred species between Simmental and Limousin taurine with local breeds has been increasing, especially with Ongole Crossbred through artificial insemination (Pamungkas et al. 2012). However, this breed has not been naturalized very well since the gestation almost always happens through artificial insemination. Therefore, the existing population is only the first filial generation of offspring (F1).

The taurine breed that has been introduced since a long time ago is the FH dairy cattle or the offspring, which are only kept and raised in highlands. Dairy cattle have existed in Indonesia since 1786, but their breed remains unknown. In 1891-1892, several breeds of dairy cattle were imported from Australia (Hereford, Shorthorn, Ayrshire, and Jersey) and from Netherlands (Holstein Friesians) to Grati, Pasuruan. Crossbreeding between these imported breeds and local cattle particularly the Ongole Crossbred became the origin of the existence of the Grati dairy cattle (Sudono 1983; Sudono et al. 2003; Siregar 1995; Soehadji 2009). In late nineteenth century in Lembang, Bandung, a big cattle farm was established. It made Bandung popular as the main supplier of milk in Indonesia. In 1912, the government signed a contract with the farming company to buy all their young male cattle to be distributed to farmers around Bandung. In late nineteenth century in Jonggrangan, Klaten, there was also a dairy cattle farm that raised FH cattle. To increase the population of dairy cattle, a large number of male FH were mated with local cattle. The initial generation of offspring has a high productivity of milk, however, in the next generations, the productivity kept decreasing. In 1939, a number of male FH were imported again to Grati to improve the quality of the dairy cattle. At the moment, the population of dairy cattle in Indonesia is about 350,000. The species mostly live in Bandung, Surakarta, and Malang. FA dairy cattle in Indonesia nowadays are mostly of pure genetic breed, because their milk production is quite satisfactory, even though there are also FH dairy cattle that are crossbred between male FH and female CO, such as the Grati.

In 1970, various breeds of superior alive cattle or their semen were introduced from Europe, the United States, Australia, and New Zealand, such as the Brahman, Brahman Cross, Simmental, and Limousine. They are considered very high-quality beef cattle because of their high rate of weight gain per day. However, they are not suitable for hot tropical areas, except the Brahman and Brahman Cross which are zebu descent. In Kebumen, the Brahman breed is mixed with OC and the offspring is named Madras, which is indigenous to the region. In 1990s, there was not enough domestic beef production, so that quantity of imported beef kept increasing day by day, mainly from Australia and the United States. In the end, young cattle—mostly the Brahman Cross and the Australian Commercial Cross (ACC) breeds—from Australia were imported to be raised and fed by a special diet to fatten them up. These breeds are crossbred between various breeds of taurine and zebu. In 2015, 650,000 ACC cattle were brought to Indonesian feedlots. Unfortunately, they only lived for 3-6 months in the feedlots before being slaughtered, and were never distributed to small farmers to be developed.

In addition to the Bali cattle, the native cattle breeds in Indonesia include the imported breed that has been raised in Indonesia for a long time and even has mixed genetically with the Bali cattle such as the Ongole Crossbred, Sumba Ongole, and Madura cattle. There are also Aceh, Pesisir, Jabres, Rancah, Rambon, Galekan, and Grati (FHI) cattle, as well as the imported cattle such as the Brahman, Brahman Cross, Simmental, Limousine, Holstein Friesians, and ACC cattle (Figure 6). The distribution of Indonesian local cattle is presented in Figure 7.

CATTLE POPULATION

Nowadays, the population of beef cattle in Indonesia is around 14.7 million (BPS 2014) and the population of dairy cattle is around 350,000. some local breeds such as Bali cattle (*Bos javanicus*), Ongole Crossbred (*Bos indicus*), and Madura cattle (*Bos indicus x Bos javanicus*) are the main source to meet the national demand of beef, even though their productivity and beef quality is not always excellent (Okumura et al. 2007). Holstein Friesians cattle are the main source of dairy products, which can only meet about 20% of the domestic demand. In addition, there are also local crossbreeds that are mostly mixed genetically among these breeds as well as between these breeds with taurine cattle that were imported later (Johari et al. 2007). Data from the Indonesian Directorate General of Livestock (DGLS 2010b) shows that local breeds of cattle in Indonesia consist of Bali cattle (33.73%), Ongole Crossbred (5.16%), and other local breeds (13.45%). Bali cattle and Ongole Crossbred are local breeds of beef cattle that have a particular strength, which make them be able to adapt very well and quickly to the surrounding environment in Indonesia, such as the climate, the availability of natural fodder and water, and the resistancy to bacteria and parasites.

Most Indonesian cattle are found in Java, which is around 45% of all local cattle (35% are in East Java). Sumatra owns about 22%, Nusa Tenggara and Sulawesi each owns 13%, and the rests are raised in other islands. Bali cattle have been brought to most provinces in Indonesia because of their suitability and high adaptability to most agro-climatic zones. Other important breeds are the Ongole Crossbred, Madura cattle, and the Holstein Friesians dairy cattle (*Bos taurus*). The most popular breeds to be mixed with local breeds, especially Ongole Crossbred, are Simmental and Limouisin. The offspring of this crossbreeding are highly preferable for fattening due to their high rate of weight gain despite the relatively high cost of production. Most cattle that are sold across islands will usually end up in Jakarta and West Java, as the main consumers (Sullivan and Diwyanto 2007).

Figure 6. The diversity of cattle breeds in Indonesia. A. Bali Cattle (Banteng), B. Madura cattle, C. Ongole Crossbred, D. Sumba Ongole, E. Aceh cattle, F. Pesisir cattle, G. Brahman cattle, H. Brahman Cross, I. Simmental bull, J. Simmental cow, K. Limousine bull, L. Limousine cow, M. Holstein Friesians bull, N. Holstein Friesians cow, O. ACC from North Australia. (from many sources)

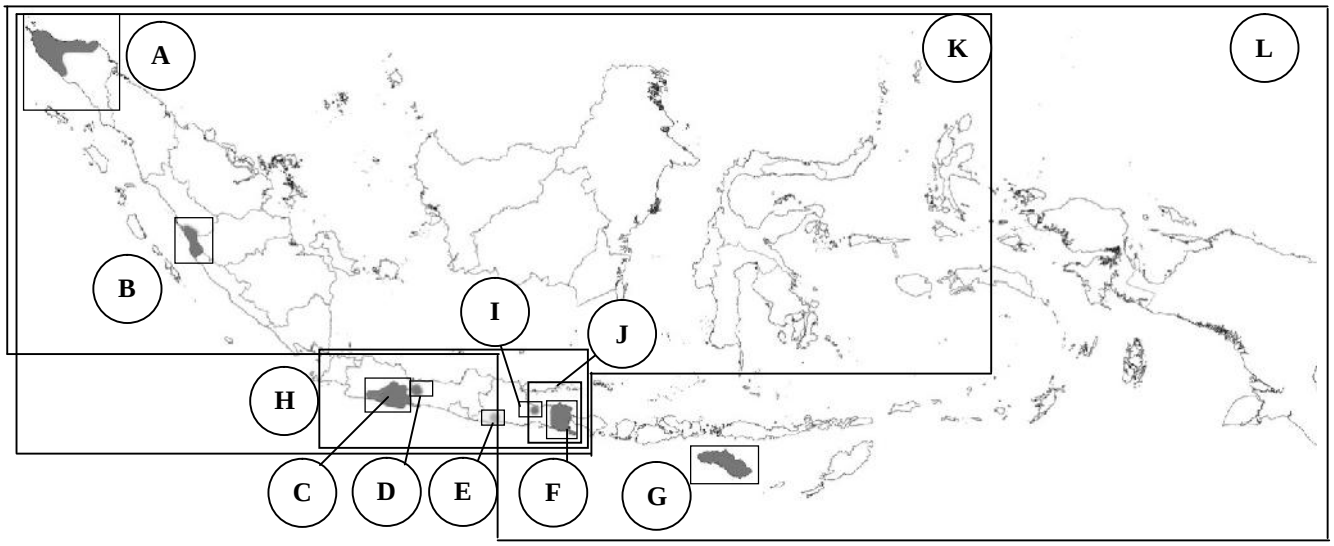


Figure 7. Distribution of Indonesian local cattle. A. Aceh cattle; B. Pesisir cattle; C. Rancah cattle; D. Jabres cattle; E. Galekan cattle; F. Rambon cattle; G. Sumba Ongole cattle; H. Holstein Friesian cattle; I. Grati cattle; J. Madura cattle; K. Peranakan Ongole cattle; L. Bali cattle (All parts of Indonesia except in Central Java, West Java and Banten) (Sutarno and Setyawan 2015)

Indonesia is one of the world's greatest importers of living cattle and beef. Import fits the gap between production and consumption; and the gap is projected to grow wider in the future. The production of beef in 2003 was 351,000 MT and the consumption was 418,000 MT. There was a 67,000 MT deficit which was filled by imports. In 2010, the production of beef was estimated to increase up to 362,000 MT and the consumption to 447,000 MT, resulting in 85,000 MT of deficit. In 2020, the deficit is expected to rise to 111,000 MT. The quantity import of living cattle is 428,000 in 2002, 374,000 in 2003, and 350,000 in 2006. In 2014, it reached 700,000 and in 2015 it reached 650,000. The main consumers of beef are Jakarta and West Java, where a large number of imported as well as local beef cattle are slaughtered (Sullivan and Diwyanto 2007).

The population of cattle has been decreasing in the last few years after the financial crisis that hit the country in late 1990s. The number of cattle declined after the crisis because the capability of importing cattle went down, which leads to an increase of local beef consumption, causing an increase in the number of slaughtered adult as well as young cattle. The rate of local cattle being slaughtered outnumbered their natural ability to reproduce, resulting in a decrease of breeding. To regain the quantity of cattle, the female cattle should not be slaughtered. However, in fact, around 40% of female cattle were slaughtered every year. Most beef cattle are raised by small farmers semi-intensively; and each farmer owns 2-3 cattle that are frequently sold because of their economic needs (Pamungkas et al. 2012). Unsustainable level of cattle sales contributes to a decrease in the number of population (Fordyce et al. 2002).

There are several inhibiting factors in developing cattle farming, including low genetic quality, limited availability of superior male species, limited ability of farmers in dealing with cattle breeding, and traditional maintenance system (Atmakusuma et al. 2014). Various attempts have been established by the government in order to increase the population of local cattle to develop them as the country's main source of beef, including reducing the slaughter of productive local cattle and introducing crossbreeding between local cattle using artificial insemination to more regions (DGLS 2010c). However, the program has lately become controversy because it is done directly in the field, which leads to uncontrollable genetic mixes and produces offspring with untested adaptability to the local climate, natural fodder, and disease.

MAJOR LOCAL CATTLE

In Indonesia, there are four local living genetic resources including Bali cattle, Ongole Crossbred, Madura cattle, and Aceh cattle (DGLSAH 2015). To maintain the genetic purity of the breeding of these breeds, the government has selected several islands to be the center for cattle conservation and breeding. Sapundi Island becomes the center for breeding Madura cattle, Nusa Penida for Bali cattle, and Raya (Rayeuk) Island for Aceh cattle. In addition, 18 districts are selected to be the center for local cattle breeding, particularly Bali cattle and Ongole Crossbred.

Furthermore, there are several breeds of cattle that have been recognized or are proposed to be recognized (DGLSAH 2015) as Indonesia's indigenous cattle, such as Sumba Ongole (SO), Pesisir, Jabres, Rambon, Galekan, and Rancah cattle. The conservation efforts gain a lot of challenges particularly due to increasing activities of

artificial insemination using frozen semen from foreign cattle and increasing pressure from other local breeds.

Bali cattle

Bali cattle (*Bos javanicus*) are a direct domestication of wild bantengs in Bali and Blambangan, East Java (MacHugh 1996; Verkaar et al. 2002; Martojo 2003; 2012; Hardjosubroto 2004). The first documentation of banteng was written by Schlegel and Muller in 1836 (Merkens 1926), which states that bantengs were found wild in small groups consisting of one male and several females and their offspring in forests in Java and Kalimantan (Borneo). Wild bantengs that were captured usually only survived up to 11 years; however, the Bali cattle can live to 20-25 years. Nowadays, wild bantengs still widely live in Java, but their existence is threatened, particularly due to habitat loss and illegal hunting (Duckworth and Hedges 1998; Pudyatmoko 2004; Steinmetz 2004). The genetic purity of bantengs is also debatable due to the possibility of hybridization with local cattle grazing in the forest (Wharton 1957; Tun Yin 1967; Hoogerwerf 1970). Meanwhile, genetic testing is not easy to conduct because of their characteristic that makes them difficult to approach to take DNA samples. The genetic purity of bantengs kept in zoos is debatable too.

At present, the popular and acceptable scientific name for bantengs is *Bos javanicus*, with three subspecies that are categorized based on their distribution areas: *Bos javanicus javanicus* (Javanese banteng) living in Java, *Bos javanicus lowii* (Kalimantan banteng) found in Kalimantan, and *Bos javanicus birmanicus* (Burma banteng) that are distributed through Southeast Asia mainland (Byers et al. 1995). Bali cattle descended from *Bos javanicus javanicus* and were given the scientific name of *Bos javanicus*. Domestication process is believed to have been conducted to the Burma banteng, even though the offspring is not purebred due to hybridization with other breeds of cattle. In Cambodia, Vietnam and Lao, people know local cattle, kouprey (Urbain 1937; Hoffmann 1986), it was believed to be the hybrid between wild banteng and zebu cattle (Galbreath et al. 2006; Hedges et al. 2007), of which the size is smaller than that of zebu cattle and have various colors (Galbreath et al. 2007). It was rated as "critically endangered" species and it may already be extinct (Timmins et al. 2008).

Bali cattle have been widely distributed throughout Indonesia, especially in Bali, Sulawesi, Java, Sumbawa, Timor, and Kalimantan (Entwistle and Lindsay 2003; Sutarno 2010). This breed is also found in North Australia and Malaysia (Toelihere 2003). Bali cattle live in North Australia as wild animals, descending from 20 cattle that were brought from Bali in 1849. Now, the population of wild Bali cattle in North Australia is about 8,000 to 10,000 (Bradshaw and Brook 2007). The genetic purity of these cattle is almost equivalent to that of the wild bantengs in Java, compared to the common Bali cattle that have supposedly received genetic mixing of zebu as well as taurine cattle. The characteristics of Bali cattle did not significantly change compared to their wild ancestors (Handiwirawan and Subandriyo 2004). Bantengs and Bali cattle differ physically in terms of size and behavior; male bantengs are way bigger and more aggressive (Martojo 2003, 2012). Bali cattle have not experienced rigorous selection as experienced by zebu and taurine. Studies on the genetic diversity of Bali cattle and bantengs are still limited (Kikkawa et al. 1995, 2003, Namikava 1981, Nijman et al. 2003, Verkaar et al. 2003). The studies are needed to understand the domestication process (Mohamad et al. 2012).

Bali cattle have large frame and solid muscle. The adult male can weigh up to 600-800 kilograms, and the adult female weigh around 500-600 kilograms (Martojo 2003). The young cattle are crimson red or reddish gold. As they grow, the females remain crimson, while the males change color into black at 12-18 months of age. Castrated adult male cattle will turn back into crimson red few months after castration. There are white spots on the legs, from the knees to the toes. The back of the pelvis is white-colored with clear oval-shaped line, and the tip of the tail is black. The black color on a castrated adult male will change into light brown, while the legs from the knees to the elbows down remain white (Williamson and Payne 1978). The skin is pigmented and smooth. The male cattle do not have withers; have a small dewlap and compact body. The head is wide and short with flat forehead and medium sized vertical ears. The horn of female cattle is short and small, while the male's horn is big and long, facing to the front top sides, sharp, with thin neck. The chest is deep and the legs are strong (Pane 1991; Susilorini 2010).

Bali cattle have high level of fertility; the reproduction efficiency is excellent because they can produce offspring every year and the life percentage of the calves is 80%. In addition, they can adapt well to tough condition, can live and grow in poor condition and hard, dry climate like in eastern Indonesia, can digest low-quality food, can survive with limited amount of food in dry season, and can easily recover to their best condition in normal season. They are also easy to maintain for any needs in agricultural system, as working animal as well as meat producing animal. The percentage of carcass is higher than that of zebu and taurine. The carcass and meat is of high-quality and meet the demands from the market because the meat is fatless, which make them having higher selling price. The leather is relatively thin but of excellent quality. The young castrated males and the adult males have standard, similar weight so that they are suitable to be transported to other islands or countries. However, it is important to consider potential negative impacts of genotype-environment interaction. Bali cattle are the most suitable breed on production systems with low input and high environmental stress, as widely practiced by millions of farmers in Indonesia (Williamson and Payne 1978; McCool 1992; Wirdahayati 1994; Copland 1996; Martojo 2003; Diwyanto and Praharani 2010; Susilorini 2010; Sutarno 2010).

However, Bali cattle also have weaknesses. Their growth is relatively slow and the production of milk is low, causing high calf mortality rate (Susilorini 2010). This breed is known to be resistant to diseases and parasites, but there are two fatal diseases that may put them at risks, malignant catarrhal disease with goats as carrier and Jembrana disease, a type of virus that attacks the brain

(Budiarso and Hardjosworo 1976). Malignant catarrhal disease becomes one of the primary causes of calf mortality, so Bali cattle are not raised in areas where goats are kept, such as in Central Java and West Java. Jembrana disease only affects Bali cattle that are indigenous to Bali, possibly due to long-term isolation of susceptible cattle with the intention of conservation instead caused inbreeding between cattle with decreasing immunity (Tenaya 2010).

Bali cattle are the ancestor of most local breeds in Indonesia. Even in Ongole Crossbred, which have relatively pure genetic, Bali cattle genes are also found. The same situation also happens to Pesisir cattle and Aceh cattle. Cattle breeds that undoubtedly have the genes of Bali cattle are Madura, Rambon, Galekan, Jabres, and Rancah cattle.

The genetic purity of Bali cattle began to be threatened; negative selection and hybridization degenerate the quality of the offspring. Negative selection occurred in Timor Island by sending high-quality cattle across islands and only leaving low-quality cattle for breeding. Consequently, after few generations, the cattle have very low weight and they are no longer profitable for trading across islands. Now, the island of Timor no longer becomes a major producer of Bali cattle. In addition, hybridization is conducted everywhere, even in Bali itself, particularly with Simmental taurine cattle through artificial insemination. During the reign of Klungkung Kingdom, the island of Bali was specially established as a region for developing Bali cattle, which prohibited any activity of importing other cattle breeds. This situation was still maintained in the colonial era. However, nowadays, Bali cattle are only specially kept and raised in Nusa Penida Island; in Bali Island, crossbreeding between Bali cattle and other cattle breeds is allowed.

The genetic purity of banteng as the ancestor of Bali cattle is also threatened due to hybridization. The utilization zones of national parks in Baluran, Alas Purwo, and Metu Betiri are used by the local residents for domestic cattle grazing, such as zebu, Bali cattle, Madura cattle, or Rambon, so that there is always possibility of crossbreeding between the cattle and wild bantengs, which may disrupt the wild banteng's genetic purity.

In 2000, the population of Bali cattle was approximately 2,300,000 with the main distribution in South Sulawesi (718,000), Bali (529,000), East Nusa Tenggara (443,000), West Nusa Tenggara (377,000), Southeast Sulawesi (300,000), and Lampung (255,000) (Talib et al. 2002).

Sumba Ongole and Ongole Crossbred (Peranakan Ongole)

Sumba Ongole cattle (*Bos indicus*) (SO) is local cattle from Indonesia. In the early of the 18th century, the government introduced various cattle races such as Javanese cattle, Madura cattle, Balinese cattle, Gujarat cattle and Ongole cattle to Sumba Island. The cattle were sent to Sumba Island to be quarantined for breeding because they grew quite good in Java and to avoid the incidence of a disease. Evidently, Ongole cattle were able to grow and to adapt very well which made people of the island abandoned other livestock. In 1914, Sumba Island was assigned to be the center of Ongole cattle breeding which produced Sumba Ongole cattle (Hardjosubroto 2004). The assignment of Sumba Island as the center of Ongole cattle breeding is followed by the introduction of 42 male Ongole cattle, 496 female Ongole cattle, and 70 crossbreed cattle. Sumba island was able to send six male Ongole cattle to Java in 1915, 254 male Ongole cattle in 1919, and 829 male Ongole cattle in 1929 (Office of Veterinary East Sumba District 1989). SO cattle have been the pioneer of other Ongole cattle as the result of Ongole breeding program ("Ongolization") conducted in Java in 1915-1929 (Hardjosubroto 2004). SO cattle are considered as superior local beef cattle because they are reported of gaining weight almost 1.18 % per day, having the percentage of carcasses more than 50%, and beef production is 77% (Ngadiyono 1995). SO cattle work very good to cultivate land due to its big body.

Ongole Crossbred (*Bos indicus*) or Benggala is the result of genetic improvement of Javanese zebu cattle, which has been existed since the beginning of the first century AD, with Sumba Ongole from Sumba Island. At the beginning of the 19th century, male and female Ongole cattle were imported from Madras, India to Java, Madura, and Sumba. Ongole cattle which were brought to Sumba Island breed Sumba Ongole (SO). This breed was then brought to Java and mated with Javanese cattle which produced Ongole Crossbred. Ongole Crossbred are famous as beef and working cattle because they are big, strong, tame and quiet, heat-tolerant, easy to adapt with environment, able to grow with limited food, having high reproduction, and having a good ability to go back to normal after giving birth.

Ongole Crossbred has white or grey colored fur, black tail and fur around the eyes, short curved shape of the head, short horn, long hanging ears, and a rather large belly. Male cattle has bright big eyes and circled by skin 1 cm from black eyes, big body and hump, short neck, long legs with strong vein, loose wattle hanging from the bottom of the head, and sometimes black splotches on his knee. Adult male cattle can weigh up to 600 kg and adult female cattle can weigh up to 450 kg. Weight gain ranges from 0.4-0.8 kg/day, but in unfavorable condition weight gain only reach 0.25 kg/day (Wiyatna et al. 2012).

Indonesia also develops other types of Zebu particularly Brahman and Brahman Cross races which are bigger than Ongole Crossbred. Pure Ongole Crossbred is difficult to find because many of them are crossed with Brahman cattle. The mating between Ongole Crossbred and Brahman produces fertile crossbreed called Ongole Crossbred due to its small size. Ongole Crossbred is sometimes called Benggala, referring to its origin in Bengal bay or Bengali, an area in East India. In Kebumen, Central Java, Ongole Crossbred is known as cow Madras referring to its original place. In this city, zebu cattle genetic improvement has been done long before *Ongolisasi* program so that Ongole Crossbred (Madras) in this area has similar quality as Ongole cattle (Utomo et al. 2015).

Madras Cow has convex and short face with round black or dark eyes, flat black snout, and backward-curved horns. Female cattle has longer horn and smaller root of horn, stand up ears which is able to move freely, white long sagging neck skin. It has also thick sag from the front splitting into two and folds. It will be straight and not break up when pulled. Female cattle also have long white umbilical, and the hair whorl is not parallel with the umbilical. Male cattle has wide forehead with slanted eyes, a hump which is big, upright, stand back, and not fall. New born calf will weigh over 28 kg. Ongole Crossbred population is estimated 4.4 million and almost 90% or around 3.4 million are in Java (DGLS 2003).

Madura cattle

Madura cattle (*Bos javanicus x Bos indicus*) are a crossbreed between Balinese cattle and zebu cattle from India. However, history of the crossbreeding is not known for certain. One source states that the crossbreeding occurs in the middle of the first millennium AD (1500 years ago). Madura cattle also dominates northern coast of East Java wherein many Madurese immigrants live, proving that these immigrants brought the cattle. The area had undergone Javanese depopulation because of the war since the 15th to 18th century. Madura immigrants filled the abandoned land because the previous owners run to save themselves from the war. Madura cattle have a crimson or red brown color with white pattern in the back-bottom, small and short horn that lead outside. Uniformity within breeds is developed by people in Madura through selection.

Madura cattle grow well even though fodder quality is poor. It has high carcass with good quality of beef and good ability to adapt with tropical environment. Madura cattle is able to run quickly and used in a cattle race (*karapan sapi*). It is also used for a beauty contest due to its good body (*sapi sonok*). Cattle race requires high energy metabolism to gain physical strength, work of skeletal muscle, and emotional power (aggressiveness). On the contrary, *sapi sonok* needs high energy metabolism to hold the stretching of skeletal muscle and control the emotion (tamed). Cattle without those characteristics belong to beef cattle. In *Karapan sapi*, the cattle taking part in a race should have a very good performance and condition. The performance and condition are influenced by genetic and environmental factors including fodder and health. Madura culture of cattle selection should be controlled whether or not it influences variation of gene involved in energy metabolism. Gene characterization in energy metabolism is needed to improve the quality of Madura cattle within animal conservation (Siswijono et al. 2010; Febriana et al. 2015).

In colonial times, Madura Island was devoted to the development of Madura cattle that made the introduction of other race of cattle was forbidden. However, the development of other race of cattle was allowed at a later period. In 1957, crossbreeding between Madura cattle with Red Danish dairy cattle (*Bos taurus*) was carried out but the result was less desirable. In the last decades, Madura cattle are crossed with Limousine (Siswijono et al. 2010) and Simmental through artificial insemination. The result of crossbreeding is highly on demand particularly in Sumenep and surrounding area. The process is carried out directly in the field and causes a concern since it may change genetic composition of Madura cattle and influences its immune toward dry climate and limited food. Madura cattle were also introduced in Flores and East Kalimantan but it failed to grow and replaced by Balinese Cattle. Sapundi Island is devoted to be the area of pure Madura cattle conservation so that it is able to avoid uncontrolled genetic changes. In 2002, total population of Madura cattle is about 900.000 (DGLS 2003).

MINOR LOCAL CATTLE

Indonesia has several kinds of superior local cattle such as Aceh cattle, Madura cattle, Javanese cattle, Grati cattle, and Pesisir cattle (Blakely and Bade 1998). Those cattle are known as local cattle. In some areas, local cattle are still desirable such as Aceh cattle. However, the high demand of the local cattle is not collateral to the production rate of the cattle. Indigenous cattle are domesticated cattle while local cattle are the offspring of several kinds of cattle that are able to adapt to certain location (Martojo 2003).

Aceh cattle are one of four kinds of Indonesian local cattle (Aceh, Pesisir, Madura, and Bali). Ongole Crossbred is also considered as Indonesian local cattle. The cattle are named after the area where the cattle are found that is Aceh, Pesisir, Java, Madura, and Bali. Aceh cattle are found in Aceh province, Pesisir Cattle are found in some part of North and West Sumatra, Madura cattle are found in Madura Island, and Bali cattle are found in Bali Island (Williamson and Payne 1978).

Although the production of indigenous cattle is lower than imported one, indigenous cattle are proven to be able to adapt to local environment including food, water availability, climate and disease (ILRI 1995; Noor 2004). Animals that are able to adapt to environment have better gene that regulate their production and reproduction when they are faced by environmental stress. Uncontrolled crossbreed between Aceh cattle and exotic cattle without considering the importance of indigenous cattle causes concern because it triggers the erosion of genetic resources and threatens the existence of this breed in the future. The loss of important genes in indigenous cattle that has been adapted to local environmental conditions will be a serious matter because the gene may not be replaced. This concern can be seen in the case of indigenous cattle extinction in India. Due to uncontrolled crossbreeding, those cattle came to extinction before they were identified properly, as reported by Sodhi et al. (2006). FAO (2000) warned that livestock are at risk of extinction, especially in developing country. This is due to new market demand, crossbreeding, change of breed, and agricultural mechanization.

Crossbreeding among local cattle or between local cattle and exotic cattle is conducted to improve genetic quality and cattle's productivity. Consequently genetic quality of local cattle decreased. Simple germplasm conservation by using a performance test makes exterior characteristics become important. In crossbreeding,

originality of germplasm is the basic thing that must be considered.

Aceh cattle

Aceh cattle (*Bos indicus*) are small local cattle developed in Aceh (Martojo 2003; Dahlanuddin et al. 2003). They were first brought in by Indian traders in the past (Abdullah et al. 2007). Aceh cattle spread widely in Aceh area and are demanded as beef and working cattle. Most of local breeder use Aceh cattle to plow rice field. Aceh cattle business is conducted by local breeder and there has been no industrial cattle business (et al. 2007; Abdullah 2008).

Aceh cattle have a brownish red body (male) and crimson body (female), whitish color around the eyes, inner ears, and upper lips. Male cattle have a darker neck than the female, blackish brown back line, crimson back thighs, and light brown rump. The face and back shape are usually concave. The horns curved upward. The ears are small. The weight of male cattle is 253 ± 65 kg, female cattle 148 ± 37 kg; carcass percentage is 49-51%. Aceh cattle have a good ability in adaptation and in working as well as good immune. Aceh cattle are very productive; cattle breeder's fertility is 86-90%, birth rate is 65-85%, age of puberty is from 300-390 days, estrous cycle is from 18-20 days, and time for pregnancy is 275-282 days (Abdullah et al. 2007).

Pesisir cattle

Pesisir cattle (*Bos indicus*) are Indonesian local cattle which have the smallest body among other local cattle. Pesisir Cattle have small and short body, slender legs, small hump, and tame. Male cattle have short head, short and big neck, wide back of the neck, big, short, and round hump. Female cattle have rather long and thin head, tilt, short, and thin steering on the back, small horn (Saladin 1983). Adult male (4-6 years old) weigh only 160 kg (Adrial 2010). They have short horn pointing outwards like a goat horns. The diversity of coat color is relatively high with single pattern. The color is grouped into five dominant colors namely crimson (34.3%), yellow (25.5%), brown (20%), black (10.9%), and white (9.3%) (Anwar 2004).

Pesisir Cattle have high reproduction efficiency (Sarbaini 2004), high birth rate; birth weight is 14-15 kg, the average of daily weight gain from birth to weaning is about 0.32 to 0.12 kg/day (Saladin 1983). Carcass percentage of Pesisir Cattle is 50.6%. This breed is able to survive in adverse environmental condition and poor greening. The ability to convert fibrous fodder into meat is high enough (Saladin 1983). Pesisir Cattle are raised traditionally relying on grasses in pasture, empty land, and rain drops, disease resistance and adaptability to a tropical environment (Hendri 2013). Improved feed quality can have a positive impact on the growth rate and carcass quality, even though it will increase the percentage of lean and fat (Khasrad and Ningrat 2010).

Most Pesisir Cattle are raised by farmers in South Pesisir District and few cattle are raised in Padang Pariaman and Agam districts, West Sumatra (Anwar 2004; Hosen 2006). The population of Pesisir Cattle in South Pesisir District continued to decline. Cattle population in 2009 was 91,777 and in 2010 was 93,881, but it has declined until 76.111 in 2011 (Office of Agriculture and Horticulture, Livestock and Plantation South Pesisir District 2012). The decline of Pesisir Cattle population is believed to be related to the extensive traditional maintenance system, the slaughtering of productive cattle, insufficient fodder, the decrease of pastureland and genetic quality (Adrial 2010). This is due to the slaughtering of cattle with good quality that left only cattle with below average of quality and performance.

Jabres cattle

Jabres cattle (*Bos javanicus x Bos indicus*) (Jabres= Jawa Brebes) are one of local cattle from Brebes, a city in central java. This breed is believed to be a crossbreed between Madura cattle or Balinese cattle with Ongole Crossbred. Jabres cattle grow very well in the plateau area of southern Brebes District. The area is at > 800m.a.s.l with average rainfall between 233-565 mm and the number of rainy days between 76-140 days per year. The ability of Jabres cattle to adapt with environment is high. It is able to consume low quality fodder, resistant to insect, and having a good ability for reproduction. Its ability to give birth is also high. One cattle is able to give birth until 15-20 times with a short birth spacing of 12 months and get pregnant again 45 days after giving birth. The average birth weight of Jabres cattle is 16 kg, male adult is between 195-269 kg and female is between 168-296 kg (Lestari 2012).

Jabres cattle have solid meat. Their carcass percentage can reach 52%, higher than the crossbreeding between Simmental and Ongole Crossbred. Besides, they have good quality of skin and can be working cattle. The colors may vary from brown, whitish brown, white, blackish brown and black. Male cattle are usually blackish brown until black and the female are usually brown. These breeds are humpless with slim, compact body shape and dense meat. Special feature that differentiate Jabres cattle with other cattle is its white rump and back leg, a stripe from the back until tail. Jabres cattle have similar characteristics to Balinese cattle but Balinese cattle have white rump and leg contrast to its brownish red body. In Jabres cattle, the color gradation makes it having no visible boundary between the red brown and the white color. The cattle are able to survive in an extreme climate with limited supply of fodder. Jabres cattle have strong immune and are not susceptible to disease.

All Jabres cattle are raised by small farmers in traditional way. Most of them are taken care by *pangon* system, a system of grazing the cattle in forest or in abandoned agricultural land from morning till evening. In the evening, cattle are put back in the barn and are fed by corn straw, rice straw, and grass. Mating system is still dominated by natural mating. Artificial insemination has not been done yet due to cost reason.

Rancah cattle

Rancah cattle (*Bos javanicus x Bos indicus*) are local cattle of southeastern of West Java, especially from Ciamis District (Indrijani et al. 2012). Rancah cattle have physical characteristics as Madura and Bali cattle. The females have

no hump with relatively small body size, mostly red brick and white on the pelvis and on the four lower legs (tarsus and carpus) with no clear restrictions. There is a stripe along the back with the older color of the dominant colors. Male cattle are similar to females, but mostly with darker body color. Some Rancah cattle male may experience changes in color from brick red to black according to sexual maturity (such as Bali cattle). Male cattle weigh on average of 240 kg and of 220 kg in females (Payne and Rollinson 1973; Huitema 1986). In Rancah, Ciamis, these cattle are relatively small compared to other cattle which are also kept by cattle breeders, such as PO, Simpo and Limpo (Derajat 2014). It can be pregnant again within 2.5-5 months after giving birth (Hilmia et al. 2013).

Rambon cattle

Rambon cattle (*Bos javanicus x Bos indicus*) are local cattle in the east of east Java particularly in Bondowoso, Situbondo, Jember, and Banyuwangi. There were three races of cattle in the past in this area. They were Ongole Crossbred, Madura cattle, and Balinese cattle. Ongole Crossbred was the new Javanese cattle that had been existed in Java since the beginning of the first century AD. Madura cattle were mainly brought conterminous with Madura movement after the conquest of Blambangan Hindu Kingdom in the sixteenth century. Besides being domesticated in Bali and introduced from Bali, Balinese cattle are believed to be domesticated from local wild bull. Wild bulls are still easily found in this area particularly in Alas Purwo National Park, Baluran National Park, and Betiri Meru National Park. Rambon cattle are natural crossbreed of three cattle races that make their genetic composition vary (Susilawati et al. 2002; Susilawati 2004).

Rambon cattle living in Situbondo and Bondowoso have features that are more dominant than Madura cattle and Ongole Crossbred. Rambon cattle in Jember and Banyuwangi have features that are more dominant than Balinese cattle and Ongole Crossbred (Susilawati et al. 2002; Susilawati 2004). It is related to geopolitical history in this area in the past. Demak and Mataram Islamic Kingdom repeatedly conquered this area but they never built an effective local government. That is why this area is still controlled by Hindu Blambangan Kingdom or under the influence of Balinese Kings. In the middle of the sixteenth century, Mataram conquered this area with the help of Dutch colonial and Regent of Madura. This war caused depopulation in this area and then was inhabited by immigrants from Madura who mostly lived in the north coast. Consequently, Rambon cattle in the north tend to resemble Madura cattle and in the south resemble Balinese cattle.

Rambon cattle weigh about 300-400 kg. Those which live in Situbondo and Bondowoso have various dominant color of skin. They are crimson, brown red, raw red with no visible color boundary, white rump coat; long black tail; colors of leg coat may vary, clear white, white, and crimson; various shapes of the back, straight or curved with or without the back line; the direction of the horn may vary; some are with hump, some are not. Skins of Rambon cattle in Banyuwangi and Jember are dominated by crimson. They have thin dewlap, black back line, and white skin in the leg, white rump, horn, black fur in tail, and no hump (Susilawati et al. 2002; Susilawati 2004).

Galekan cattle

Galekan cattle (*Bos javanicus x Bos indicus*) are breed of Javanese and Balinese cattle that need to be preserved. Coat color is light brown, dark brown and darkish crimson. It has white or light brown rump and dewlap with no visible boundary between the two. Its tail is long with black hair. It also has black eyes circle, the back with black straight line, hump, horn, and ears with black line. These breeds live in dry lowland.

Galekan cattle are local race of Trenggalek District, East Java. They belong to superior cattle. However, their existence is threatened by the development of Ongole Crossbred and other new cattle of artificial insemination. Frequent natural crossbreeding with Ongole Crossbred decreases the purity of its genetic and makes their breeds difficult to be identified as Galekan cattle. Nowadays, the number of pure superior Galekan cattle is estimated less than 20. These breeds live in Pringapus village, Dongko district, and Panggul village, Panggul district, Trenggalek District, East Java.

Grati cattle

Grati cattle are the only local dairy cattle that are still raised by people. In the beginning of the 20th century, Holstein Friesians (HF) dairy cattle were imported to develop dairy cattle in Indonesia. In 1939, 22 male of Holstein Friesians were imported from the Netherlands to be taken care in Grati, Pasuruan. Prior to Holstein Friesians are Shorthorn, Ayrshire, and Jersey that were imported from Australia. Crossbreeding between the imported cattle and the local cattle (Javanese or Madura cattle) produced new dairy cattle known as Grati. They are internationally recognized as Indonesian local dairy cattle (Payne 1970). This breed was mainly reared in the highland of Pasuruan and Malang (Pujon, Nongkojajar, Batu, and surrounding area) (AAK 1995). They are also known as Holstein Friesians crossbreed. In its development, Grati cattle are the result of crossbreeding of pure male HF and female Ongole Crossbred. These breeds are known as Indonesian Holstein Friesians. Unlike their predecessors that continue to decline in quality and abandoned by farmers, HF is still being developed until today and the cement is also still being used for artificial insemination. Recently, old Grati cattle population is estimated less than 10.000, while the new Grati (Indonesian Holstein Friesians) has not been recorded (Sariubang 1992; DGLS 2003).

Grati cattle have similar color to Holstein Friesians cattle. They have black and white stripes fur but not as clear as Holstein Friesians. There is a white triangle on the forehead, the chest, and the lower abdomen. Their tail and leg are white with white, long, and straight head. They have small and short horn facing to the front. Their body's size and milk production are lower than Holstein Friesians'. In the beginning, Grati cattle were able to produce around 15 liters of milk per day but because there was no further genetic improvement, nowadays, they are

only able to produce 12.3 liters per day, with lactation period of 9 months. This breed can adapt to hot tropical environment, and easily controlled because it is tame and quiet. With intensive feed, their weight can be increased 0.9 kg per day (Darmono 1993; Yulianto and Saparinto 2010; Syarif and Harianto 2011).

EXOTIC CATTLE

In the 1970s, new type of zebu and taurine cattle were introduced in the form of frozen cement and live cattle. They were then crossed with local cattle. Zebu cattle that were mainly imported were Brahman and Brahman Cross, and from taurine were Simmental, Limousine, HF, and AAC. In Indonesia, there were also other foreign cattle but they were not much raised. ACC were generally put in cattle fattening farm and were not propagated to small farmers. In the beginning, artificial insemination was less successful because farmers were not used to raise cow intensively. Successful breeding is usually between zebu and zebu because the calves are able to live in hot climate and limited food (Martojo 2003). While farmer's knowledge improves, more crossbreeding between Ongole Crossbred and Simmental or Limousine using frozen cement are found. In the long term, there is some concern that genetic composition of Indonesian local cattle will change (Putro 2009).

Holstein Friesians

Holstein Friesians (HF) (*Bos taurus*) have been developed since the 13th century in the Netherlands (North Holland and Friesland) and North Germany (Schleswig-Holstein) to produce a type of cattle that are able to consume local grass. After a century, the breeding effort resulted in the best dairy cattle in the world with typical black and white color. These colors are preferable than the original brown of this race. In Indonesia, HF cattle were first imported from the Netherlands in the 19th century. However, the next import was coming from Australia, New Zealand, USA, Japan, and Canada. These cattle have a good ability to produce milk and meat, and good reproduction ability. They are mainly raised in the highland of Java Island; 700 meters above the sea level with temperature between 16 - 23° C and also moist and wet environment. However, they are also able to live in low land, 300 meters above the sea level with temperature 28 - 35° C and also moist and wet environment.

In Indonesia, the population of HF in 2002 is around 354.000 (DGLS 2003). This group mainly belongs to relatively pure HF because HF crossbreeding that was developed over the last 100 years has not been continued because the pure cattle produce more milk and meat. However, HF crossbreed, the result of crossbreeding between male HF with female Ongole Crossbred is still offered. This type of cattle was called Grati before being called as Indonesian HF. This breed has a high genetic quality obtained from the male parent and a high ability to adapt with tropical environment obtained from the female parent. HF has low birth weight (35 kg in average) but with rapid growth after birth. First ideal pregnancy is around 25 months with short calving interval around 12.6 months. Milk production is high with good production resistance due to high genetic quality and good adaptation to tropical environment.

Pure Holstein Friesian is generally black with white stripes but sometimes red with white stripes and with clear color boundary. The head is long, wide, and straight. The horn is short and curved facing toward (Sudono et al. 2003; Siregar 1995). This breed has wide mouth, wide open nostrils, strong jaw, clear eyes, medium ears, wide forehead, long and thin neck, good shoulders located on the chest wall and form a good joint with the body; strong and flat back with backbone that connected to each other very well. It also has long and wide steering on the back, quadrangular. Its nails are short with good sphere. The heel is low with flat palm. The udder is big and hanging down near the hind legs (Samad and Soeradji 1990).

Simmental

Simmental cattle (*Bos taurus*) originated in Simme valley, Switzerland. This breed is one of the oldest of all breeds of cattle in the world that survive until today. Simmental cattle have been domesticated since the thirteenth century and have contributed to the creation of other newer breeds. They are raised for milk, beef, and as working animals. Simmental cattle had been distributed to many places, for example to Italy in 1400s. However, large scale breeding started in 1960 in the United States. In 1972, Simmental cattle were exported to Australia and New Zealand. In 1985, Simmental cattle and their frozen semen arrived in Indonesia from those countries. Since Simmental cattle are subtropical animal, in Indonesia their pure breed are only raised for their semen in barns belonging to the government or large farmers in highlands. They have muscular and sturdy body, fast muscle growth, they produce high-quality low-fat beef carcass, and the weight of an adult cattle can exceed 1,000 kilograms. Simmental cattle are commonly black due to a selection in the U.S. in 1970-1980, however, the specific breed found in Indonesia have brownish yellow or red face, with white lower legs and white tail ends, similar to the pure breed. In Indonesia, Simmental cattle are mostly kept as beef cattle and widely crossbred with local cattle through artificial insemination, particularly with Ongole Crossbred, Madura cattle, and Bali cattle. In Java, artificial insemination is also conducted on Simmental cattle with Holstein Friesian cattle. From the crossbreeding, male offspring are much preferred due to their faster growth, while the female offspring do not grow very well and produce only a little milk. The artificial insemination is conducted directly on the field, so the offspring have not been adaptable to the local climate, food, and diseases. However, farmers seem to like the effort because the offspring are bigger and grow faster compared to other local breeds. By the age of 2.5 years old, a Simmental cow can weigh up to 1,000 kilograms. For this reason, artificial insemination is done continuously. In long term, this issue needs to be addressed because it is related to the genetic changes of Indonesian local cattle.

Limousin

Limousin cattle (*Bos taurus*) originated from the Limousin and Marche regions of France. The history of Limousin cattle is believed to begin in the sixteenth century; however, the first effort to ensure the breed's purity and improvement was done in 1886 by establishing the French Limousin Herd Book and the distribution to other parts of the world began in 1960s. Limousin cattle have large, long, and compact body, large chest, shallow ribs, and thick meat whose pattern is better than that of Simmental cattle. They have sharp eyes and strong legs. The males have curved horn and dark red, light brown, or greyish yellow body, except around the udders which is white and the lower legs and around the eyes which are lighter in coloration. Nowadays, people raise hornless black Limousin cattle. An adult male can weigh up to 1,400 kilograms and a female 850 kilograms. The most productive Limousin are at the age of 10 to 12. Their rate of weight gain is the highest among other breeds, which is 1.1 kilogram per day. Since they are originally from a subtropical region, Limousin cattle are only suitable for breeding on highlands with high precipitation. This breed is one of the most immune ones that are resistant to various diseases.

Limousin cattle around the world are widely hybridized with other cattle breeds. In Indonesia, their semen is used mainly for artificial insemination on local breeds, particularly the Ongole Crossbred and the Brahman cattle.

Brahman and Brahman Cross

The Brahman Cross cattle (*Bos indicus x Bos taurus*) are crossbreeds of Brahman breed of zebu with taurine in Australia. Brahman cattle were first domesticated in the United States from four breeds of zebu (Kankrej, Gujarat, Ongole, and Gir) which are imported from India since 1849. These breed have been resource of genes for several new breeds of cattle. The Brahman Cross have large, long, and deep body, have hump on the shoulders, and are loose-skinned with sagging skin from the lower jaw to the tip of the front part of the chest. The head is large and long with big hanging, pointed ears. They have large legs with thick and loose skin. The coloration highly varies, but commonly they are grayish white, even though many are black, brown, red, yellow, or striped. The Brahman Cross is one of the best beef cattle for breeding in lowlands due to their resistance to high temperature and endoparasites as well as ectoparasites (Banerjee 1978; Gunawan 2008).

Brahman cattle from the United States were exported to Australia in 1933 and frequently hybridized with cattle breeds that had previously existed in Australia, such as Hereford, Shorthorn, Santa Gertrudis, Droughmaster, Simmental, and Limousin. The offspring were then crossbred with Brahman cattle so that the genetic mix of the offspring is various, but the physical appearance and the features are similar to Brahman cattle because the Brahman cattle genes are more dominant (Banerjee 1978; Turner 1977; Friend and Bishop 1978). Brahman Cross have a fairly good growth with daily weight gain of 1.0-1.8 kilogram, high carcass yield of 45-55%, and are resistant to various diseases, lice, and mites.

In 1973, Brahman Cross began to be imported to Sulawesi from Australia (Gunawan 2008). The cattle are mostly used for draft animals and are slaughtered when they get old, so they can only fulfill the demand of traditional market. In 1975, Brahman Crosses were imported to Sumba Island to improve the genetic quality of Sumba cattle. In 2000 and 2001 they were brought to Sumbawa and in 2006 they were distributed widely to many parts of Indonesia to support the acceleration to achieve self-sufficiency of beef. Nowadays, in Indonesia, cattle feedlots have become popular particularly in West Java, Banten, and Lampung. The breeders intensively fatten cattle especially the Brahman Cross. Ideal breeding for fattening is 60-70 days for female cattle and 80-90 days for male cattle, because if they are bred and fattened for too long, their growth will slow down and they will experience extensive fat marbling which is not preferred by local consumers.

Australian Commercial Cross (ACC)

The Australian Commercial Cross (ACC) cattle (*Bos indicus x Bos taurus*) do not have a very clear genetic background. These breeds are supposed to be the descendant of open crossbreeding on grazing lands between various types of cattle raised in North Australia and Queensland that have dry climate. On these grazing lands, many cattle breeds are found, such as the Brahman, Shorthorn, and Hereford (Beattie 1990), so that the ACC are believed to have been originated from a crossbreeding between the Brahman breed of zebu with Shorthorn and Hereford taurine (AMLC 1991; Ngadiyono 1995). However, unlike the Brahman Cross, the physical characteristics of ACC cattle are more similar to that of Shorthorn and Hereford, with shorter and more compact body, large head, small ears that are not hanging, no hump and wither, fur around the head, and color variation similar to Shorthorn and Hereford. These breeds are very good for fattening program because they can adapt easily to suboptimal environment like the Brahman do, and have fairly fast growth like the Shorthorn and Hereford. Young skinny ACC cattle can be fattened in a relatively short time (60 days) and will be very profitable because they gain ±1.61 kilograms per day with the fodder conversion of 8.22 compared to when they are fattened for a longer period (90 or 120 days) (Hafid and Hasnudin 1998). Together with the Brahman Cross, ACC cattle are the most favorite breed for large feedloter companies in Indonesia.

THE DEMAND FOR CATTLE BREEDING

Cattle play an important role in the development of human culture and civilization (Achaya 2002; Lodrick 2005). In addition to agricultural work and ceremonial traditions, cattle are also raised for the production of meat and milk because of their high protein and fat content (Baig et al. 2005). Cattle are raised worldwide as livestock for meat (beef and veal), as dairy animals for milk and other dairy products, and as working animals. Cattle accounts for the largest share of world meat production (Umar 2009), accounting for about 50% of meat demand worldwide, as

well as 95% of milk demand and 85% of leather demand (Bappenas 2007). Cattle's ability to consume and digest high fiber materials in larger amount than other ruminants do leads to their relatively more rapid growth compared to other animals (Cheeke and Dierenfeld 2010; Purvis et al. 2011).

Beef cattle business in Indonesia is a very potential, considering that the demand of beef is much higher than the supply. The needs for beef cattle increase sharply during two national holidays, the Eid al-Fitr and Eid al-Adha. Until the 1970s, Indonesia was one of the world's biggest beef exporters. However, in the next years, Indonesia became an importer. The amount of imported cattle and beef kept increasing from year to year, resulting in dependence on imported livestock products. Even in the last three years (from 2013 to 2015) there has always been chaos in the domestic market relating to the soaring price of beef. The increase of beef demand is caused by the population growth, the increase of living standard, the pattern changing in food consumption that have led to the increase of the consumption of animal-based foods, and the presence of expatriates who are used to consuming beef of certain quality (Mintert et al. 2001; Norton 2003; DGLS 2010a). In the next 10 years (2014-2024), the national demand for meat increased by almost 1.5% (Faculty of Animal Sciences of Gadjah Mada University 2014), while the world demand increased by almost 3% (OECD 2016).

The high demand of beef in Indonesia is not followed by improvement in quantity and quality of beef cattle (Khasrad and Ningrat 2010), because even high-quality young cows that have not yet reached the standard weight are also slaughtered. A study conducted by the Faculty of Animal Sciences of Bogor Agricultural University (2012) in ten provinces shows that the majority of local cattle that have been slaughtered have not reached the targeted slaughter weight. The financial crisis that hit Indonesia in late 1990s caused Rupiah exchange rate to fall sharply against USD and as a consequence, the government reduced the imports of cattle. This condition led to a significant increase in the slaughter of domestic cattle, which causes a decrease in the number of offspring in the next several years. The increased demand for beef is not only happened in Indonesia, but also in other large population countries such as China and the United States (Feuz 2009; Hoffman 2014; OECD 2016), thus increases environmental pressure, particularly for livestock feed, water and grazing areas as well as global warming (Machovina 2015).

The government of Indonesia has set a long-term policy to achieve beef self-sufficiency by increasing domestic production. The objective of the policy is to reduce reliance on imported beef and cattle, by at least 10 percent. However, the policy, which was introduced in 2000, has been unsuccessful. The same program was tried again in 2010 and once more in 2015 but still failed (DGLS 2010b; Mahbubi 2014). The government had imported live cattle and frozen semen from various types of cattle to increase domestic production. However, other factors such as the limited amount of land for grazing and limited fodder supplies have contributed to the failure.

Agricultural land in Indonesia that are mainly located in Java have been affected by residential and commercial development pressures (Fitriani 2005; Rohman and Hayati 2015; Wuryanta and Susanti 2015). Due to the decreasing area of agricultural land, there is not enough acreage to grow field crops to be used as forage, which affects the productivity of domestic cattle (Harianjogja.com 07/09/2014; Republika.co.id 14/01/2016). The decline of cattle population is also attributed to the slaughter rate that is much higher than the growth of the cattle population due to high demand of beef (Diwyanto 2011); even, productive beef cows and dairy cows are also slaughtered (Soejosopoetro 2011; Fauzi et al. 2013). It was banned by the government (Permentan No. 35/Permentan/ OT.140/7/2011), but the enforcement of these rules is not decisive.

Despite the limited area of land in Java, there are a lot of lands outside Java that can be used for cattle raising, for example lands under palm plantation (Aritonang 1986; Wirdateti et al. 2012) or cocoa plantation (Tanjung 2015), lands that have been deforested due to illegal logging (Santoso 2012), and abandoned mining sites (Diwyanto et al. 2009; Ali et al. 2014). In Papua, there are vast areas of unexploited lowland and highland pastures that can be used for raising tropical and sub-tropical cattle (Rajab 2009; Soltief 2009; Sa'adah 2013; Saiya 2013). These opportunities have never been considered seriously since there is no political policy and initiatives from the government. An estimation of the needs for beef in the next ten years is presented in Table 1.

Table1. Estimated amount of beef supply and consumption (2014-2024)

Year	Production (ton)	Consumption (ton)	Difference/ Deficiency (ton)	Fulfillment from domestic product (%)
2014	435,086.19	593,516.62	-158,430.42	73.31
2015	446,180.61	639,857.57	-193,676.96	69.73
2016	457,275.03	684,884.27	-227,609.23	66.77
2017	468,369.45	729,910.96	-261,541.51	64.17
2018	479,463.87	774,937.66	-295,473.79	61.87
2019	490,558.29	819,964.36	-329,406.06	59.83
2020	501,652.71	864,991.05	-363,338.34	58.00
2021	512,747.13	910,017.75	-397,270.62	56.34
2022	523,841.55	955,044.45	-431,202.90	54.85
2023	534,935.97	1,000,071.14	-465,135.17	53.49
2024	546,030.39	1,045,097.84	-499,067.45	52.25

Source: Faculty of Animal Sciences of Gadjah Mada University (2014)

THE DEVELOPMENT OF CATTLE INDUSTRY AND ITS CHALLENGES

The development of cattle industry in Indonesia has been done for thousands years and is still being done until today to improve the quality and quantity of cattle. The quality of cattle is determined by genetic as well as environmental factors (climate, food, disease, etc.). Both can be manipulated in order to improve the quality of cattle; however, genetic factors play a more important role since they determine the rate of reproduction, meat or milk productivity, percentage of carcass, daily weight gain rate, food efficiency, immunity to climate and diseases, physical strength as working animals, and so on. Genetic studies have been done to give more understanding about the loss of genetic diversity due to inbreeding and its implication to the natural population. Genetic diversity conservation is important because it represents the evolution potential of a certain species (Frankham et al. 2002). One example of genetic studies of cattle in Indonesia that includes all types of cattle breed is conducted by Mohamad et al. (2009).

Nowadays, the main challenge in the sustainable use of cattle as a source of protein is the lack of information about the population of local cattle, their geographic distribution, and genetic characteristics (Long 2008). Phenotypic and genetic characteristics of cattle population are still limited (Hannotte and Jianlin 2005). The world's cattle population is mostly the descendant of two bovine species, zebu (humped) and taurine (humpless), which are scientifically called *Bos indicus* and *Bos taurus*. The history of the two breeds from their ancestor the wild aurochs has been traced through Mitochondrial DNA or mtDNA (Baig et al. 2005). Bali cattle (*Bos javanicus*) are the only breed of bovine that is significantly developed.

The diversity of cattle is developed through mutations, genetic shifts, and artificial selection of wild ancestor species in order to enable the cattle to grow and breed optimally in a local environment (Long 2008). Genetic studies are important to prevent a decline of cattle's genetic quality. Similar to wild species, the biggest threat for domesticated cattle is inbreeding and the loss of genetic variations. To ensure that a population can grow and breed continuously, the rate of genetic variation in the population must be determined. Genetic factors that affect the productivity and sustainability of cattle in a long term must be identified. Since genetic variation is often correlated with health, a decline in genetic variability may limit the ability of the population to respond to environmental changes such as climate change, disease, or parasites (Frankel and Soule 1981). Inbreeding causes a decline of genetic variation that leads to a decreasing immunity of the cattle in responding to environmental changes and disease. Inbreeding mostly occurs in small isolated populations that do not have the chance of getting new genes from outside. Cattle isolation in Bali that is done by preventing new genes to enter is believed to cause a decline in the cattle's immunity so that they can easily get infected with Jembrana disease, while other Bali cattle living outside the island do not get infected even though the population size is bigger.

On the other hand, new genes input through hybridization with other cattle breeds may threaten the purity and special characteristics of a certain species. During the colonial era, Madura Island was exclusive for raising Madura cattle and was closed for other types of cattle; and Bali was limited only for raising Bali cattle since the reign of the Klungkung Kingdom. However, today, the two islands become the target for improving cattle quality through artificial insemination using frozen semen from zebu (Brahman and Brahman cross) and taurine (Simmental, Limousin, etc.) cattle. The breeding conducted directly in the field started to become uncontrollable, so that the long-term effect is unpredictable. The development of Ongole Crossbred industry is a success story of cattle quality improvement in Indonesia, which has produced offspring that are highly adaptable to the climate, fodder, and diseases in Indonesia and are suitable as working animals. However, due to their low daily weight gain compared to other types of cattle, these cattle have become the target of hybridization. Crossbreeding between Madura cattle with various types of taurine dairy cattle shows failure because the offspring unexpectedly have low immunity and milk productivity, so that they can no longer be found in Indonesia.

The quality improvement through crossbreeding between the same breed of cattle, for example Ongole Crossbred (*Bos indicus*) with Brahman (*Bos indicus*) or Brahman Cross (*Bos indicus x Bos taurus*), are generally successful. However, crossbreeding between different breeds is mostly unsuccessful. Even if it is successful, the quality of offspring will decrease after several generations. For example, a crossbreeding between Madura cattle (*Bos javanicus x Bos indicus*) with Red Danish (*Bos taurus*) produces offspring that grow and raise well and can adapt to the local environment. Therefore, there must be pure male semen available for hybridization. Another example is crossbreeding between Holstein Friesians cattle (*Bos taurus*) and Ongole Crossbred (*Bos indicus*) that produces Grati cattle, in which the quality of offspring decline after few generations, so that new Holstein Friesians semen is always available for breeding. The same case also happens to the crossbreed of Simpo and Limpo, in which the success rate of female offspring's pregnancy inseminated with Simmental or Limousin semen is lower compared to the crossbreeding with female Ongole Crossbred. However, in cases of beef cattle, farmers generally do not care about the long-term condition because the offspring are intended for being slaughtered instead of being raised, so that they need to provide frozen semen from pure breeders. Nowadays, most male cattle that are crossbred are of the Simmental and Limousin breed, and the female are Ongole Crossbred. However, there are also successful mating between female Bali cattle and male Madura cattle. In some cases, crossbreeding between different types of cattle can also produce high quality offspring after several generations, for example Madura, Brahman Cross, and ACC cattle. Before conservation and management efforts are done, it is very important to understand the rate of genetic variations in a certain cattle population.

DAFTAR PUSTAKA

AAK. 1995. Practical Guide of Cattle Farming. Kanisius, Yogyakarta. [Indonesian]

Abdullah MAN, Noor RR, Martojo H, Solihin DD, Handiwirawan E. 2007. Phenotypic diversity of Aceh cattle in Nanggroe Aceh Darussalam. J Indon Trop Anim Agric 32 (1): 11-21. [Indonesian]

Abdullah MAN. 2008. Genetic Characterization of Aceh cattle using Phenotypic Diversity Analysis on D-loop region of Mitochondrial DNA and DNA Microsatellite. [Ph.D. Dissertation]. School of Graduates. Bogor Agricultural University. Bogor. [Indonesian]

Achaya KT. 2002. A Historical Dictionary of Indian Food. Oxford University Press, Oxford.

Achilli A, Bonfiglio S, Olivieri A, Malusà A, Pala M, Kashani BH et al. 2009. The multifaceted origin of taurine cattle reflected by the mitochondrial genome. PLoS ONE 4 (6): e5753. DOI: 10.1371/journal.pone.0005753

Adam, T., 1921: Oudheden te Djambi, in: Oudheidkundig Verslag, 194-197.

Adrial. 2010. Potential and development efforts of Pesisir cattle in West Sumatra. Jurnal Penelitian dan Pengembangan Pertanian 29 (2): 66-72. [Indonesian]

Ajmone-Marsan P, Garcia JF, Lenstra JA. 2010. On the origin of cattle: how aurochs became cattle and colonized the world. Evol Anthropol 19: 148-157.

Ali HM, Alam G, Syamsu JA, Salengke, Asja MA. 2014. Average Daily Gain, AST and Blood Nitrogen Urea (BUN) Responses of Bali Beef on Cocoa Waste Extract Supplement. J Adv Agric Technol 1 (1): 4-9.

AMLC [Australian Meat and Livestock Corporation]. 1991. A Workshop for tropical feedlot managers: An Introductory Workshop for Feedlot Managers in the Philippines. Australian Meat and Livestock Corporation, Perth Western, Australia.

Anwar. 2004. Diversity of External Character and Microsatellite DNA of Pesisir Cattle West Sumatra. [Ph.D. Dissertation]. School of Graduates. Bogor Agricultural University, Bogor. [Indonesian]

Arifah. 2013. Site Cangkuang: Meeting of Hindu and Islamic civilization. DikbuD 4 (2): 26-29. [Indonesian]

Ariswara. 1994. Prambanan. 4th ed. Intermasa, Jakarta.

Aritonang D. 1986. Palm oil plantations, a source of animal feed in Indonesia. Jurnal Litbang Pertanian 4 (4): 93-99. [Indonesian]

Asmadi S, Soemadi H. 2004. Sukuh Temple. C.V. Massa Baru, Surakarta [Indonesian]

Atmakusuma J, Harmini, Winandi R. 2014. Is it possible be realized meat self-sufficiency? Risalah Kebijakan Pertanian dan Lingkungan 1 (2): 105-109. [Indonesian]

Baig M, Beja-Pereira A, Mohammad R, Kulkarni K, Farah S, Luikart G. 2005. Phylogeography and origin of Indian domestic cattle. Curr Sci 89: 38-40.

Banerjee GC. 1978. Animal Husbandry. Oxford and IBH Publishing Co, New Delhi.

Bappenas. 2007. Animal Feed. Rural Community Economic Development Project-Bappenas, Jakarta. [Indonesian]

Barker G. 1985. Prehistoric Farming in Europe. Cambridge University Press, Cambridge, UK.

Bhattacharya G. 1977. Nandin and Vṛṣabha, Zeitschrift der Deutschen Morgenländischen Gesellschaft, Supplement III,2, XIX. Deutscher Orientalistentag, pp. 1543-1567.

Blakely J, Bade DH. 1998. The Science of Animal Husbandry. 8th ed. Prentice-Hall, Inc., New York.

Bosch FDK. 1915/16. De Sanskrit-inscriptie op den steen van Dinaja. TBG 57: 410-444

Bottenberg RW. 2010. Śriwijaya: Myth or Reality? [M.Sc. Thesis]. Leiden University, The Nederland.

BPS. 2014. Preliminary figures of 2013 Agricultural Census Results. BPS, Jakarta. st2013.bps.go.id [2 Oktober 2015] [Indonesian]

Bradshaw CJA, Brook BW. 2007. Ecological-economic models of sustainable harvest for an endangered but exotic megaherbivore in northern Australia. Nat Res Mod 20 (1): 129-156.

Budiarso IT, Hardjosworo S. 1976.Jembrana disease in Bali cattle. Aust Vet J 52 (2): 97.

Byers O, Hedges S, Seal US (eds.). 1995. Asian wild cattle conservation assessment and management plan workshop. Working document. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, Minnesota, USA.

Cheeke PR, Dierenfeld ES. 2010. Comparative Animal Nutrition and Metabolism. CABI, Wallingford, Oxfordshire, UK.

Chen S, Lin BZ, Baig M, Mitra B, Lopes RJ, Santos AM, Magee DA, Azevedo M, Tarroso P, Sasazaki S et al. 2010. Zebu cattle are an exclusive legacy of the South Asia Neolithic. Mol Biol Evol 27: 1-6.

Coedes G. 1968. The Indianized States of Southeast Asia. Vella WF (ed). Cowing SB (transl.). Australian National University Press, Canberra.

Copland J. 1996. Bali Cattle: Origins in Indonesia. In: Wilcox GE, Soeharsono S, Darma DMN, Copland JW. ACIAR Proceeding. 75: 29-33.

Dahlanuddin DV, Liang TJB, Adams DB. 2003. An exploration of risk factors for bovine spongiform encephalopathy in ruminant production system in the tropics. Rev Sci Tech Off Int Epiz 22: 271-281.

Darmono. 1993. Management of Cattle Fattening Business. Kanisius, Yogyakarta. [Indonesian]

de Casparis JG. 1941. Nogmaals de Sanskrit-inscriptie op den steen van Dinojo. TBG 81: 499-514

DGLS [Director General of Livestock Services]. 2003. National Report on Animal Genetic Resources Indonesia; A Strategic Policy Document. Director General of Livestock Services, Jakarta. [Indonesian]

DGLS [Director General of Livestock Services]. 2010a. General Guidelines for Self-Sufficiency Beef Program in 2014. Director General of Livestock Services, Jakarta. [Indonesian]

DGLS [Director General of Livestock Services]. 2010b. Blue Print of Self-Sufficiency Beef Program in 2014. Director General of Livestock Services, Jakarta [Indonesian]

DGLS [Director General of Livestock Services]. 2010c. Technical Guidelines of PSDS Operational Activities. Director General of Livestock Services, Jakarta [Indonesian]

DGLSAH [Director General of Livestock Services and Animal Healts]. 2015. Guidelines for the Implementation of Strengthening Native/Local Cattle Breeding in Selected Island (Pulau Raya, Sapudi Island and Nusa Penida Island) and the Strengthening of Beef Cattle Breeding in Selected Districts (Siak, West Pasaman, South Lampung, Kebumen, Barito Kuala, Barru, Gunung Kidul, and Central Lombok). Director General of Livestock Services and Animal Healts, Jakarta. [Indonesian]

Diwyanto K, Hasinah H, Nurhayati IS. 2009. Cattle breeding and development system of integrated rice plants, palm oil and cocoa. In: Integration System of Livestock and Crops: Rice-Palm Oil-Cocoa. LIPI Press, Jakarta.

Diwyanto K, Praharani L. 2010. Reproduction management and breeding strategies to improve productivity and quality of cattle.Proceeding of the Conservation and Improvement of World Indigenous Cattle. Bali, 3-4 September 2010.

Diwyanto K. 2011. Save productive cows. Sinar Tani 30: 2-4. [Indonesian]

Duckworth JW, Hedges S. 1998. Tracking Tigers: A Review of the Status of Tiger, Asian Elephant, Gaur, and Banteng in Vietnam, Lao, Cambodia, and Yunnan (China), with Recommendations for Future Conservation Action. WWF Indochina Programme, Hanoi, Vietnam.

Entwistle K, Lindsay DR (ed). 2003. Strategies to improve Bali cattle in eastern Indonesia. ACIAR Proceedings No. 110, Aciar, Canberra.

Faculty of Animal Sciences of Bogor Agricultural University. 2012. Activity Report Faculty of Animal Science, Bogor Agricultural University and the Directorate General of Livestock and Animal Health Ministry of Agriculture, Republic of Indonesia: Carcass Survey 2012. Bogor Agricultural University, Bogor.

Faculty of Animal Sciences of Gadjah Mada University. 2014. Roadmap of beef industry development in Indonesia. Seminar on Roadmap of Beef Cattle Industry in Indonesia. Faculty of Animal Sciences of Gadjah Mada University and APFINDO, Yogyakarta 9 Oktober 2014. [Indonesian]

FAO [Food and Agriculture Organization]. 2000. World Watch List for Domestic Animal Diversity. 3rd ed. FAO, Rome.

Fauzi RA, Sarwiyono, Setyowati E. 2013. Evaluation of slaughtered Friesian Holstein Crossbreed diary cows in productive age at Karangploso Subdistrict Malang. Faculty of Animal Husbandry, University of Brawijaya. Malang. [Indonesian]

Febriana A, Farajallah A, Perwitasari D. 2015. Indel incident simultaneously on the intron 7 Gen branched-chain α-keto acid dehydrogenase E1a (BCKDHA) in Madura cattle. Jurnal Ilmu Pertanian Indonesia 20 (2): 97-102. [Indonesian]

Felius M, Beerling ML, Buchanan DS, Theunissen B, Koolmees PA, Lenstra JA. 2014. On the history of cattle genetic resources. Diversity 6: 705-750.

Feuz D. 2009. Understanding Beef Demand: What factors change the demand for beef? Beef Feb 24, 2009. http:// beefmagazine.com/sectors/retail/0225-understanding-beef-demand

Fitriani AA. 2005. Analysis of the Carrying Capacity of Agricultural Land and Population Pressures (Case Study of Districts in East Java Province). [Hon. Thesis]. Department of Economic Development, Faculty of Economics, Universitas Sebelas Maret Surakarta. [Indonesian]

Fordyce G, Panjaitan T, Muzani H, Poppi D. 2002. Management to facilitate genetic improvement of Bali cattle in Eastern Indonesia. In: Proceeding of an ACIAR Workshop on "Strategies to Improve Bali Cattle in Eastern Indonesia", Denpasar, Bali, Indonesia.

Frankel O, Soule M. 1981.Conservation and Evolution. Cambridge University Press, Cambridge.

Frankham R, Briscoe DA, Ballou JD. 2002. Introduction to conservation genetics. Cambridge University Press, New York, New York, USA.

Friend J, Bishop D. 1978. Cattle World. Blandford Press, Dorset.

Galbreath GJ, Mordacq JC, Weiler FH. 2007. An evolutionary conundrum involving kouprey and banteng: A response from Galbreath, Mordacq and Weiler. J Zool 271 (3): 253-254.

Galbreath GJ, Mordacq JC, Weiler FH. 2006. Genetically solving a zoological mystery: was the kouprey (*Bos sauveli*) a feral hybrid? J Zool 270 (4): 561-564

Gunawan (ed). 2008. Maintenance Instructions of Brahman Cross Cattle. BPTU Sembawa, Ditjen Peternakan, Palembang. [Indonesian]

Handiwirawan E, Subandriyo. 2004. Potential diversity of genetic resources of Bali cattle. Wartazoa 14 (3): 107-115. [Indonesian]

Hannotte O, Jianlin H. 2005. Genetic characterization of livestock populations and its use in conservation decision making. In: Ruane J, Sannino A (eds.). The Role of Biotechnology in Exploring and Protecting Genetic Resources. FAO, Rome.

Hardjosubroto W. 1994. Application of Cattle Breeding in the Field. Gramedia Widia Sarana, Jakarta. [Indonesian]

Hardjosubroto W. 2004.Alternative policy of sustainable management of genetic resources of local beef cattle in the local livestock breeding system. Wartazoa 14 (3): 93-97. [Indonesian]

Harianjogja.com. 07/09/2014. Yogyakarta Shortage of Land for Forage Crops. http://www.harianjogja.com/baca/2014/09/07/diy-kekurangan-lahan-untuk-tanaman-pakan-ternak-533752. [Indonesian]

Hassanin A, An J, Ropiquet A, Nguyen TT, Couloux A. 2013. Combining multiple autosomal introns for studying shallow phylogeny and taxonomy of Laurasiatherian mammals: Application to the tribe Bovini (Cetartiodactyla, Bovidae). Mol Phylogenet Evol 66: 766-775.

Hedges S, Groves CP, Duckworth JW, Meijaard E, Timmins RJ, Burton JA. 2007. Was the kouprey a feral hybrid? A response to Galbreath et al. (2006). J Zool 271 (3): 242-245

Helmer D, Gourichon L, Monchot H, Peters J, Saña Segui M. 2005.Identifying early domestic cattle from prepottery Neolithic sites on the middle Euphrates using sexual dimorphism. In: Vigne JD, Peters J, Helmer D (eds.). The First Steps of Animal Domestication.Oxbow Books, Oxford, UK.

Hendri Y. 2013. Development of Pesisir Cattle as a local bred of West Sumatra. J Litbang Pert 32 (1): 39-45 [Indonesian]

Hilmia N, Noor RR, Sumantri C, Gurnadi RE, Priyanto R. 2013. Productivity and genetic diversity of local cattle in Ciamis West Java. J Indon Trop Anim Agric 38 (1): 10-19.

Ho SY, Larson G, Edwards CJ, Heupink TH, Lakin KE, Holland PW, Shapiro B. 2008. Correlating Bayesian date estimates with climatic events and domestication using a bovine case study. Biol Lett 4: 370-374.

Hoffman B. 2014. How Increased Meat Consumption In China Changes Landscapes Across The Globe .Forbes Mar 26, 2014. http://www.forbes.com/sites/bethhoffman/2014/03/26/how-increased-meat-consumption-in-china-changes-landscapes-across-the-globe

Hoffmann RS. 1986. A new locality record for the kouprey from Viet Nam, and an archaeological record from China. Mammalia 50 (3), pp. 391-395.

Hoogerwerf A. 1970. Udjung Kulon—the Land of the Last Javan Rhinoceros. E. J. Brill, Leiden. The Netherlands.

Huitema H. 1986. Animal Husbandry in the Tropics, Economic Meaning and Ability. Yayasan Obor Indonesia and PT Gramedia, Jakarta. [Indonesian]

ILRI [International Livestock Research Institute]. 1995. Global Agenda for Livestock Research. Proceedings of the Consultation for the South-East Asia Region. 10-13 May 1995 IRRI, Los Banos, The Philippines.

Jarrige JF. 2006. Mehrgarh Neolithic. Proceedings of the International Seminar on the "First Farmers in Global Perspective", Lucknow, India, 18-20 January 2006.

Jha DN. 2002. The Myth of the Holy Cow. Verso, London.

Johari S, Kurnianto E, Sutopo, Aminah S. 2007. Diversity of blood protein as biogenetic parameter in Java cattle. J Indon Trop Anim Agric 32 (2): 112-118. [Indonesian]

Kern H. 1910. Een woord in 'Sanskrit opschrift van Toegoe verbeterd. TBG 52: 123.

Keyes CF. 1995.The Golden Peninsula: Culture and Adaptation in Mainland Southeast Asia. SHAPS Library of Asian Studies, University of Hawai'i Press, Honolulu.

Khasrad, Ningrat RWS. 2010. Improving carcass quality of indigenous cattle of West Sumatera fed local feed resources. Pakistan J Nutr 9 (8): 822-826.

Kikkawa Y, Amano T, Suzuki H, 1995: Analysis of genetic diversity of domestic cattle in East and Southeast Asia in terms of variations in restriction sites and sequences of mitochondrial DNA. Biochem Genet 33 51-60.

Kikkawa Y, Takada T, Sutopo, Nomura K, Namikawa T, Yonekawa H, Amano T. 2003. Phylogenies using mtDNA and SRY provide evidence for male-mediated introgession in Asian domestic cattle. Anim Genet 34 96-101.

Lenstra JA, Bradley DG. 1999. Systematics and phylogeny of cattle. In: Fries R, Ruvinsky A (eds) The Genetics of Cattle. CAB International, Wallingford.

Lenstra JA, Theunissen B, Felius M. 2014. Domestic cattle and buffaloes. In: Melletti M, Burton J (eds). Ecology, Evolution and Behaviour of Wild Cattle: Implications for Conservation. Cambridge University Press, Cambridge, UK.

Lestari CMS. 2012. Exploration Potential of Jabres Cattle Production, as Local Beef with Method of In vivo and Non-invasive to the In situ and Ex situ Maintenance. [Ph.D. Dissertation]. School of Graduates, University of Diponegoro, Semarang. [Indonesian]

Lodrick DO. 2005. Symbol and sustenance: Cattle in South Asian culture. Dialectical Anthropol 29 (1): 61-84.

Long JA. 2008. Reproductive biotechnology and gene mapping: Tools for conserving rare breeds of livestock. Reprod Dom Anim 43: 83-88.

Lukas H. 2001. Theories of Indianisation exemplified by selected case studies from Indonesia (Insular Southeast Asia). Proceedings of Papers. "Sanskrit in Southeast Asia: The Harmonizing Factor of Cultures", International Sanskrit Conference, May 21-23, 2001. Sanskrit Studies Centre and Department of Oriental Languages, Silpakorn University (Mahachulalongkornrajavidyalaya Press), Bangkok.

Machovina B. 2015. The number thing each of us can do to protect biodiversity: Reducing our consumption of animal products can go a long way toward conserving endangered habitat around the world. http://ensia.com/voices/the-number-one-thing-each-of-us-can-do-to-protect-biodiversity/

MacHugh D.E. 1996. Molecular biogeography and genetic structure of domesticated cattle [Theses]. Department of Genetics.Trinity College, Univ. Dublin, Dublin.

Mahbubi A. 2014. Madura development program as a cattle island; perspective of sustainable cattle supply chain management. Agronomika 3 (2): 98-109. [Indonesian]

Martojo H. 2003. Indigenous Bali Cattle: The Best Suited Cattle Breed for Sustainable Small Farms in Indonesia. Laboratory of Animal Breeding and Genetics, Faculty of Animal Science, Bogor Agricultural University, Bogor. [Indonesian]

Martojo H. 2012. Indigenous Bali Cattle is Most Suitable for Sustainable Small Farming in Indonesia. Reprod Domest Anim 47: 10-14.

Mason IL. 1988. World Dictionary of Livestock Breeds. 3rd edn. CAB International; Wallingford, CT, USA.

McCool C, 1992: Buffalo and Bali cattle-exploiting their reproductive behaviour and physiology. Trop Anim Health Prod 24: 165-172.

Merkens J. 1926. De Paarden en Runderteelt in Nederlandsch Indie. Veeartseijkundige Mededeeling. No. 51. Landsdrukkerij-Weltevreden, Nederland.

Mintert J, Schroeder TC, Marsh T. 2016. Factors Affecting Beef Demand. Kansas State University, Manhattan, KS

Mohamad K, Olsson M, Andersson G, Purwantara B, van Tol HTA, Rodriguez-Martinez H, Colenbrander B, Lenstra JA. 2012, The Origin of Indonesian Cattle and Conservation Genetics of the Bali Cattle. Breed Reprod Domest Anim 47: 18-20.

Mohamad K, Olsson M, van Tol HTA, Mikko S, Vlamings BH,

Andersson G, Rodriguez-Martinez H, Purwantara BE, Paling RW, Colenbrander B, Lenstra JA. 2009. On the origin of Indonesian cattle. PLoS ONE 4 (5): e5490. http://doi.org/b65mtp

Namikawa T. 1981. Geographic distribution of bovine Hemoglobin-beta (Hbb) alleles and the phylogenetic analysis of the cattle in Eastern Asia. Z Tierzuchtg Zuchtgsbiol 98 151-159.

Ngadiono N. 1995. Growth and Qualities of Carcass and Beef of Sumba Ongole, Brahman Cross and the Australian Commercial Cross intensively reared at Various Cut Weight. [Ph.D. Dissertation]. Institut Pertanian Bogor, Bogor. [Indonesian]

Nijman IJ, Otsen M, Verkaar E.L.C, Ruijter C.D, Hanekamp E et al. 2003. Hybridization of banteng (*Bos javanicus*) and zebu (*Bos indicus*) revealed by mitochondrial DNA, satellite DNA, AFLP and microsatellites. Heredity 90: 10-16.

Noor RR. 2004. Genetics of Livestock. Penebar Swadaya, Jakarta.

Norton M. 2003. Factors affecting beef and cattle producer prices movements. Monthly Labor Review May 2005: 32-40.

OECD. 2016. Meat Consumption (indicator). Organization for Economic Co-operation and Development. doi: 10.1787/fa290fd0-en

Office of Agriculture and Horticulture, Livestock and Plantation South Pesisir District. 2012. Report of the Office of Agriculture, Horticulture, Plantation and Animal Husbandry (Dipertahorbunnak), South Pesisir District, Painan. [Indonesian]

Office of Veterinary East Sumba District. 1989. Development Program of Sub-sector Livestock. Kabupaten Daerah Tingkat II Sumba Timur, Waingapu. [Indonesian]

Okumura T, Saito K, Sakuma H, Nade T, Nakayama S, Fujita K, Kawamura T. 2007. Intramuscular fat deposition in principal muscles from twenty-four to thirty months of age using identical twins of Japanese Black steers. J Anim Sci 85 (8): 1902-1907.

Omerling FJ. 1957. The Timor Problem. A Geographical Interpretation of an Underdeveloped.Island. 2nd ed. J.B. Wolters, Groningen, Netherlands.

Pamungkas D, Antari R, Mayberry DE, Poppi DP. 2012. A Growth Comparison of Ongole and European Cross Cattle kept by Smallholder Farmers in Indonesia. Proceeding of the The 15th Asian-Australian Animal Production (AAAP) Congress, Bangkok, Thailand, November 2012.

Pane I. 1991.Produktivity and Breeding of Bali Cattle.Faculty of Animal Science, University of Hasanuddin, Ujung Pandang. [Indonesian]

Parkvall M. 2010. *Bos primigenius*, aurochs, Skånes djurpark, Höör, Sweden.

Payne WJA, Hodges J. 1997. Tropical Cattle: Origin, Breeding and Breeding Policies. Blackwell Science, Oxford, UK,

Payne WJA, Rollinson DHL. 1973. Bali cattle. World Anim Rev 7: 13-21.

Payne WJA. 1970. Cattle Production in the Tropics. Logman, London.

Permentan [Regulation of the Minister of Agriculture] No. 35/Permentan/OT.140/7/2011 on Animal Control of Female Productive Ruminant. [Indonesian]

PNRI. 2014. Temple Literature: Sukuh (Central Java). Perpustakaan Nasional Republik Indonesia, Jakarta [Indonesian]

Poerbatjaraka RMNg. 1952. Indonesia History I. Jambatan, Jakarta. [Indonesian]

Poesponegoro MD, Notosusanto N. 2010. Indonesia's National History II: Ancient Times. Balai Pustaka, Jakarta [Indonesian]

Pudyatmoko S. 2004. Does the Banteng (*Bos javanicus*) have a future in Java? Challenges of the conservation of a large herbivore in a densely populated island. Knowledge Marketplace Reports. The 3rd IUCN World Conservation Congress, Bangkok.

Purvis G, Downey L, Beever D, Doherty ML, Monahan FJ, Sheridan H, McMahon BJ. 2011. Development of a Sustainably-Competitive Agriculture. In: Lichtfouse E (ed.) Agroecology and Strategies for Climate Change: Sustainable Agriculture Reviews Volume 8. Springer, Netherlands.

Putro P. 2009.Crossbreeding Impact on the Reproduction of Parent Offspring, Clinical Study Results. Workshop on Crossbreeding Cattle in Indonesia: Applications and Implications for Development of Cattle in Indonesia, Lustrum VIII, Faculty of Animal Science, Gadjah Mada University, Yogyakarta 8 August 2009. [Indonesian]

Pyle CM. 1995. Update to: Some late sixteenth-century depictions of the aurochs (*Bos primigenius* Bojanus, extinct 1627): New evidence from Vatican MS Urb. Lat. 276. Arch Nat Hist 22 (3): 437-438

Qiu Q, Zhang G, Ma T, Qian W, Wang J et al. 2012. The yak genome and adaptation to life at high altitude. Nat Genet 44: 946-949.

Rajab. 2009. The Study on Development of Bali Cattle Breeding in Raja Ampat, West Papua Province. [M.Sc. Thesis]. Bogor Agricultural University, Bogor. [Indonesian]

Republika.co.id. 14/01/2016. Western Java Shortage of Land for Animal Feed. http://nasional.republika.co.id/berita/nasional/daerah/16/01/14/o0xwq3370-jabar-kekurangan-lahan-pakan-ternak [Indonesian]

Rohman MN, Hayati R. 2015. Analysis of Population Pressure of Agriculture in Central Java Province in 2020. Geo Image 4 (1): 1-8. [Indonesian]

Rokosz M. 1995. History of the Aurochs (*Bos taurus primigenius*) in Poland. Anim Genet Resour Inform 16: 5-12.

Ruspoli M. 1983. The Cave of Lascaux: The Final Photographic Record. Abrams, New York.

Sa'adah N. 2013. Cattle Ranch Development Planning in Kebar District, West Papua using Map Manager Land Use. [M.Sc. Thesis]. Bogor Agricultural University, Bogor. [Indonesian]

Saiya HV. 2013. Acclimatization of Ongole Crossbred and Bali cattle in Response to Weather Changes in Merauke Papua. [M.Sc. Thesis]. Bogor Agricultural University, Bogor. [Indonesian]

Saladin R. 1983. The Performance of Production and Reproduction Characteristics of South Pesisir Local Cattle of West Sumatra. [Ph.D. Dissertation]. School of Graduates. Bogor Agricultural University, Bogor. [Indonesian]

Samad MS, Soeradji.1990. General Animal Husbandry. CV. Yasaguna. Jakarta. [Indonesian]

Santoso T. 2012. Design of Land Development Model based on Agro-silvopasture in Lebong District. [M.Sc. Thesis]. Faculty of Forestry, Gadjah Mada University, Yogyakarta. [Indonesian]

Sarbaini. 2004. Study on Diversity of External Characteristics and DNA Microsatellite of Pesisir cattle, West Sumatra. [Ph.D. Dissertation]. School of Graduates, Bogor Agricultural University, Bogor. [Indonesian]

Sariubang M. 1992. Feedloting system of Grati cattle.Sub Research Center for Animal Production Grati, Pasuruan. [Indonesian]

Siregar SB. 1996. Maintenance of Dairy Cow Lactation in Lowlands areas. Center for Agricultural Research and Development, Ministry of Agriculture, Bogor. [Indonesian]

Siswijono SB, Subagiyo I, Nurgiartiningsih VMA, Kusmartono, Hartutik, Tadjuddin. 2010. Perception of Madurese community on crossbreeding program of Limousin and native Madura beef cattle in Madura Island of Indonesia. 9th World Congress on Genetics Applied to Livestock Production, Leipzig, Germany, August 1-6, 2010

Sodhi M, Mukesh M, Prakash B, Ahlawat SPS, Sobti RC. 2006. Microsatellite DNA typing for assessment of genetic variability in Tharparkar breed of Indian zebu (*Bos indicus*) cattle, a major breed of Rajasthan. Genetics 85: 165-170.

Soedono A. 1983. Developments Large Ruminant based on Dairy Cattle Breeding Science in Indonesia. Proceedings of the Scientific Meeting of Large Ruminant. Cisarua, 6-9 December 1982. Livestock Research and Development Center, Bogor. [Indonesian]

Soehadji. 2009. History of Dairy Industry Development. Directorate General of Agro and Chemical Industry, Ministry of Industry, Jakarta. [Indonesian]

Soejosopoetro B. 2011. The study of productive female cattle slaughter in Malang slaughterhouse. Jurnal Ternak Tropika 12 (1): 22-26. [Indonesian]

Soekmono. 1976. Chandi Borobudur: A Monument of Mankind. UNESCO Press, Paris.

Soltief MS. 2009. The Study on Beef Cattle Region in Raja Ampat, West Papua Province. [M.Sc. Thesis]. Bogor Agricultural University, Bogor. [Indonesian]

Sonbait LY, Santosa KA, Panjono. 2011. Evaluation of cattle sharinglopment of cattle farming for the farmer groups under self-rooted institutions in the community of Manokwari District, West Papua. Buletin Peternakan 35 (3): 208-217. [Indonesian]

Steinmetz, R. 2004. Gaur (*Bos gaurus*) and banteng (*B. javanicus*) in the lowland forest mosaic of Xe Pian Protected Area, Lao P.D.R.: abundance, habitat use, and conservation. Mammalia 68: 141-157.

Sudono A, Rosdiana F, Setiawan BS. 2003. Intensive Dairy Cattle Farming. Agromedia Pustaka. Jakarta. [Indonesian]

Sullivan GM, Diwyanto K. 2007. A Value Chain Assessment of the Livestock Sector in Indonesia.United States Agency for International Development, Washington DC.

Susilawati T, Subagyo I, Budiarto A, Ciptadi G, Kuswati. 2002. Phenotype and Genotype Identification of Local Breed for Conservation and Improvement Strategies of Local Cattle Production

in East Java. Faculty of Animal Husbandry, Brawijaya University, Malang and Office of Livestock Production, East Java Province, Surabaya. [Indonesian]

Susilawati T. 2004. Local Cattle of Indonesia.[Research Report]. Faculty of Animal Husbandry, Brawijaya University, Malang. [Indonesian]

Sutarno R. 1997. Various Ancient Temple in Indonesia. Dhahara Prize. Semarang. [Indonesian]

Sutarno, Setyawan AD. 2015. Genetic diversity of local and exotic cattle and their crossbreeding impact on the quality of Indonesian cattle. Biodiversitas 16 (2): 327-354

Sutarno. 2010. Genetic variation among Indonesian native cattle breeds based on polymorphisms analysis in the growth hormone loci and mitochondrial DNA. Biodiversitas 11: 1-5.

Syarif EK, Harianto B. 2011. Farming and Business of Dairy Cattle. AgroMedia Pustaka, Jakarta. [Indonesian]

Talib C, Entwistle K, Siregar A, Budiarti-Turner S, Lindsay D. 2002. Survey of population and production dynamics of Bali cattle and existing breeding programs in Indonesia. In: Proceeding of an ACIAR Workshop on Strategies to Improve Bali Cattle in Eastern Indonesia, Denpasar, Bali, Indonesia.

Tanjung FN. 2015. Analysis of beef cattle integration with Cocoa plants. [Hon. Thesis]. Andalas University, Padang. [Indonesian]

Tenaya IWM. 2010. Studies of the pathogenesis of Jembrana disease virus infection in *Bos javanicus* [Ph.D. Dissertation]. Murdoch University, Perth, Australia.

Timmins RJ, Hedges S, Duckworth JW. 2008. Bos sauveli. The IUCN Red List of Threatened Species 2008: e.T2890A9491262. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T2890A9491262.en.

Toelihere MR. 1981. Artificial Insemination in Livestock. P.T. Angkasa, Bandung. [Indonesian]

Tun Yin U. 1967.Wild Animals of Burma. Burma Forest Dept., Rangoon.

Turner HL. 1977. The Tropical Adaptation of Beef Cattle an Australian Study. In: Animal Breeding: Selected Articles from The World Animal Review. FAO Animal Production and Health Paper 1: 92-97.

Umar S. 2009. Potential of Oil Palm Plantations for Development Centre of Beef Cattle in Revitalizes and Accelerate Sustainable Development of Animal Husbandry. Inauguration of Professorship speech in the field of Animal Reproduction Science, Faculty of Agriculture, University of North Sumatra, Medan. [Indonesian]

Urbain A. 1937. Le kou-prey ou bœuf gris cambodgien. Bulletin de la Société Zoologique de France 62 (5): 305-307.

Utomo B, Oelviani R, Subiharta. 2015. Enhancing perfomance of weaned Ongole calf through management improvement using local resources. Pros Sem Nas Masy Biodiv Indon 1: 838-842. [Indonesian]

Uzzaman MR, Bhuiyan MSA, Edea Z, Kim KS. 2004. Semi-domesticated and Irreplaceable Genetic Resource Gayal (*Bos frontalis*) Needs Effective Genetic Conservation in Bangladesh: A Review. Asian Austr J Anim Sci 27 (9): 1368-1372

Van Vuure C. 2001. Retracing the Aurochs. Universität Paderborn, Höxter, Germany.

Verkaar ELC, Nijman IJ, Boutaga K, Lenstra JA. 2002. Differentiation of cattle species in beef by PCR-RFLP of mitochondrial and satellite DNA. Meat Sci. 60: 365-369.

Verkaar ELC, Vervaecke H, Roden C, Mendoza LR, Barwegen MW, Susilawati T, Nijman IJ, Lenstra JA. 2003. Paternally inher- ited markers in bovine hybrid populations. Heredity 91: 565-569.

Vigne JD. The origins of animal domestication and husbandry: A major change in the history of humanity and the biosphere. C R Biol 334: 171-181.

Vogel JP. 1918. The Yupa Inscriptions of King Mulavarman from Koetei (East Borneo). BKI 74: 167-232

Wharton, C. H. 1957. An ecological study of the kouprey, *Novibos sauveli*. Institute Science Technology, Manila, Monograph 5: 1-111.

Wheatley P. 1975. Satyānrta in Suvarṇadvīpa: From Reciprocity to Redistribution in Ancient Southeast Asia. In: Sabloff J, Lamberg-Karlovsky CC (eds.) Ancient Civilisation and Trade. University of New Mexico Press, Albuquerque.

Williamson G, Payne WJA. 1980. An introduction to animal husbandry in the tropics. Tata McGrow-Hill Pub.Co.Ltd, New Delhi, India.

Wirdahayati RB. 1994. Reproductive characteristics and productivity of Bali and Ongole cattle in Nusa Tenggara, Indonesia. [Ph.D. Dissertation]. Depatment of Farm Ainmal Medicine and Production. University of Queensland, Brisbane, Australia.

Wirdateti, Semiadi G, Kurniati H, Dahruddin H, Fitriana YS. 2012. Integration Development of Cattle at Palm Oil Plantation in East Kalimantan. Research Center for Biology, Indonesian Institute of Sciences, Bogor. [Indonesian]

Wiyatna MF, Gurnadi E, Mudikdjo K. 2012. Productivity of Peranakan Ongole cattle on the community husbanry in Sumedang District. Jurnal Ilmu Peternakan 12 (2): 22-25. [Indonesian]

Wuryanta A, Susanti PD. 2015. Spatial analysis of population pressure on agricultural land in Keduang Sub-Watershed, Wonogiri District, Central Java. Jurnal Penelitian Sosial dan Ekonomi Kehutanan 12 (3): 149-162. [Indonesian]

Yulianto P, Saparinto C. 2010. Intensive Beef Cattle Fattening. Penebar Swadaya, Jakarta. [Indonesian]

Zeder MA, Emshwiller E, Smith BD, Bradley DG. 2006. Documenting domestication: The intersection of genetics and archaeology. Trends Genet 22: 139-155.