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Assessment of the feasibility of goat keeping in the indigenous Penan community of Long Lamai (Sarawak, Malaysia)

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

AEZ	Agro-ecological zone
AGB	Aboveground biomass
ASEAN	Association of Southeast Asian Nations
CBBP	Community-based breeding program
CF	Crude fiber
CLA	Caseous Lymphadenitis
CP	Crude protein
DCP	Digestible crude protein
DM	Dry matter
DOA	Department of Agriculture Sarawak
FEC	Faecal egg-count
FECRT	Faecal egg count reduction test
GE	Gross energy
HS	Hemorrhagic septicemia
ME	Metabolizable energy
PPP	Penan Peace Park
SE-Asia	Southeast Asia

1. Introduction

Sarawak, the largest federal state of Malaysia and situated in the north-west of Borneo, is anthroposphere and home of 2.4 Million people. About a half of Sarawak's population is indigenous and represented by roughly 30 different cultures and languages, *inter alia* the Eastern and Western Penan [WEISSHAIDINGER ET AL., 2012]. In 2010 Sarawak's Penan population was estimated to be approx. 16.000 people of whom about 77 % have settled down permanently, remaining 20 % are seminomadic, while 3 % are still nomadic [LYNDON ET AL., 2013].

The Penan, originally a folk of nomadic hunter-gatherers and followers of the Animism were not permitted to keep livestock by virtue of the principles of their religious persuasion. Additionally, their nomadic way of life did not enable the Penan to rear livestock so as to contribute to the extension of their perpetual source of food. Due to British missionaries, the Penan converted to Christianity in most instances, however, maintained several characteristics of Animism.

The community of Long Lamai, a village of the Eastern Penan, located in the upper reaches of Sarawak's Baram River basin with a population of nowadays approx. 600 people, were the first major settlement of Penan in the Upper Baram region roughly 60 years ago [FIBL 2012]. The settlement of the Penan of Long Lamai came along with the cultivation of crops to extend their food diversity, mainly rice cultivation. They learned the basics on agriculture, mostly from British colonial servants. Notwithstanding of the conversion to Christianity, keeping livestock was still incompatible with the vestiges of the Animism.

In the course of time, hunting became more difficult as a result of the loss of hunting skills and the increasing avoidance of the proximity by the prey.

In 2014 a co-operation of Keruan, a local Penan self-help organization, the Research Institute of Organic Agriculture (FiBL Austria) and the Bruno Manser Fund (Switzerland) started a project with the focus on "Sustainable agriculture and resource management in the Upper Baram Area" (SARM). Main objective is to develop a catalogue of measures for sustaining agricultural practices in the long-run mainly to permit subsistence of livelihood and at the same time the conservation of natural resources (viz. primary forests, soil, water, biodiversity). The project´s aims correspond also with the objectives of the Penan Peace Park (PPP). The PPP is a proposal of 18 Penan villages of the Upper Baram region to preserve their anthroposphere and fulfill the responsibilities of their cultural and territorial heritage. The PPP aims, *inter alia*, at the promotion of sustainable management of agricultural land [PENAN PEACE PARK PROPOSAL 2012-2016]. In 2016 other ethnic communities were included and the initiative renamed into "Taman Damai Baram / Eco-Community Park".

By reasons of decreasing hunting success and increasing demand for protein of animal origin and approachability towards livestock keeping, members of the community of Long Lamai expressed an interest in continuing their previous project discussions regarding the introduction of goats as a livestock component in their developing agricultural system.

The Penan of Long Lamai are mainly interested in goat keeping because of meat production for consumption and marketing in nearby markets. Against the backdrop of missing experience and knowledge due to the cultural ban of animal husbandry, the Penan of Long Lamai face a completely new situation. Therefore, a feasibility study to assess different aspects of goat keeping, advantages and possible disadvantages, as well as challenges of such a new branch of production is needed.

Hence, the purpose of this master thesis is the assessment of the feasibility of goat keeping in Long Lamai in consideration of all significant aspects of animal husbandry. Based on the findings, recommendations will be provided to the community of Long Lamai and the SARM project concerning the suitability of goats in this region.

Thus, this master thesis builds the base for prospective extension of agricultural practices, the implementation of ruminant livestock and enhancement of agricultural knowledge to enable the community of Long Lamai to extend their perpetual source of income and food diversity.

2. Research questions

The aim of this study is to investigate the feasibility of introducing goat keeping in Long Lamai considering of all important aspects of animal husbandry. Therefore, the following research questions have been formulated:

1. Is goat production under the current circumstances feasible and to which extent concerning number of animals and production goals of the community members?

2. What are the ecological, economic and social requirements that have to be met for a sustainable introduction of goats in Long Lamai?

3. What kind of technical and financial external support is needed over which time period to support the establishment of a sustainable goat production?

3. Literature review

3.1 Animal Production Systems

Extensive literature regarding farming systems of the world indicate that animal production systems are determined by agro-ecological zones (AEZ) through prevailing climatic, edaphic and biotic conditions, mostly as a consequence of the influence on qualitative and quantitative parameters of feed resources. The interactions between crops/feed resources and livestock affect the feasibility and efficiency of an animal production system [DUCKHAM AND MASEFIELD, 1970; SPALDING, 1979; DEVENDRA AND THOMAS, 2002] (Table1). Therefore, the current ruminant production systems in South-East Asia (SE-Asia) have emerged, especially as a response to the availability of land and the extent and intensity of crop production, from the agro-ecological zones, notably the sub-humid and humid tropics.

Several international meetings and scientific papers [BOUWMAN ET AL., 2005; DEVENDRA, 1986a; DEVENDRA AND THOMAS, 2002; KOSGEY ET AL., 2008; STEINFELD ET AL., 2006; VAN EYS ET AL., 1986] have copiously discussed small ruminant production systems in tropical regions and classified them into three categories, as described in some detail below:

1) Extensive production systems
2) Systems combining arable cropping and animal production
    i) Roadside, communal and arable grazing systems
    ii) Tether-grazing
    iii) Cut-and-Carry feeding systems
3) Systems integrated with tree cropping

3.1.1 Extensive production systems

Extensive unrestricted grazing is commonly practiced where land is not necessarily appropriate for agricultural cultivation or too costly. Usually unproductive native grasslands, fallows and marginal land are used, which are unable to support crop production [DEVENDRA, 1993a; DEVENDRA AND MAHADEVAN, 1986].

This extensive form of animal production applies to all types of ruminants in the Asian region, but is generally dominated by small ruminants, usually owned by smallholder farmers. With regard to goat production, this system is used for meat or hair goats rather than for dairy goats [AGROMISA, 2015]. Furthermore, the extensive system is declared as a system of low resource use and low productivity, by reasons of low labor input, low costs and inadequate nutritional management. The system does not or only to a very limited extent provides additional feed and nutritive substances by the use of concentrates, mineral licks or other supplementation [DEVENDRA, 1993a; MCMILLIN ET AL., 2012]. The animals graze during daytime and they are locked in sheds or yards at night to shelter them from predators or thieves.

The flock sizes of extensive systems tend to be relatively high, based on the low labor demand and the relatively high returns of this production system in reference to the input. Flock sizes in Asian regions are often up to 15 heads and the stocking rates usually vary between one and four heads per hectare [DEVENDRA, 1993a; GALL, 1981].

The extensively managed small ruminant system is probably the most common production system in developing countries, though it is more prevalent in arid and semi-arid regions. In sub-humid and humid zones small ruminants are kept under more controlled conditions during the day, as, for instance, tethering or stall feeding. Presumably, due to climatic conditions, the use of most of the land for food production and the availability of more forage and crop residues, highly intensive production systems are rare in the humid tropics [AGROMISA, 2015; DEVENDRA, 1993a; MCMILLIN ET AL., 2012; SUMBERG AND MACK, 1985]

In Malaysia, extensive production is mainly practiced by farmers along the coastal plain, but more than 59 % of them do not own land and only a few plant improved pastures for grazing purposes [Chee and Peng, 2006].

Rogosic et al. [2006] determine the possibility of browsing as a characteristic feature of extensive production systems and report that goats will eat about 50.5 g DM per kg body weight of shrubs per day.

3.1.2 Systems combining arable cropping and animal production

The three systems, which combine animal production with arable cropping, are not mutually exclusive, as, for instance, grazing on roadsides, when land is under arable crop cultivation.

3.1.2.1 Roadside, communal and arable grazing system

This system combines ruminants with arable cropping, frequently seen in paddy and annual cropping areas and involves inter alia grazing in rice fields, restrained to periods forthwith after harvest, when the available feed resources consist of the aftermath of the rice crop (e.g. rice stubble, grasses on paddy bunds, weeds growing in the paddy). Stubble grazing may be sternly restricted or non-existent, if multiple cropping is practiced and the aftermath may be burnt after harvest. An advantageous effect is the possibility to supplement the diet of the ruminants and facilitate their selective feeding to overcome dietary deficiencies [AGROMISA, 2015; DEVENDRA, 1986a; CHEE AND PENG, 2006].

3.1.2.2 Tether-grazing

Tethering is commonly practiced and adopted to areas of intensive cropping, when there is a need to prevent the animals to wander and damage areas, which are being cropped. The animals are tethered with a rope on rice fields after harvest to regulate stubble grazing, browse along roadsides and adjacent forests, on waste grazing areas close to the farm or on fallows to utilize the native grasses [DEVENDRA, 1993a; DEVENDRA ET AL., 1997 DEVENDRA AND SEVILLA, 2002; SHRESTHA 2012, CHEE AND PENG, 2012].

To supply qualitatively and quantitatively appropriate grasses and leaves it is essential to move the animals frequently to new grazing areas, at least once a day, to ensure a good and sufficient nutrition and to avoid that the animals are forced to feed on weeds, which contain anti-nutritive compounds and may even be potentially toxic.

Basically, tethering is merely practicable for small herds, and only the mature animals are tied, while the juvenile animals are often let loose. Supplements or concentrates are provided sporadically. Animals graze by day and are housed at night. Due to the little amount of work involved if herds are small, tethering is a system of low labor demand.

Because of the widespread multiple cropping, this type of confinement feeding is most popular in SE-Asia. For instance, tethering is common in the scattered crop lands and roadsides of Sumatra, Kalimantan, as well as Java and in the outer islands of Indonesia [AGROMISA, 2015; CHANIAGO, 1993; DEVENDRA, 1993a; DEVENDRA AND SEVILLA, 2002; MCMILLIN ET AL., 2012].

3.1.3 Cut-and-Carry feeding systems

In the cut-and-carry feeding system, also noted as stall-/hand-feeding or zero-grazing, the animals are fed in confinement with limited access to land. Feedstuffs, as for example cultivated grass, by-products or leaves, are usually brought in from the area of holding. The animals are typically kept inside all the time, possible exceptions could be mating, bathing or medical treatments. Seasonal abundance and shortages of feed characterize this system.

Hand-feeding is generally found in areas of high intensive cropping and high population densities, where space for grazing is limited or crops are vulnerable to damage through grazing, though crop residues, by-products or other feedstuffs are available in sufficient amounts.

The performance and body condition of animals raised in this system is generally better than of animals tethered or scavenging, due to the fact that the system usually provides better quality and quantity of feed. Furthermore, it provides maximum protection from uncontrolled environmental factors and the health of animals can be monitored more easily by the farmer. The permanent housing of the animals is well-suited to productive animals (e.g. improved dairy goats), exotic breeds and their crosses, which are more susceptible to diseases and enables to control the potentially destructive aspects of the goats' feeding habits. Nonetheless, a cut-and-carry feeding system demands high labor and capital input to meet the animals' requirements. The quality and the amount of feed offered to the animal have to be sufficient and entirely depend on the farmers' capability and knowledge about appropriate feed. [AGROMISA, 2015; CHANIAGO, 1993; DEVENDRA, 1993a; HARYANTO AND DJAJANEGARA, 1993; MCMILLIN ET AL., 2012]. Zero-grazing is commonly practiced on intensively-cropped small farms in SE-Asia and the highlands of South-Asia. In Indonesia, especially on Java, small numbers of animals (2-3 head/farm) are kept in semi-intensive or cut-and-carry feeding systems as a consequence of the limited availability of land. However, the higher capital and labor input of stall-feeding in comparison to other production systems may lead to an avoidance of the system in large parts of SE-Asia [Devendra, 1993a; Devendra et al., 1997; Devendra et al., 2000].

3.1.4 Systems integrating tree cropping

Perennial tree crops, as, for instance rubber, palm oil or coconut, provide momentous opportunities for the integration of animal production with cropping, where ruminants graze the understory of the native vegetation or leguminous cover crops. The integration of ruminants with perennial tree crops in SE-Asia has been associated with several advantageous side-effects, inter alia increased soil fertility through the return of dung and urine, control of weed herbage growth and as a consequence reduced use of herbicides, increased crop yields and further socio-economic benefits to small farmers. Furthermore, the trees provide shade, which results in reduced heat stress for the ruminants, presupposed that suitable pasture species are found to grow under conditions of reduced light [Chen and Harun, 1994; Devendra, 1993a; Devendra, 2005; Devendra and Thomas, 2002].

Animal production integrated with tree cropping is especially common in sub-humid and humid regions. In the ASEAN (Association of Southeast Asian Nations) sub-regions, in particular Malaysia, Indonesia (Sumatra, Kalimantan, Sulawesi), and the Philippines, it is of great importance and one of the major crop-animal systems. The integration of animal production with perennial tree cropping has a vast potential in SE-Asia, due to the fact, that an estimated area of about 210 million hectare is found under perennial tree crops. In Malaysia it is about 60 % of the total land area [Alexandratos, 1995; Devendra, 1991; Devendra et al., 1997 and 2000]. Merely a fractional part of the estimated area is used by animal production. For example, the oil palm plantations in Malaysia comprises an area of approx. 4.7 million hector, however, only 3 % of the land is used for the integration of livestock [Colchester et al., 2011; Devendra, 2015]. Chee and Peng [2006] observed an increase of the system practiced by both large plantation owners and smallholders.

3.1.5 The significance and implication of mixed farming systems

Feeding and nutrition, and thus the availability and efficient use of feeding resources, are the major restraints to maximize the productivity performance from animals throughout SE-Asia. The above-mentioned production systems, which integrate livestock with perennial and annual cropping, provide the opportunity to surmount these obstacles and to increase the animal performance [Devendra, 2007; Devendra et al., 1997; Devendra and Leng, 2011]. Small-scale, mixed farming systems – mainly rice-based systems – dominate and characterize the SE-Asian agriculture, though several other crops (e.g. cassava, maize, and perennial tree crops) are an alternative possibility and of certain importance alike. In the SE-Asian sub-region, both non-ruminants and ruminants are integrated into systems of annual and perennial crops. Nevertheless, at the small-holder level, ruminants are much more widespread than non-ruminants [DEVENDRA AND THOMAS, 2002; DEVENDRA ET AL., 1997]. DEVENDRA [1983A] and STEINFELD [1998] state that in this region more than 90 % of the total population of large and small ruminants are kept on mixed farms and 77 % of the ruminant meat is provided by mixed farming. The extent and efficiency of the integration with crop cultivation largely depends on the crops being grown and their importance for livestock. For instance, with regard to the integration of goats, in Fiji, 70 % of the goat population is found in sugar cane growing areas [DEVENDRA, 1978].

Mixed farming systems have several environmental benefits and provide opportunities to farmers to add value to crops or their by-products, to diversify risks from single-crop-cultivation and to use the labor input more efficiently. Especially, the maintenance of soil fertility and soil biodiversity as well as minimizing soil erosion and conserving water are vital environmental advantages [DE HAAN ET AL., 1997; DEVENDRA AND THOMAS, 2002].

Devendra [2007] outlines two categories of mixed farming crop-animal systems:

1. Systems combining animals and annual cropping. E.g. Maize-groundnut-goat (Indonesia)
2. Systems combining animals and perennial cropping. E.g. Oil palm-cattle (Malaysia)

3.1.6 Cropping strategies to overcome shortage of animal feed

Rain-fed lowland and upland farming areas in Asia struggle, in most instances, with the insufficient supply of animal feed over the entire year. As a consequence, the productivity is limited and feed scarcity within farms relatively often leads to overstocking of grazing areas, and thus to degradation. The availability of forages on smallholder mixed farms in Asia depends on the agro-ecological zone, size of farmland, cropping intensity, labor availability, tillage requirements and socioeconomic factors. The introduction of improved forage species (particularly legumes) for ruminants can promote the sustainability of the cropping systems [DEVENDRA ET AL., 1997, 2001; DEVENDRA AND SEVILLA, 2002].

Strategies to overcome the shortfalls of animal feed and to implement a sustainable all-year-round feeding system are as followed [DEVENDRA, 2000; Burgers et al., 2005]:

- Food-Feed cropping systems (e.g. cassava – cowpea)
- Inter-cropping with cereal crops (e.g. rice – Sesbania rostrata) (Table 3 Inter-cropping with mungbean and Siratro, DEVENDRA 2000)
- Relay-cropping
- Intensive use of available crop residues
- Forage production on rice bunds
- Alley cropping
- Crop-fallow rotations

3.1.6.1 Food-feed cropping systems

Food-feed cropping systems are associated with the cultivation of food and feed crops on farm and their harvest for human consumption, whereas the feed crop-derives (crop residues, by-products) are used as feed for livestock. Concepts of food-feed cropping systems include relay and inter-cropping of forage legumes or dual-purpose crops and the utilization of rice herbages. Advantageous effects of a food-feed cropping system are presented below (see Chapter 3.1.6.2). Additionally, food-feed cropping systems have the opportunity to incorporate the use of tree legumes with complementary advantages of forage production, fuel wood supply, role in fence line, and enrichment of soil fertility in the lowland and upland areas.

Requirements of an optimal food-feed cropping system is a cropping pattern wherein the feed crop provides many beneficial effects without competing for land, soil nutrients and water with the food crop. An example of such an efficient food-feed cropping system is the integrated dairy-cassava system with Cowpea or *Phaseolus calcaratus* (rice bean), where cassava hay can be produced as dairy feed [CHANTHAKOUN ET AL., 2008; DEVENDRA ET AL., 2001; WANAPAT, 1999, 2009; WANAPAT ET AL., 2000, 2006].

3.1.6.2 Inter-cropping with cereal crops

Food-feed inter-cropping, as a strategy to develop an all-year-round feeding system, has two essential advantages [DEVENDRA, 2000]:

- The increasing of forage production, improvement of soil fertility and the enhancement of rice production through the introduction of forage legumes into the cropping system.
- Possible promotion of sustainable agriculture via the complementary roles of crops and animals.

An inter-cropping system with annual and perennial crops is crucial in permanently settled hilly regions, especially those with steeper slopes. The permanent cover, provided by perennial crops, can help to minimize soil erosion.

A case study in the lowlands of Pangasinan (Philippines) investigated the impact of the replacement of rice/fallow by rice/mung bean combined with inter-cropping with the forage legume Siratro (*Macroptilium atropurpureum),* therefor Siratro was introduced in the last two years of a six-year rice cropping period. The positive change of the rice yield is illustrated in Table 1.

Furthermore, the cattle, previously fed on rice straw, used Siratro forage together with rice bran and urea as feed resources and obtained improved nutrition [DEVENDRA, 1993a].

Table 1 Intercropping with mung bean and Siratro in Pangasinan, Philippines

Cropping System	Rice yield (mt/ha)	Mung bean yield (mt/ha)
Rice – fallow – rice	3.0	-
Rice – mung bean – rice	3.7	1 – 1.5
Rice – mung bean+Siratro - rice	4.5	1 – 1.5

Source: C .DEVENDRA, 1993.

3.1.6.3 Relay cropping

To extend the supply of feed throughout the year via relay cropping, a second crop is planted into the first harvest, e.g. the introduction of leguminous forages (groundnut or pigeon-pea) into a main crop of rice or wheat. In Bangladesh, for instance, rice-based systems are improved by the introduction of annual leguminous forages as relay crops [Devendra, 2000; Devendra et al., 2000, 2001].

3.1.6.4 Intensive use of available crop residues

The emphasis of the SE-Asian agriculture on food crop production induces an abundance of crop residues, such as straws of rice, corn, as well as vines of soybean or sweet potato, which are potentially useful and valuable as feed for ruminants. Therefore, the promotion of intensive use of crop residues should be a principal aim to improve feeding and nutrition of livestock [DEVENDRA, 1986a; HARYANTO AND DJAJANEGARA, 1993; LENG AND DEVENDRA, 1995].

3.1.6.5 Forage production on rice bunds

Planting of leguminous or improved grasses and shrubs along rice bunds to produce forage, e.g. *Sesbania rostrata* or *Paspalum conjugatum,* is an effective possibility to enhance the forage yield for animal consumption [DEVENDRA ET AL., 2001]. Approximately 5-10 % of the land rice area is made up of rice field bunds [VICTORIO AND MOOG, 1995] and can contribute significantly to high additional yields of green fodder (SINSINWAR, 1996]. TENGCO ET AL. [1990] indicated that the replacement of native grasses in bunds by forage legumes can improve the quality and quantity of available feeds without adversely affecting the rice yield.

3.1.6.6 Alley cropping

Alley cropping, also known as hedgerow inter-cropping, is an agroforestry practice in which arable crops are cultivated simultaneously with perennial, particularly leguminous trees or shrubs. Beneficial side-effects of alley cropping are the reduction of soil erosion, improved crop performance and decreasing utilization of chemical fertilizer. An example is the cultivation of *Leucaena leucocephala* or *Gliricidia sepium* with maize [KANG AND GUTTERIDGE, 1993].

3.1.6.7 Crop-fallow rotations

Forage legumes may be used as fallow species in a rotational system and provide a suitable feed source for integrated livestock. Households in Eastern Indonesia, for example, use *Leuceana leucocephala* in a rotational system with maize as a fallow species. The management of the cultivated fallow species can be practiced by both zero-grazing cut-and-carry methods and free roaming of ruminants. Though, free roaming of ruminants may result in overgrazing of the young fallow or soil compaction due to trampling. Furthermore, the establishment of a fenced-off grazing area is necessary in case of free roaming livestock. Nevertheless, integration of livestock with a crop-fallow rotation may increase the soil fertility due to the return of dung/urine and the beneficial effects of cultivated leguminous forages. In addition, it can be expected that the economic output increases through an improved production performance [BURGERS ET AL., 2005; METZNER; 1983]. Further advantages and constraints of the integration of livestock into a crop-fallow rotation are presented in Table 2:

Table 2 Some potential advantages and constraints of integrating livestock

	Advantages	*Constraints*
Productivity	• Improved productivity due to efficient nutrient cycle • Diversification of production • Intensification of production	• Grazing practices slow down fallow vegetation • Trampling may lead to soil compaction
Socio-economic	• Additional fertilizer in the form of manure • Supply of draft power • Cash income • Less dependent on good transport facilities • Additional food product	• Greater labor demands • Fencing and/or tethering needs • Relatively high initial capital investment
Environmental	• Reduced pressure on forest (if fenced) • Decreased burning frequency when fallow becomes fodderbank	• Decreased above-ground biodiversity • Below-ground biodiversity? • Loss of carbon stocks in permanent mixed crop-livestock systems

Source: BURGERS ET AL., (2005).

3.1.7 Feed supplementation

The purpose of feed supplementation is to provide additional nutrients to meet the requirements of animals of a certain physiological status and productive performance. The necessity to supplement certain nutrients or energy will depend on the actual conditions. Usually supplementation focuses on protein and energy, which are frequently limiting productivity of the animals. However, mineral and vitamin supplementation may be of similar importance.

In tropical regions, the nutritional supplementation of small ruminants is not often practiced due to the low availability of concentrate supplements and their high acquisition costs [HARYANTO AND DJAJANEGARA, 1993; SANCHEZ, 1991].

3.2 Feed resources in the humid tropics

The humid tropics of South-East Asia, such as the vast tropical rainforest of Borneo, are home to plentiful and various types of potential feed plants, which are mostly underutilized. Though, especially the availability and the efficient use of feed resources are the primary drivers of the performance to maximize the animal productivity in these regions. Therefore, it is inevitable to know the available feed resources and their potential and limits in the production system.

3.2.1 Feeding behavior of goats

Goats are essentially browsers, though equally well adapted to consume and utilize leaves, grass, forbs and shoots of shrubs, and thus regarded as browsers and grazers. They are classified as intermediate opportunistic feeders due to their possession of physiological, morphological and behavior characteristics. Goats tend to select more nutrient-dense diets consisting of shrub and tree foliage, whereas sheep and cattle may consume grass and roughage. Their versatile feeding habits and ease of adaptation to vegetation changes allow the goats - in comparison to other ruminants - to select and have a greater availability of native vegetation, especially in regions where quality and quantity of feed are low [DEVENDRA, 1987; DU PLESSIS ET AL., 2004; HOFMAN, 1989; LU, 1988; LU AND COLEMAN, 1984; MALECHEK AND PROVENZA, 1983]. DEVENDRA and BURNS [1983] presume that under such circumstances goats meet the basic nutrient requirements for body function better than other species of livestock.

3.2.2 Feed categories

To understand the efficient and potential use of available feed resources, Devendra and Leng [2011] mention the classification of feed into four categories:

I. Pastures – Including native and improved grasses, herbaceous legumes and multipurpose trees.
II. Crop residues – e.g. rice straw or sweet potato vines
III. Agro-industrial by-products (AIBP) – e.g. copra cake, molasses, soya bean meal
IV. Non-conventional feed resources (NCFR) – by definition refer to feeds that are not traditionally used in animal feeding, e.g. sugarcane bagasse or oil palm leaves palm press fiber

Apart from copra cake, as an AIBP, other agro-industrial by-products and NCFR's are not relevant as feed resource in Long Lamai. Therefore, no further information regarding AIBP and NCFR are provided below.

3.2.2.1 Pasture

<u>*Herbaceous Legumes & Legume Tree Foliage*</u>

The implementation of leguminous forages as feed supplements into the diet of goats may have significant effects on an improved animal performance. Especially, with regard to the provision of nutrients (particularly protein and fermentable nitrogen for efficient rumen functions), influence on increased dry matter intake, digestibility, the efficiency of feed conversion and the improvement of the rate of passage. In addition to their feeding value, leguminous forages provide further environmental benefits due to the control of soil erosion and the increase of soil fertility [Devendra and Sevilla, 2002; D´Mello and Devendra, 1995].

Several leguminous plants occur in humid tropical regions and provide an important basis of ruminant feed resources [Fadiyimu et al., 2012; Haryanto and Djajanegara, 1993; Ibrahim and jayatileka, 2000]:

- Examples of tree legumes in SE-Asia: *Leucaena leucocephala*, *Inga edulis* and *Gliricidia sepium*
- Examples of herbaceous legumes in SE-Asia: *Centrosema pubenscens*, *Pueraria phaseoloides* and groundnut (*Arachis hypogaea*)

Various studies indicate, that the above-mentioned tree legumes have a potential as livestock feed in tropical regions. Fadiyimu et al. [2012] analyzed the preference for selected multipurpose trees in Nigeria by West African Dwarf goats and concluded that *G. sepium, Leucaena leucocephala* and *I. edulis* are highly acceptable to ruminants fed in a cut-and-carry system (Table 3). Yet, gliricidia leaves disseminate an astringent odor and unpalatable secondary compounds, which may reduce the consumption by animals. Therefore, it is favorable to let the leaves wilt before feeding [MATHIUS ET AL., 1985; NITIS, 1986]. Sukanten et al. [1996] observed the performance of goats fed with grass, shrub and tree fodders during the dry season in Bali, Indonesia. The study resulted in the conclusion that goats fed grass supplemented with gliricidia foliage eat more forage, gain more live-weight and have a better carcass quality than those fed grass only. Though, investigations indicated that more than 30 % of gliricidia foliage in diets may reduce the cellulose digestion, therefore gliricidia foliage has to be limited to 30 % in the diet to obtain optimal growth of goats [HARYANTO AND JOHNSON, 1988]. Generally, it can be stated that too high amounts of tree legumes foliage or herbaceous legumes in the diet may have adverse effects on the goat's performance, as, for instance, a reduced digestible dry matter intake, due to anti-nutritional constituents [NAVAS-CAMACHO ET AL., 1993; NORTON, 1994a,b,c, RAVHUHALI ET AL., 2011, OLOGHOBO, 1989]

Table 3 Average preference index (API) values and ranking of MPT[1] species

Species	API	Rank
G. sepium	0.99	1
D. guineense	0.93	2
I. edulis	0.56	3
L. leucocephala	0.53	4
A. cordifolia	0.39	5
G. pubescens	0.27	6
X. xylocarpa	0.09	7
A. niopoides	0.03	8
A. santalinoides	0.02	9
P. africana	0.01	10
C. calothyrsus	0.005	11
M. thonningi	0.004	12
E. cyclocarpum	0.004	13
Mean	0.29	
S.E.M.[2]	0.34	

[1] *Multipurpose Tree* [2]Standard error of the mean

Source: Fadiyimu et al, 2014.

Multipurpose Trees

Multipurpose trees and shrubs are consciously grown and managed for more than merely one function. They may provide food, firewood, construction wood, shade, living fencing or nitrogen to the soil providing habitat. Aside from that, multipurpose fodder trees contribute valuable additional nutrients to the diet of goats [DEVENDRA, 1986b; SUKANTEN ET AL., 1996]. Even NITIS in 1989 illustrated the potential value of multipurpose trees and shrubs in small farming systems by his estimation with a dry matter yield of 7 kg/tree, and thus an annual production surplus of 150 t, if the agricultural land in Asia were planted with 230 multipurpose trees and shrubs per hectare. Studies of DJAJANEGARA ET

AL. [1982] highlighted the importance of non-leguminous fodder trees as an essential feed source in certain areas. Upland farmers in West Java used leaves of banana, cassava and jackfruit in shares of 72, 22 and 10 %, whereas merely 3 % of farmers in lowland areas used cassava leaves as forage for small ruminants (Table 4). Nevertheless, the usage of multipurpose tree species for human utilization and animal production may lead to conflicts of use due to an imbalanced and unsustainable management. GUARIGUATA ET AL. [2011] and HERRERO-JÁUREQUI ET AL. [2013] assessed and described the extent and possibilities of conflicts of use in multipurpose tropical forest trees.

cassava (*Manihot esculenta Cranzt*), an annual root crop, for instance, is widely grown in tropical and subtropical regions and is used as a readily fermentable energy (root) and protein (leaves) source in ruminant rations. However, due to condensed tannins, the intake and digestibility of cassava leaves is limited [REED ET AL., 1982; WANAPAT, 2009].

Other commonly used multipurpose trees in SE-Asia, besides the aforementioned, are inter alia coconut (*Cocos nucifera*), rambutan (*Nephelium lappaceum*), mango (*Mangifera indica L.*) and pineapple (*Ananas comosus L Merr.*) [DEVENDRA, 1988].

Table 4 Percentage of farmers feeding various forages to small ruminants in West Java

Forage	Lowland (in %)	Upland (in %)
Native grass	86	100
corn tops	2	70
Legume straw	1	32
Rice straw	0	13
Sesbania sp.	20	0
Artocarpus sp.	0	10
Banana leaves	0	72
Cassava leaves	3	22

Source: Djajanegara et al., 1982.

Native and Improved Grasses

In general, goats will prefer browse over grass, but, as a result of the partially limited utilization of leaves (condensed tannins, nutrient composition), a lack of knowledge concerning varieties of fodder sources, prevailing production systems and the abundant distribution, grasses are still a preferable feed source. Improved pastures generally include introduced pasture/grass species, are more productive than local native grasses and have higher contents of protein and metabolisable energy [CHEE AND WONG, 1985; MANNETJE, 1985].

A small overview about native forage grasses in Malaysia: *Axonopus compressus, Paspalum conjugatum, Ischaemum mutican, Ischaemum timorense, Ottochloa nodosa, Imperata cylindrica.*

Paspalum conjugatum, for instance, grows well under tree canopies (coconut, palm oil), on rice bunds and drains under cutting or grazing [YUSOFF ET AL., 1982].

Imperata cylindrica, a widely spread component of native pastures in South-East Asia and adaptable to infertile soils is usually considered to be a weed species of crops. In some cases, *Imperata cylindrica* is used for thatching purposes (e.g. Bali, Indonesia) [FALVEY, 1981]. Nevertheless, several studies, conducted in Malaysia [HUTAGALUNG, 1977], Indonesia [SOEWARDI AND SASTRAPIPRADJA, 1976], Thailand [FALVEY AND ANDREWS, 1979] and Papua New Guinea [BUNNING, 1975; HOLMES ET AL., 1976] stated that *Imperata* is an available and often underutilized feed resource in SE-Asia and may support ruminant production at low rates of live-weight gain.
A small overview about improved forages grasses in Malaysia: napier grass (*Pennisetum purpureum*), para grass (*Brachiaria mutica*), signal grass (*Brachiaria decumbens*), guinea grass (*Panicum maximum*), *Digitaria* species.

Napier grass, also known as elephant grass, is a high yielding, perennial grass, which can withstand drought better than most other grasses. Napier strips are relatively easy to establish and manage, also applicable as soil erosion control measure. Napier grass is often integrated in agroforestry systems to provide mulch and is recommended for zero-grazing due to its high biomass production (7,8 tons/ha/year) [AGROMISA, 2015; AGUS, 1994; MAGCALE-MACANDOG ET AL., 1998; MERCADO ET AL., 1996].
Another important grass species in SE-Asia, for both human and ruminant consumption is sugarcane (*Saccharum officinarum*). It is a tall perennial plant whose crop is mainly used for sugar and ethanol production. MUI ET AL. [2000] determined the feeding value of sugarcane for growing goats. A sugarcane proportion of 230 g/ kg of DM in diets of growing goats increases the feed efficiency and the body weight gain in comparison to diets with guinea grass.

<u>*Further Forages*</u>
The vast biodiversity of the humid tropical regions in SE-Asia provides several other valuable and nutritious feed sources. Among the abovementioned, ferns, such as *Stenochlaena palustris* and *Nephrolepsis biserrata* (giant swordfern) are potential fodder plants in South-East Asia. The giant swordfern is an aquatic, evergreen, perennial herb, which has no noticeable seasonal variation in the energy and moderately high crude protein (CP) content. The availability of Nephrolepsis throughout the year makes it suitable as a feed resource especially during the dry season [BABAYEMI ET AL., 2006].

3.2.2.2 Crop Residues
To improve the nutrition of goats in tropical regions, the efficient utilization of available feed resources, notably crop residues, is unavoidable. Devendra [1987] categorized crop residues on the basis of their nutrient potential and the priority of usage regarding animal species and production goals (Table 5). Especially in developing countries, fibrous crop residues (third category) are the basis of ruminant feeding systems. Rice production in SE-Asia provides the basis of human nutrition, and as

a consequence, rice straw is available in large amounts. It is estimated that approx. 1 kg of straw is produced for each kilogram of rice grain harvested [DEVENDRA, 1997]. Rice straw is a highly lignified material with a low nutritive value, therefore it is not suitable to provide sufficient nutrients to high producing goats. Furthermore, low rates of rumen degradation and low rates of passage through the rumen reduce the intake of rice straw by goats. Nevertheless, rice straw is an important feed resource in SE-Asia due to the high quantity and the economic benefits of its usage [DOYLE ET AL., 1986; HUE ET AL., 2003; SARNKLONG ET AL., 2010]. Crop residues of sweet potato (*Ipomoea batatas*), particularly the vines and roots, features other nutritional characteristics. It contains less energy than rice straw, but has a considerable higher crude protein content. The productive potential of Sweet potato depends on the different varieties (dual-purpose or foliage species) and varies between 4.3 – 6 tons DM/ha (vines) and 3 – 4 tons/ha (roots)]. The chemical composition of sweet potato roots and vines (Appendix I) makes it a suitable goat feed [DUNG, 2001; PETERS, 2008; RUIZ ET AL., 1981].

Table 5 Priorities for crop residue use by animals in Asia

Type of residue	**Nutrient potential**	**Species**
Good quality (*e.g. oilseed cakes/meals, cassava leaves*)	High-protein, mineral, high-energy supplement	Pigs, chickens, ducks, ruminants*
Medium quality (*e.g. coconut cake, sweet potato vines*)	medium-protein	Pigs, chickens, ducks, ruminants*
Low quality (*e.g. cereal straw, stovers*)	low protein, very fibrous	Ruminants*, camels, donkeys, horses

*Ruminant refers to buffaloes, cattle, goats and sheep

Source: Devendra C., 1987.

3.2.3 Water

An adequate provision of water is inevitable to ensure animal health and productivity. Reduced water supply will restrict feed intake and feed efficiency, and will concomitantly affect reproduction, growth and milk production of goats. Limiting factors for water intake can be the water quality, feed composition, the environment and animal factors [AGROMISA, 2004; KAWAS ET AL., 2011; QUINISA AND BOOMKER, 1998]:

- *Water quality*: Goats avoid contaminated water and prefer clean water. Furthermore, it may be a source of various diseases.
- *Feed composition*: An excess of salt or a high protein level increase the water consumption.
- *Environment*: Climatic conditions also affect the intake of water. Especially hot and humid climates cause a higher water intake than normal to regulate body temperature through water evaporation.
- *Animal factors*: Intake depends on age, health status, physical activity and body size of the goat. Older goats require less water than younger animals.

Due to the abovementioned factors, the essential daily water intake of goats varies. DENEK ET AL. [2006] state that the daily intake of small ruminants will be 2 liters per kg DM consumed in the humid cool winter season. Heat stress, during the hot summer season, may increase the intake to up to 6 liters per kg DM consumed.

3.2.4 Dry matter intake and nutrient requirements

Meeting the nutrient requirements of goats implies generally, in the most instances, to deal with energy and protein requirements. Though, further, the requirements also include micro- and macronutrients and vary depending on the physical and metabolic level of the goat, as maintenance, growth, lactation or pregnancy.

Nutrient requirements of goats are determined by various general and individual factors, as the breed, production system, climatic conditions, as well as age, sex, parasitism, body size and physiological stage [Peacock, 1996; Rashid, 2008]. The nutrient needs of goat breeds of smaller mature body size and lower growth rate, native to humid tropical regions, presumably differ from those of high performing breeds in temperate regions [Mandal et al., 2005]. Therefore, a general statement concerning the nutrient requirements of goats is not reasonable.

Various studies and scientific papers discussed and specified the nutrient requirements of goats [Luo et al., 2004a,b; NRC, 1981, 2007; Sahlu et al., 2004; Salah et al, 2014]. Few papers are published addressing the nutrient needs of low performance goats in humid tropical regions (Table 6). Consequently, it is difficult to state the explicit requirements of goats native to Malaysia. Nevertheless, Devendra (1983b) analyzed the energy and protein requirements during pregnancy for indigenous Katjang goats in Malaysia. According to the study, energy requirements for maintenance and pregnancy are 602.5 kJ DE/$W^{0.75}$kg/day and 734.3 kJ DE/$W^{0.75}$kg/day, respectively and the mean digestible crude protein (DCP) requirements for maintenance and pregnancy are 3.6 g DCP/$W^{0.75}$kg/day. Devendra assumed that the lower requirements of Katjang goats in comparison with other breeds supposedly exist, apart from breed differences, due to the adaptability of Katjang goats and its efficient performance in case of lower planes of nutrition.

The mineral and trace elements requirements of goats are precisely described by the National Research Council (NRC 2007), though, not explicitly for indigenous goats in the Southeast Asian region.

Dry matter intake (DMI) is the amount of feed a goat consumes per day on a moisture-free basis and the main determinant of nutrient supplies. Appropriate DMI is important to formulate a diet, which prevents under- or overfeeding of nutrients and to promote efficient nutrient utilization. Hence, it is significant to analyze the daily DMI of goats in order to estimate the incorporation of nutrients [Agromisa, 2015; NRC, 2001, 2007]. However, adequate nutritional management is difficult in case of free-grazing animals [Cornelis et al., 1999; Freer, 2002].

On average, the DMI of goats per day is approx. 3 % of the body weight (BW) [Agromisa 2015; Devendra, 1993a]. The potential dry matter intake of goats is characterized by its physical capacity for feed and its demand for nutrients [NRC 2007]. Though, the amount of voluntary DMI is influenced by several factors, as, inter alia, environmental and animal factors, as well as feed characteristics. For instance, the amount of the daily DMI of young goats is generally higher than of mature ones, and also affected by the quality of the feed. Poor-quality roughage, as straw, low in digestibility due to a low-protein and high-fiber content, constrains the dry matter intake of goats. Whereas, supplementation with protein, as leguminous forages, can increase the DMI, as well as the digestibility of the roughage. The rate and level of digestibility affect the intake. The faster the feed passes through the digestive tract, the more it allows for an increase of dry matter intake. [AGROMISA, 2015; DEVENDRA ET AL., 2001; HARYANTO AND DJAJANEGARA, 1993; NRC, 2001; SAUVANT ET AL., 1991]. Among smallholder farmers in tropical and subtropical regions, crop residues of low quality are practically a major component or partially the basis of diets for ruminants [LENG, 1990]. On the other hand, the high moisture content of various roughages in humid tropical regions may also adversely affect the voluntary intake [PEACOCK, 1996].

According to PEACOCK [1996], the DMI of Katjang goats in the tropics is 2.5 % of the body weight, but it is probably better to marginally overestimate the goat's needs and utilize 3 % as a guideline. General statements concerning the daily dry matter intake of goats are given by the NRC [1981, 2007].

Table 6 Daily energy and protein requirements and feed intake of goats of different ages and weights for maintenance (including early pregnancy), plus low activity (intense housed management) and high activity (grazing sparse vegetation)

Weight	Energy		CP		DM intake		As % of weight	
kg	ME (MJ) per day		g/day		kg/day			
	Low act	High act	Low	High	Low	High	Low	High
10	3.0	4.2	27	38	0.36	0.5	3.6	5.0
20	5.0	7.0	46	64	0.6	0.8	3.0	4.2
30	6.8	9.6	62	87	0.8	1.1	2.7	3.8
40	8.5	11.8	77	108	1.0	1.4	2.5	3.5
50	10.0	14.0	91	128	1.2	1.7	2.4	3.3
60	11.4	16.0	105	146	1.4	1.9	2.3	3.2

Source: Agromisa, 2015.

3.3 Health Management

Diseases and parasites are, besides malnutrition, one of the major constraints of goat production in the countries of South-East Asia and responsible for losses and impaired production performance. The economic loss due to diseases and parasites is probably high and for low-income farmers it must be even more considerable. Improved livestock management, medications, vaccines, and the use of disease-resistant or disease-tolerant goats may be an option to avoid losses and to ensure the level of productivity. Nevertheless, in the most areas of SE-Asia, the veterinary care and diagnostic services are rather rarely found and remedies prohibitively expensive. Therefore, other veterinary drugs or remedial measures are necessary, as, for instance, the use of native plants, to control diseases and parasites in goat production.

3.3.1 Common Diseases of Small Ruminants in South-East Asia

3.3.1.1 Infectious Diseases

Prevalent diseases of small ruminants in SE-Asia caused by bacteria or viruses are [AGROMISA, 2015; GINTING ET AL., 1993; SANI ET AL., 2014]:

- Pneumonia
- Footrot
- Anthrax
- Pink Eye
- Clostridial Infections
- Infections caused by *Escherichia coli*
- Foot-and-Mouth Disease (FMD)
- Brucellosis
- Mastitis
- Peste des petits ruminants (PPR; Small ruminants pest)
- Contagious caprine pleuro-pneumonia (CCPP)
- Pasteurellosis
- Contagious Ecthyma (Orf)

Brucellosis, for instance, a zoonotic bacterial disease caused by the bacterium *Brucella melitensis*, is very common at goat farms in Peninsular Malaysia and may cause infertility, reduced milk production or the inducement of an abortion, and thus leads to high economic losses. Reasons for the persistence of the infection at local goat farms are inter alia the illegal trading of uncertified goats and the large numbers of goats imported from various countries, in connection with deficient monitoring of farmers and traders by the veterinary authority [AZIZ ET AL., 2012; BAMAIYI ET AL., 2014A; BAMAIYI ET AL. 2014B].

In Malaysia, Pasteurellosis, a respiratory infection caused by *Pasteurella* bacteria, is regarded as the main cause of death in goats [SAHAREE AND FATIMAH, 1993]. It often results from adverse physical or physiological stressors, as heat, overcrowding, malnutrition, insufficient ventilation and transportation in combination with viral or bacterial infections, when the resistance of the animal is low. The mortality is particularly high in young goats due to their susceptible state of health in comparison to adults. Avoiding stress as a preventive measure and antibiotic treatments, in case of an already existing acute affection, are the most suitable options to deal with Pasteurellosis [BROGDEN ET AL., 1998; SAHAREE AND FATIMAH, 1993; SYMOENS ET AL., 1993].

3.3.1.2 Metabolic Disorder

<u>Bloat</u>

Bloat is mainly caused by an excessive intake of feed with a high water and protein content and the therewith associated abnormal fermentation of the feed or due an obstruction of the esophagus. It results in an accumulation of frothy gas in the rumen and its distension [AGROMISA, 2015; GINTING ET AL., 1993].

<u>Diarrhea</u>

A sudden change in the diet of goats regarding the kind of feed may cause liquid faeces. For example, the switch from dry roughage to fresh, wet grasses. Worms, flukes and Coccidiosis can also cause diarrhea [AGROMISA, 2015].

3.3.2 Parasites

3.3.2.1 Ectoparasites

Ectoparasites are external parasites, which parasitize at some point of their life cycle on goats and live or feed on the skin or related tissues of the host animal. They cause irrigation of the skin, which may lead to wounds and they can transfer endoparasites or diseases. External parasites, as, for instance, ticks and the tick-borne diseases associated therewith, are particularly important in animal production systems throughout the tropical world [CARMICHAEL, 1993]. Especially under hot and wet environmental conditions, ticks population multiply rapidly. Further ectoparasites of economic importance in SE-Asia are inter alia lice, Screw-worm flies and Mange mites (*Sarcoptes scabiei*). Infestation with sucking and biting lice cause excessive scratching and rubbing, culminating in weight loss, anemia and reduced milk production. Mange mites, also known as scabies, pierce the skin of the goats for feeding and oviposition purposes and cause excessive scratching. These scratch lesions manifest with intense pruritus and formation of crusts. Consequences of sarcoptic mange are decreased reproduction, weight gain and milk yield [AGROMISA, 2015; CARMICHAEL, 1993]. A survey of DORNY ET AL. [1994] considered *S. scabiei* in Peninsular Malaysia as the cause of Dermitis and the major reason for emaciation and death in goat and revealed the prevalence of *S. scabies* to be 55.8 % among goats.

3.3.2.2 Endoparasites

Endoparasites live within a host and obtain their required nutrients from organs or tissues of the host in order to grow and reproduce. The health status of the host declines due to the presence of the endoparasites. Some internal parasites cause little or no ill effects, whereas some endoparasites are harmful and lead to illness and death of the host [CARMICHAEL, 1993] Endoparasites are divided into three categories: nematodes (roundworms), cestodes (tapeworms), and trematodes (flukes).

Nematodes are of great importance and cause severe economic losses in the livestock sector of the humid tropics, and also trematodes are responsible for losses in certain areas. Cestodes, on the contrary, are of minor importance under humid environmental conditions and will not be further discussed. The most common endoparasites in Malaysia are inter alia [AMIN ET AL., 1990; SANI ET AL., 2004; WAHAB AND ADANAN, 1993]:

- *Haemonchus contortus*
- *Trichostrongylus spp.*
- *Oesophagostomum spp.*
- *Cooperia curticei*
- *Strongyloides papillosus*
- *Eimeria spp.*
- rumen flukes
- pancreatic flukes

Especially intestinal parasites, which infect the gastro-intestinal tract, are of paramount importance and cause major health problems for livestock production in tropical and subtropical environments [CARMICHAEL, 1993; IBRAHIM, 1996; SYKES, 1994]. Helminthiasis can cause reduced voluntary feed intake and efficiency of nutrient absorption of the host, as well as considerable levels of anemia and eventuates in severe morbidity and high rates of mortality [AUMONT ET AL., 1997; CARMICHAEL, 1993; COOP AND KYRIAZAKIS, 1999; FAYE ET AL., 2002]. SAITHANOO [1990], for instance, described the mortality in goats caused by gastrointestinal parasites as markedly high in the rural areas of Southern Thailand, particularly in young kids up to weaning. A survey in Laos, Cambodia and Vietnam estimated that approx. 15 % adult mortality and 51 % kid mortality were closely related to gastrointestinal parasitism [SANI ET AL., 2004]. In addition to it, KOINARI ET AL. [2013] provided information about the prevalence of gastrointestinal parasitic infestation of small ruminants in Papua New Guinea with an infection level of 89 % (goats) and 72 % (sheep).

In Malaysia, and in SE-Asia in general, strongyles as *Haemonchus contortus, Trichostrongylus spp*. and *Oesophagostomum spp*. are the most important and the most prevalent gastrointestinal parasites and cause severe economic losses in the livestock industry of Malaysia [DORNY ET AL., 1994; HASHIM

AND YUSOF, 2016; SANI AND CHANDRAWATHANI, 1996; ZAINALABIDIN ET AL., 2015]. Most notably haemonchosis, caused by the pathogenic nematode *Heamonchus contortus* and typically characterized by anemia, emaciation and digestive disturbances, is the second most important cause of mortalities in small ruminants in Malaysia after pneumonia [DORNY ET AL., 1994; NOR-AZLINA ET AL., 2011a,b; SANI AND CHANDRAWANTHANI, 1996; WALLER, 1997]. Losses due to haemonchosis occur mostly in young kids, recently weaned but yearling, though in mature goats as well. Promotive conditions for the prevalence of haemonchosis in small ruminants are lush pastures, host susceptibility, overcrowding, low plane of nutrition and the hot and warm environmental conditions [FAYE ET AL., 2002; MESELE ET AL., 2013; WALLACE ET AL., 1995]. However, the tropical humid climate of Malaysia is also a very favorable environment for a year-round development and survival of trichostrongyles and other gastrointestinal parasites on pastures [Daud-Ahmad, 1991; Ibrahim, 1996]. Additionally in this context, Daud-Ahmad [1991] recorded a mortality rate of 80 %, in a herd in Malaysia, among goats under one year of age and proved that one-third of the deaths were due to trichostrongylosis. Besides helminthiasis, coccidiosis, a diarrhea disease caused by *Eimeria spp*., is also of economic importance for goat production in Malaysia. Several studies, conducted in Malaysia, attested high prevalence of *Eimeria spp*. and strongyles infestations in small ruminant farms. A study of ZAINALABIDIN ET AL. [2015] in Perak, Malaysia revealed infestation rates of 92.57 % and 86.86 % among small ruminants farms with *Eimeria spp*. and *H. contortus*. A conducted study in Terengganu, Malaysia [HASHIM AND YUSOF, 2016] attempted to investigate the relation between rearing systems (intensive, semi-intensive, extensive) and gastrointestinal parasites in goats. 89.2 % and 45.6 % of the tested goats showed an infestation with *Eimeria spp*. and *Strongyloides spp*.. In regard to the rearing system, infestation with *Strongyloides spp*. was relatively high in semi-intensive (83.1 %) and extensive systems (43.3 %) and rather low in the intensive system (1.9 %). Whereas infestation with *Eimeria spp*. was at its highest level in the intensive system (99 %) although all systems have shown high infestation rates (semi-intensive: 80.6 %; extensive: 90 %). At least the influence of the rearing system on the prevalence of *Eimeria spp*. can be ruled out. On the contrary, studies of CARMICHAEL [1991] and DORNY ET AL. [1995] about helminth parasitism in small ruminants in Southeast-Asia have indicated high incidence and mortality where grazing is the prevailing practice.

In humid tropical regions, as Malaysia, where little variation in temperature occurs, the variation in rainfall is the major factor influencing occurrence of gastrointestinal parasites and their infection patterns in small ruminants. An appropriate level of moisture is essential for the development of the pre-parasitic stages and the larval migration onto grasses. During the period of highest rainfall in Malaysia (November – February), the prevalence of parasitic gastroenteritis in grazing goats reaches their highest level. Whereas dry conditions have an adverse effect on the survival of free-living stages on the pasture, as well as too excessive rainfall through washout-effects [CARMICHAEL, 1993; SANI ET

AL., 2004; WALLER, 2006; DORNY ET AL., 1995]. However, epidemiological studies in goats predicate that grazing goats in Malaysia ingest many infective larvae of *H. contortus* at all times of the year [DORNY ET AL., 1995; SANI ET AL., 1985].

3.3.3 Control and Treatment of Gastrointestinal Infections

As indicated above, gastrointestinal parasites are a major health problem for livestock production in SE-Asia and cause enormous economic losses. Therefore, it is of utmost importance to control and treat gastrointestinal infections in goats. Preventive measures, as, for instance, an appropriate grazing management or breeding for resistance are suitable methods especially in low-income areas, where the utilization of anthelmintics is not affordable. Besides anthelmintics, alternative non-drug methods as the use of traditional medical plants or biological control of gastrointestinal parasites are also potential techniques to avoid severe losses and to maintain an adequate state of health.

3.3.3.1 Anthelmintics

Anthelmintics are chemical de-wormer, used to treat infections of parasitic worms, and classified according to their chemical structure/mode of action into different groups (inter alia Benzimidazole, Levamisole and Organophosphates).

Particularly the costs and availability of anthelmintics, notably in the pastoral areas, restrict their utilization by smallholder farmers in SE-Asia. Aside from that, the worldwide more or less complete reliance on anthelmintics as a worm control agent results in a development of parasite resistance to most of the commercial anthelmintics, and thus to severe problems. [DEVENDRA, 1993a; WALLER, 2003a, 2006]. Also in Malaysia, worm control through excessive utilization of anthelmintics induced a rise of parasitic resistance [DORNY ET AL., 1993, 1995]. A nationwide survey of DORNY ET AL. [1994] depicted the resistance of *H. contortus* to the benzimidazole group in 33 out of 96 randomly selected smallholder goat farms. Another investigation, conducted by CHANDRAWATHANI ET AL. [1999], presented the presence of worm resistance to all classes of anthelmintics in mostly all of the 48 tested small ruminant farms. The supply of breeding stock to other farms may spread the resistant strains of the parasites and would intensify the adverse effects. Further investigations of CHANDRAWATHANI ET AL. [2013] in two smallholder goat farms, which were actively distributing their animals to other farms, reinforce the assumption that resistant worms are dispersed all over the country. Anthelmintic resistance of *H. contortus* and *Trichostrongylus colubriformis*, tested by using the Faecal Egg Count Reduction Test (FECRT), to all of the four tested anthelmintic groups, were detected in both farms. A study about the nematode anthelmintic resistance on government small ruminant farms in Peninsular Malaysia [KHADIJAH ET AL., 2006] also resulted in resistance of nematode populations in all five farms.

3.3.3.2 Alternative non-drug agents

As aforementioned, parasite resistance to anthelmintics is an increasing and severe problem in the small ruminant livestock sector of Malaysia. Hence the application of alternative agents to reduce losses caused by gastrointestinal parasites is inevitable. Plant secondary metabolites, such as terpenes, alkaloids and especially condensed tannins have shown anthelmintic effects and have a wide reputation among natives being curative for intestinal-worm infections. Studies of MIN AND HART [2003] and MIN ET AL. [2005] suggest that condensed tannins directly influence the animal parasite load, as well as a retarding larval development in the pasture. Several surveys observed the effects of condensed tannins as an anthelmintic agent in ruminants by feeding forage of cassava (*Manihot esculenta*) [GRANUM ET AL., 2002; NETPANA ET AL., 2001; SOKERYA ET AL., 2009] or Taro (*Colocasia esculenta*) [KUBDE ET AL., 2010] and recorded decreasing worm burdens.

However, the utilization of forages, as, for instance cassava, which are rich in terpenes, alkaloids and condensed tannins must be strictly limited due to the toxic effects of the mentioned secondary metabolites on liver, kidneys and the epithelium of the digestive tract [LANDAU ET AL., 2000; SILANIKOVE ET AL., 1996].

3.3.3.3 Traditional anthelmintic remedies

Particularly in rural areas, where the availability of veterinary services is low, traditional medical plants play a significant role as prevention and treatment against diseases and worm infestation. The efficacy of most of these remedies is questionable and not scientifically confirmed. Nevertheless, the native farmers are convinced of the potential of their medical plants and some are indeed effective against gastrointestinal parasites, at least to a certain degree. Studies of ISKANDAR ET AL. [1983] and TANGALIN [2010] for example, about the anthelmintic effects of betel nut (*Areca catechu*) as a de-wormer to small ruminants, showed a sort of potential of *Areca catechu* as an anthelmintic agent.

Further traditional anthelmintic remedies and remedies against common diseases are listed in the Appendix V.

3.3.3.4 Grazing management

An appropriate grazing management, as a part of an integrated parasite control program, can be an efficient preventive measure and also an enhancement of pasture utilization. Several investigations [AUMONT ET AL., 1997; CRUZ ET AL., 2000] proved the efficacy of rotational grazing in wet tropical environments to minimize parasitic infections in small ruminants. BARGER ET AL. [1994] analyzed the longevity of parasitic stages in Fiji in pasture of *Haemonchus contortus, Trychostrongylus colubriformis,* and *Oesophagostomum columbianum* and generated a rotational grazing system consisting of ten paddocks with a grazing sequence of 3.5 days. High pasture infectivity developed within a week, but the large majority of the larvae died within one or two months. The faecal egg count of rotationally grazed goats were less than half of the comparative set-stocked flock and additionally required nearly four times less anthelmintic treatments over the course of a year. However, larval development and their survival rate may vary in other areas of the wet tropics and thus the grazing sequences must be adjusted [SANI ET AL., 1995].

Rotational grazing may not be applicable to certain types of management, for example in areas of limited available land. Further constraints to implement a rotational grazing system may be the high establishment costs (fencing) and the labor requirements [AGROMISA, 2015; MANUELI, 1996; WALLER, 2006].

3.3.3.5 Breeding

Breeding of goats resistant to internal parasites may be an alternative method and can be improved by three selection strategies. Namely selection for resistance, selection for resilience and selection for reduced number of (anthelmintic) treatment [BAKER ET AL., 1991; WOOLASTON AND BAKER, 1996]. Breeding strategies, as the recently mentioned, can be a successful opportunity to deal with internal parasites, though the feasibility through farmers in Long Lamai is more than questionable and thus no subject of further explication. Another aspect of breeding, to control losses due to parasites, is the utilization of indigenous goat breeds, which are mostly more resistant to gastrointestinal parasites than exotic breeds. Several authors have investigated the ability of indigenous breeds to develop effective acquired resistance [CHIEJINA ET AL., 2002; COSTA ET AL., 2000; MANDONNET ET AL., 2001]. PRALOMKARN ET AL. [1997] have shown that Thai native goats are more resistant to *H. contortus* than Anglo-Nubian crossbred goats and DEVENDRA ET AL. [1997] indicated that the Malaysian Katjang goat is resistant to many internal parasites. Thus, there is considerable evidence that indigenous goat breeds are more resistant to diseases and infections than exotic breeds.

3.3.3.6 Biological control

Most of the methods to control gastrointestinal parasites are directed at the parasitic stage within the host, whereas the biological control is targeted at the free-living stages on pasture. The nematode-destroying micro-fungus *Duddingtonia flagrans*, fed to goats, stunts the development of the worm at larval stage, thereby interrupting the life cycle and consequently reduces parasitic worms [ARAÚJO ET AL., 2006; LARSEN ET AL., 1998; WALLER, 2003b]. Studies of CHIE [2002] revealed reduction of larval development by nearly 95 % in worm-infected animals. The spores of *D. flagrans* were able to reduce larvae by 80-90 % within 48 hours and the effects were seen at least 3-4 days after the treatment. The availability and practicability of biol. control via *D. flagrans* in Long Lamai is, due to its local conditions, questionable and thus no subject of further explanations. Another ‘type’ of biological control is the collection of dung. The collected dung is also useful as fertilizer or fuel.

3.3.3.7 Dietary supplementation

As previously mentioned, gastrointestinal nematodes reduce the nutrient availability to the host through both reduced voluntary feed intake and/or reduced efficiency of nutrient absorption [COOP AND KYRIAZAKIS, 1999]. Studies of FAYE ET AL. [2002] suggested that animals could withstand the adverse effects of parasites and maintain the same level of productivity as would dewormed ones by means of supplementation. Similar studies of BLACKBURN ET AL. [1991, 1992] have shown that young goats offered a high-protein diet had better live-weight gains during an infection with *H. contortus* than those offered a low-protein diet. KONWAR ET AL. [2015] investigated the effect of protein dietary supplementation on faecal egg counts and hematological parameters in goat kids and pointed out that dietary supplementation may have significant beneficial effects on reducing the worm egg count and on improving hematological parameters. However, some studies mentioned the need, particularly in tropical environments, to consider both protein and energy components in dietary supplementation, due to its sometimes scarce incidence in some seasons, to reduce effects of gastrointestinal parasites. The interactions between protein and energy are particularly relevant to consider in goats, inter alia, because of the effects of energy metabolism on the use of protein. Trials, conducted by SINGH ET AL. [1995], HAILE ET AL. [2002] and KNOX AND STEEL [1996], have shown the importance of the interactions between protein and energy components by using a source of non-protein nitrogen (urea supplementation) and cottonseed meal to reduce the effects of gastrointestinal infections. Nevertheless, it is not evident and scientifically proved that the improvement of the host nutrition has effects on host resistance to gastrointestinal parasites. The manipulation of host nutrition may at least contribute to improve the resilience of the host and their responses against worm infections.

Providing extra feed to goats, as long as available, as part of an integrated parasite control program, seems to be a good opportunity to reduce production losses due to gastrointestinal parasite infections in pastoral tropical regions.

3.4 Breeding Management

Especially for small-scale farmers in tropical regions, the efficiency of meat production is exceedingly characterized by their capability to produce regularly offspring. Besides an increasing reproduction performance, the reduction of mortality rate, an accelerating of the growth rate and carcass merit are desirable objectives. Goat breeds native to SE-Asia, as, for instance the Katjang goat, are generally small in size and thus the output of meat per animal is minimal. Furthermore, the breeding management of small-scale farmers in these regions, with regard to selection for traits, pedigree recording and mating control, is inadequate. Responsible for the insufficient or partially nonexistent breeding management are among others: high labor demand, lack of knowledge regarding breeding techniques and breed characterization, small flock sizes and single sire flocks. Uncontrolled mating, frequently disregarding inbreeding, is a common approach of smallholders to ensure the continued existence of their goat flock and to maintain the meat production [ALEXANDRE ET AL., 2010; ALEXANDRE AND MANDONNET, 2005; BOSMAN ET AL., 1997; DEVENDRA AND MCLEROY, 1982; SHRESTHA AND FAHMY, 2003; WILSON, 2009]. In the following, feasible options for an improved breeding and reproduction management, as well as common goat breeds in SE-Asia and there adaptation to the local climatic environment are shown to demonstrate the possibilities to enhance goat meat productivity.

3.4.1 Predominant goat breeds in Malaysia

Breed evaluation is an important opportunity to identify breeds with a genetic potential to increase the goat meat production. Though, production traits, as for instance growth rate and mature size, are not necessarily the decisive factors for or against a breed. WILSON [2009] noted that, in the tropics, the right animal is not basically the one that produces the most. The capacity of small ruminants in tropical regions to utilize low-quality feed, being adapted to harsh environmental conditions, prevailing diseases/parasites and management practices is also a significant parameter for a productive system. Several studies have shown that local breeds are well adapted to humid, tropical environments, have the ability to develop effective acquired immunity in regard to their pathological environment and exploit the feed resources more efficiently than exotic breeds [BARKER, 1996; COSTA ET AL., 2000; FAYE ET AL., 2002; MANDONNET ET AL., 2001; WINUGROHO ET AL., 1993]. Morphological responses as smaller body sizes, changes in feeding behavior and the reduction of the basal metabolic rate are inter alia components of the adaptation of indigenous breeds to the prevailing conditions [ALEXANDRE AND MANDONNET, 2005; DEVENDRA, 1987]. Natural adaptation of indigenous goat breeds or, at least, the inclusion of adaptation traits as breeding objectives for exotic or local breeds is essential to ensure sustainable goat improvement in most tropical areas [BAKER AND REGE, 1994; WILSON, 1998].

3.4.1.1 Native Breeds

- *Katjang*: The Katjang goat, locally called *Kambing Katjang*, is a very hardy breed, indigenous to Malaysia and Indonesia and well adapted to the humid tropical conditions. The Kambing Katjang is also native to Southern Thailand and locally known as Southern Thai Native goat. It is small in size, males measure at withers about 60-65 cm on average, females approx. 56cm. The Malaysian Katjang goat is a little bit larger than the Indonesian. It is usually reared for meat and due to the low milk output rarely milked. The daily live-weight gain amounts to 55g with an average mature weight of 25kg (males) and 20kg (females). The Katjang goat is a very prolific breed, twinning is the norm and triplets are quite common. The average litter size is 1.7 – 1.8 kids per birth and the age of females at first kidding is 15 – 16 months. The Katjang breed is also being crossed with Jamnapari, Anglo-Nubian, Saanen, Boer and the German Fawn goat and represents the sole native breed in Malaysia. [ALEXANDRE AND MAHGOUB, 2012; ANOTHAISINTHAWEE ET AL., 2010; IBRAHIM, 1996 PRALOMKARN ET AL., 2011].

  The Katjang goat is very well known for its high fertility and hardiness, though an excessive and uncontrolled breeding policy with exotic breeds reduced the numbers of pure bred animals in Malaysia and Indonesia substantially. This may result in severe erosion and wastage of local breeds and, in the long-term, cause a loss of valuable genetic material [DEVENDRA, 1993a].

3.4.1.2 Exotic Breeds

- *Anglo-Nubian*: The Anglo-Nubian goat has its origin in the U.K. and is a dual purpose breed. It is introduced and used for crossbreeding with the aim of a larger body size and higher productivity to increase the milk yield, but is also well suited to meat production. The Anglo-Nubian goat is a very heavy and tall breed with a great capacity for adapting to hot climates. However, crosses of native, hardy breeds with Anglo-Nubian may be less resistant to gastrointestinal parasites than the pure native breed [SAITHANOO, 1996; PRALOMKARN ET AL., 1996].
- *Boer Goat*: The Boer goat is a breed resulting from long selection of local goats in South Africa and is mainly kept for meat production, though Boer goats have also a reasonable potential for milk production. Due to its tremendous potential as meat producer and its good adaptability to arid tropical climates, the Boer goat is widely used throughout the arid tropical regions. The breed is characterized by good fertility and a higher proportion of muscle in the carcass compared with the most goat breeds and a live-weight up to 130 kg (male), 80 kg (female), respectively. Studies indicated the suitability of Boer goats for crossbreeding in tropical regions to increase the live-weights in local goats. Nevertheless, the extensive goat-raising systems, which are common in the tropics, perceptibly reduce the

production performance and carcass characteristics in the Boer goat [AGROMISA, 2015; ALMEIDA ET AL., 2006; DHANDA ET AL., 2003; ERASMUS, 2000; NIMBKAR ET AL., 2000; WARMINGTON AND KIRTON, 1990].

- *Kalahari Red*: The Kalahari Red goat, named after the colour of the sand in the Kalahari Desert, originates as well as the Boer goat from South Africa and is used for meat production. The Kalahari Red goat is ideally suited to harsh arid and semi-arid conditions, resistant to parasites and their even pigmentation functions as a natural resistance to both sun and heat. It is regarded as a "minimum care/maximum profit" breed and known for its excellent mothering abilities. The carcass size of the Kalahari Red goat is similar to the South African Boer goat: average weight of bucks 115 kg, does reach 75 kg in average. Crossbreed Kalahari Red can improve the carcass weight of indigenous goats and enhance the tenderness of the meat [KOTZE ET AL., 2004; RAMSAY ET AL., 2001].
- *Jamunapari/Etawah*: The Jamunapari goat is a dual-purpose goat (meat & milk), native to the Indian subcontinent. In Indonesia it is known as the *Etawah goat*. It is well adapted to tropical climates. The average bodyweight amounts to 60 kg (male) and 50 kg (female). Crosses of Etawah x Katjang, known as *Peranakan Etawah*, are common in the Southeast Asian region. Crossing of Katjang with the Jamunapari goat increases the general size and endowed the goats with a larger body frame, a convex profile and longer ears [DJOHARJANI, 1996; HASSAN ET AL., 2010; SODIQ AND TAWFIK, 2003; SODIQ AND SUDEWO, 2008; SODIQ AND SUMARYADI, 2002].

3.4.2 Breeding strategies

Goat breeding, respectively livestock breeding in general, comprises several working steps to improve the productivity of the animals in the following generations. The definition of breeding goals is important to focus on specific characteristics or traits, which are selected to enhance and optimize the progeny according to the production concept. The determination of a breeding structure or breeding program defines the way in which the goals will be achieved through breeding. At issue is whether a selection of animals within a breed or between breeds, as well as the concept of the breeding program. Performance testing is subsequently followed by mating of the selected animals. Controlled and monitored mating is essential to implement previously defined goals.

3.4.2.1 Breeding goals

The selection of animals, respectively specific traits, is significant to maintain and improve the properties of a population. Morphological characteristics and production performance are important to optimize the productivity of a farm. The main selection goals to enhance the mentioned productivity are the improvement of reproduction, growth, meat production and/or milk production. Especially reproduction is an important aspect of goat production for meat in SE-Asia due to the small size of the animals and therewith associated minimal meat per animal. Thus profitability relies on having numerous kids born and raised. More specifically, the reproduction efficiency is characterized by the following components: I) Age of first mating II) Productive lifespan of males and females III) Annual mortality IV) Kidding percentage/Litter size V) Time between litters. The selection for growth (meat production) can be classified in two ways I) Growth rate of the animal II) Maximum live-weight. Most of the farmers are much more attracted to a rapid increase in growth rate and mature size of their animals, but for tropical livestock sometimes adaptive traits, as resistance to parasites/diseases, or fitness characters are more important than high growth rates or a large body size. Particularly indigenous breeds can have valuable characteristics as parasite resistance or climatic adaptation, however they never have been consciously selected for breeding purposes. Besides genetic characteristics, environmental (e.g. climate, feed quality and availability) and animal factors (e.g. sex and age) determine the properties of a goat. Also a large breeding population is crucial to provide sufficient genetic variability for productively important traits, which allows to increase the intensity of selection, while reducing the rate of inbreeding [AGROMISA, 2004, 2015; ALEXANDRE AND MANDONNET, 2005; DEVENDRA, 1981; REKIK ET AL., 2012; SHRESTHA AND FAHMY, 2003; SÖLKNER ET AL., 1998]

3.4.2.2 Breeding structures

The low levels of production of goats in tropical regions can partly be associated with low genetic potential. Due to deficient knowledge about and partial disregard of the productive capacity of indigenous breeds and its value, as well as limited purposeful selection and breeding, the production performance of goats has been generally poor. In the tropics well organized breeding programs with routine data recording, performance evaluation and strategic mating strategies are missing.

Genetic improvement of goats by smallholder farmers is, besides the abovementioned complicated and inadequate data recording, negatively affected by the small flock sizes. Nevertheless, genetic improvement by controlled breeding is possible and worthwhile, though to a reduced extent [ALEXANDRE AND MANDONNET, 2005; JAITNER ET AL., 2001; MASON AND BUVANENDRAN. 1982; REKIK ET AL., 2012; SHRESTHA, 2011; SHRESTHA AND FAHMY, 2003; VAN DER WAAIJ, 2001]. Strategies for genetic improvement of tropical goats imply two main pathways [BAKER AND GRAY, 2003]:

I. *Crossbreeding:* Crossbreeding with exotic breeds from temperate regions widely used in tropical areas. Considerable promise in improving efficiency of production. Often unsustainable in the long-term. Crossbreds partially not adapted to climatic conditions or to the low-input production systems due to higher nutrient requirements [REWE ET AL., 2002; WOLLNY ET AL., 2002]. Can achieve rapid genetic changes when there are large genetic differences between breeds in traits of importance [SIMM ET AL., 1996]

II. *Selection within breeds (or strains):* Usually carried out in individual populations. Normally selecting on productivity (e.g. mature size, litter size). Intended to increase the average level of genetic merit of the population. In harsh environments it is an appropriate state when management can only be improved marginally and crossbreds are unlikely to perform well [Kosgey et al., 2006; Peacock, 1996].

Improved goat productivity is possible through a better management and controlled breeding. In this regard, an open nucleus-breeding scheme has been recommended for small ruminants as one option. In the last years a new concept of community-based breeding programs has shown positive impacts in improving livestock production (Mueller et al., 2015). However, adaptation of breeding schemes by smallholders in SE-Asia is, as already mentioned, constrained by the small animal populations, inadequate performance and pedigree recording, as well as single sire flocks and organizational shortcomings [Kosgey et al., 2006; Peters, 1987].

3.4.2.3 Mating decisions

Reproduction of small ruminants by smallholder farmers in the tropical regions of Southeast Asia primarily takes place through uncontrolled mating. Monitored mating would demand exact servicing data and more labor, which can be a serious problem especially at times of land preparation or crop harvest. Thus restricted access of bucks to does avoid emerging work peaks at unfavorable seasons by controlling the date of mating. Additionally, the choice of mating period and frequency enables the farmers to reach an equilibrium between variable poor resources and high levels of requirements of the flock. In tropical regions goats are mainly mated more than once a year. In systems with a focus on meat production 3 kiddings in two years are recommended, as long as the feed resources permit such a kidding interval. The local goat breeds either are non-seasonal breeder or exhibit only a weak seasonality of reproduction. Under tropical conditions, seasonal reproductive patterns are more influenced by variations in temperature, precipitation, and available feed than by day length. An insufficient nutrition often causes a prolonged anoestrus and anovulatory periods as well as a reduction in fertility and prolificacy. On the contrary, obesity of bucks causes losses in libido and in dexterity in mating. The vigor, stamina and potency of bucks are also affected by a lack of care and an appropriate management. Too intensive solar radiation due to inadequate shade during summer and in the time leading up to mating may be responsible for a reduction of semen production. Though, bucks must be in excellent condition at mating, otherwise the mating performance and consequently the kidding performance could be depressed [Agromisa, 2004, 2015; Alexandre and Mandonnet, 2005; Chaniago, 1993; Chemineau, 1986; Devendra and Burns, 1983; Gatenby, 1986; Lu, 2011; Rekik et al., 2012 Webb et al., 2004].

3.5 Housing

In the humid tropical regions of Southeast-Asia an adequate housing is indispensable to protect the goats from various weather conditions, as precipitation or extreme solar radiation, as well as predators or thieves. Direct sunshine, draught or too much rainfall can adversely affect the state of health, for example excessive wetting of goats by rain can cause pneumonia. Furthermore, housed goats are more easily to control and monitor regarding mating, rearing of kids and in the event of illness or parasite infestation. Additionally, it enables the farmer to provide (supplementary) feed for the goats and to collect the manure to utilize it as fertilizer. Regardless of whether the goats are permanently kept in a shed or merely temporarily, the construction of a shed has to fulfill several requirements, as, for instance an optimal positioning of the house, adequate ventilation and an appropriate roof and floor [AGROMISA 2004, 2015; CHANIAGO, 1993; KOCHAPAKDEE AND SAITHANOO, 2004].

3.5.1 Positioning

An ideal positioning of the shed is essential to prevent the sun from heating the housing up too much. This is achieved by placing the longitudinal axis of the stable East-West. Building the shed along the North-South axis allows the sun to dry up the floor and to reduce parasite populations (Figure 1). To avoid smell, the shed should not be located too close to the village or on the windward side [AGROMISA 2004, 2015; CHANIAGO, 1993].

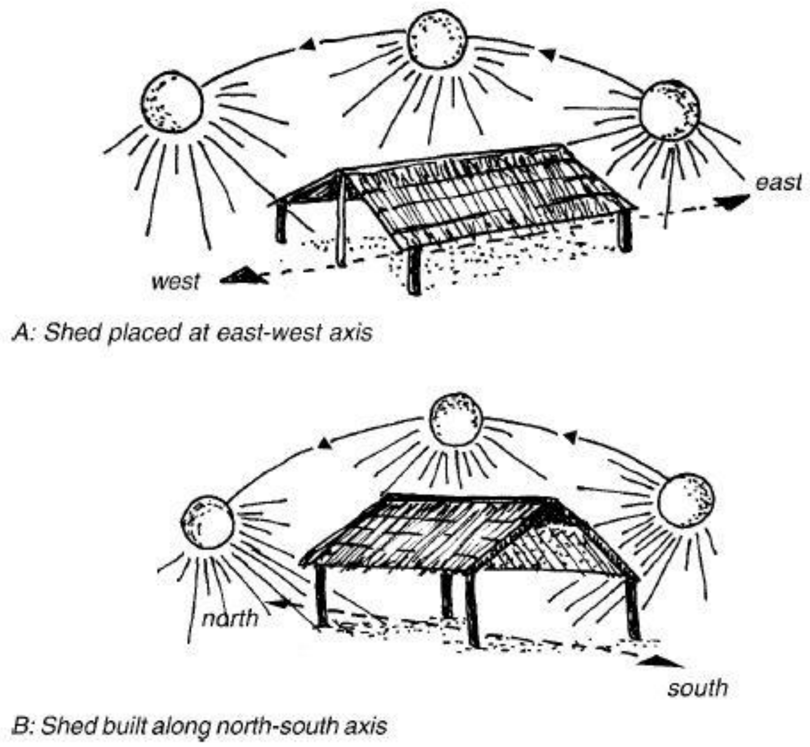

Figure 1: Positioning of the shed (Source: AGROMISA, 2004).

3.5.2 Floor

Stilted housing types, elevated from the ground, are widely used in the humid tropics due to high precipitation rate and high temperatures (Figure 2). An elevated floor protects animals from wet and facilitates collection of manure. Therefore, the floor should be approx. 1.5 m above the ground. Combined with a slatted floor, an elevated housing provides greater air movement around the goat and thus a reduction of the adversely effects of high temperatures. The slatted floor also allows faeces and urine to fall through. As construction material for the slats bamboo or locally available wood is convenient and the distance between the slats should be approx. 1 – 1.5 cm. In addition, an elevated slatted floor housing has a vast advantage in the control of internal parasites through the gap between ground and floor.

The size of the floor area depends on the type of stalling. Permanent stalling of goats without grazing requires 1.5 – 2 m^2/goat. Whereas partial stalling – goats are kept penned only at night or during part of the day – requires merely 1 m^2/goat [AGROMISA 2004, 2015; CHANIAGO, 1993; KOCHAPAKDEE AND SAITHANOO, 2004].

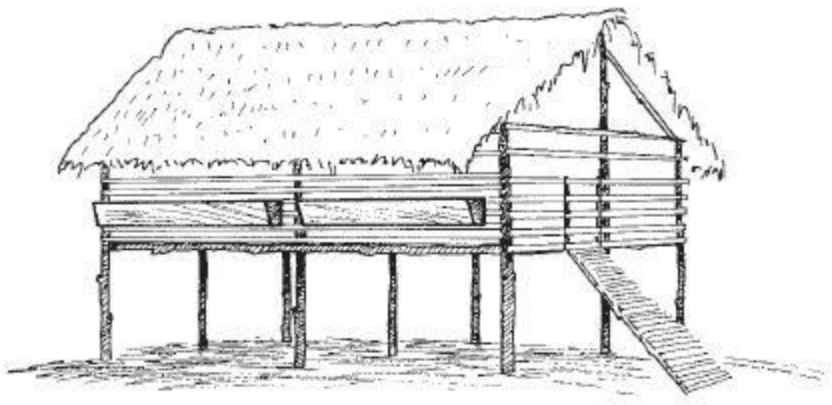

Figure 2: Silted goat shed (Source: AGROMISA, 2015).

3.5.3 Roof

The roof is important to provide shade from direct sunlight and to protect the goats against heavy rainfall. It should be sloping and waterproof with large overhangs to prevent too much sun from shining in. Utilizable roof materials are inter alia coconut, banana or palm leaves, *Imperata cylindrica* or corrugated iron sheets [AGROMISA 2004, 2015; CHANIAGO, 1993].

3.5.4 Ventilation

Goats suffer from draught and damp, therefore an adequate ventilation of the shed, especially in the humid tropical regions is essential. Ventilation provides fresh air and removes the heat and humidity from the inside of the shed. Openings in the wall must be planed high enough, so that the air does not blow directly past the goats. A low wall (approx. 1 m) on the side the wind comes is sufficient in the warm climates of the tropics [AGROMISA 2004, 2015; CHANIAGO, 1993].

3.5.5 Separation

Goats are herd animals, thus individual housing should be avoided. Nevertheless, too large flock size can cause anxiety within the flock. Separation is necessary and useful to segregate different categories of goats and thus different requirements. An example of a possible separation is given in figure 3. Parturient females should be separated from the flock to ensure the establishment of a close maternal-offspring bonds and sufficient colostrum intake by the kids. Sick animals should also be separately penned to avoid additional infections and to treat them adequately. Usually the bucks are separated in a single pen to avoid uncontrolled mating and does are single penned or in groups. Kids are normally kept in group pens, which are separated by sex. Further subdivision can be made by females in late pregnancy or during lactation due to their specific feed requirements [AGROMISA 2004, 2015; CHANIAGO, 1993].

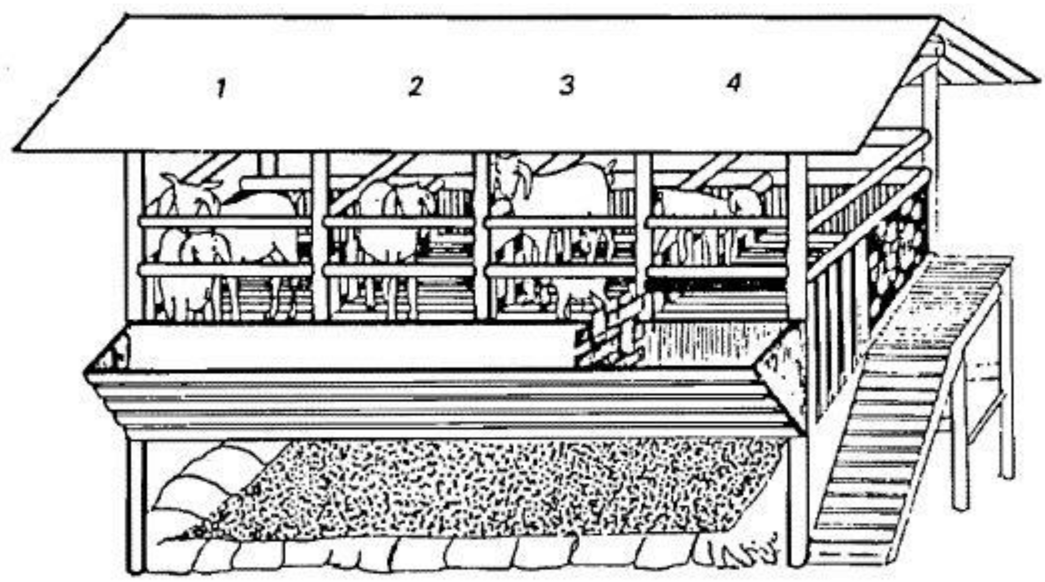

Figure 3: Subdivision of a shed; 1. Males, 2. Pregnant and lactating females, 3. Parturient females, 4. Young weaners. (Source: CHANIAGO T.D., 1993).

4. Material and Methods

4.1 Study area

Sarawak is the largest federal state of Malaysia and situated on the island of Borneo, the world's third largest island (approx. 750.000 km^2). The population of Sarawak is approx. 2.4 million people and comprises roughly 30 different cultures and languages [FIBL, 2012, Laville, 2008].

The study was conducted in Long Lamai (3°10'21,9''N 115°22'57,1''E) (Figure 4), a village of the Eastern Penan in the Upper Baram area, close to the Indonesian border, which can be merely be reached by boat or by foot. Neighboring communities are the villages of Long Puak and Long Banga, inhabited by Kenyah, Saban, Kelabit and Penan. The nearest city, Miri, is about 300 km away.

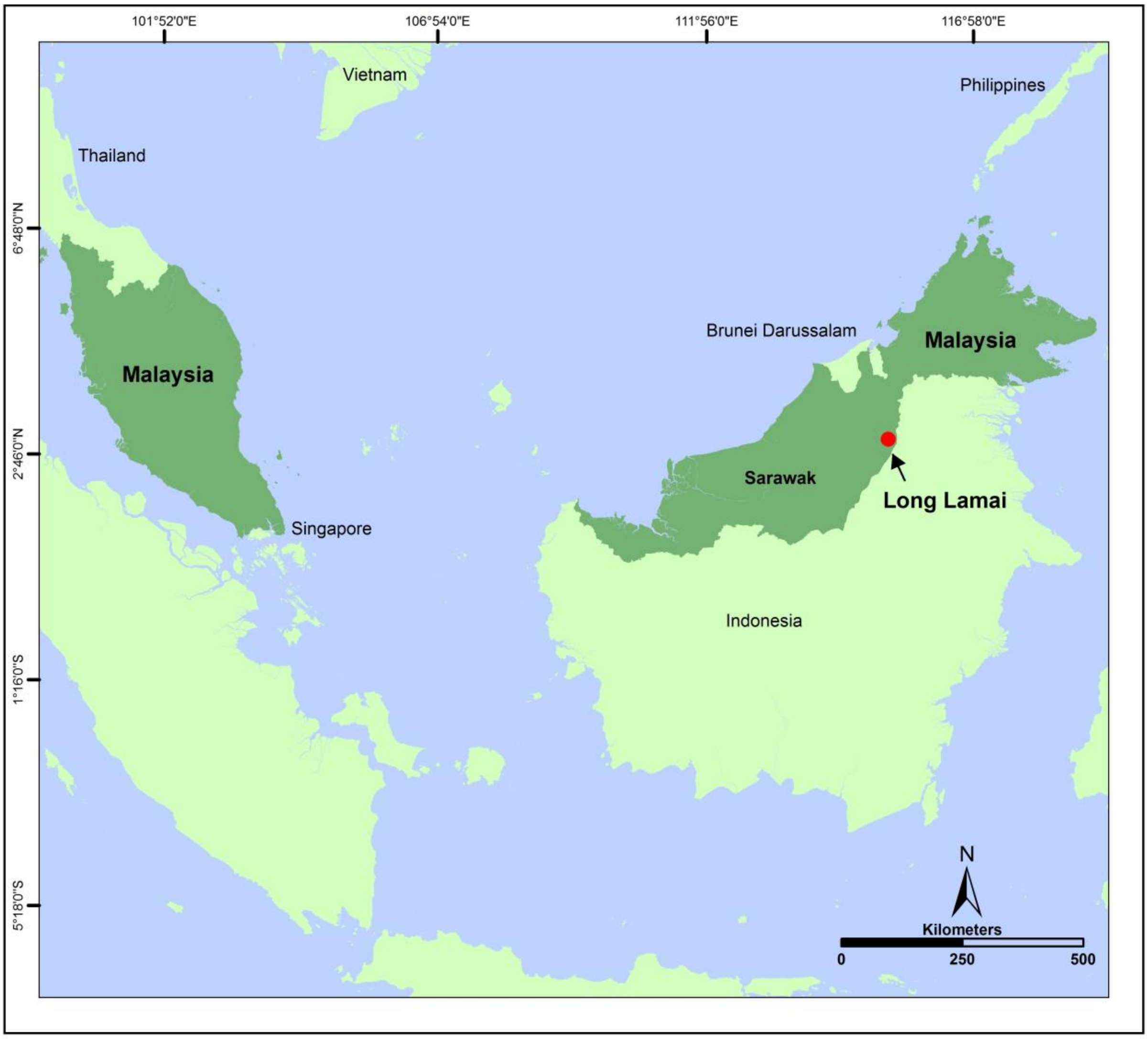

Figure 4: Map Borneo (Source: FiBL, Alexander Hollaus)

The surrounding of Long Lamai is characterized by an equatorial, humid, tropical climate with a vegetation of secondary lowland tropical rainforest. Secondary forests are, in contrast to primary forests, typified by a smaller tree size with light-demanding and fast-growing trees and a lower biological diversity. The average temperature ranges from 24°C to 28°C with a monthly average rainfall of about 300 mm and the village is located at an altitude of about 1400 meters above sea level. A cycle of seasons is non-existent, solely the occurrence of pluvial periods [FIBL, 2012; LAVILLE, 2008; ZAMAN ET AL., 2015, 2016].

The village of Long Lamai was one of the first settlements of the formerly nomadic Penan in the late 1950ies. Hunting and gathering characterized their way of living and is partly still present. Besides that, shifting cultivation provides the staple foods, as rice, for the consumption of the community. In addition to it, several village residents started to cultivate vegetables in home gardens to extend the food variety. Nowadays, Long Lamai houses approx. 600 Penan, many of whom are periodically in neighboring villages or in the coastal area for extended periods of time due to working or attending school.

4.2 Methods

4.2.1 Data collection

Participatory approach

The main part of the information gathering was conducted on site in Borneo with local people of the village Long Lamai, staff members of various departments of agriculture in Sarawak and a local goat breeder from Kota Samarahan (Sarawak). However, a literature review of basic information about the local conditions and livestock husbandry in similar humid tropical regions was performed before the start of the field work. A participatory research approach was used as a way to integrate the local Penan, their knowledge and experience. The participatory approach facilitated to involve the local community into the process of this study and formed the basis for research and planning. The local knowledge and opinions are necessary to understand the complex of interactions between nature, natives and their cultural background. Furthermore, it enables to focus on locally defined priorities and perspectives, whereas it is often neglected by conventional approaches. Locally defined priorities and perspectives ensure appropriate recommendation regarding reasonableness and viability. Additionally, the integration of locals into the process may empower them mentally and can construe as a sign of respect. A participatory approach indicates research carried out with and by local people rather than imposing new findings on them [BURKEY, 1993; CORNWALL AND JEWKES, 1995; FAO, 2003; KHANLOU AND PETER, 2005; MARTIN AND SHERINGTON, 1996].

Transect Walk

Transect walks are a useful tool to describe and show local conditions, to gather information about resources, its distribution, and land use. The information are gathered by direct observation while walking along a given transect accompanied by locals, who have qualified knowledge about the location. Normally, transect walks are conducted during the initial phase of the fieldwork [FAO, 2001; FAUNA & FLORA INTERNATIONAL, 2013; ZEEUW AND WILBERS, 2004]. Primarily, a preparation workshop was held to inform the participating locals about the purpose and the procedure of the walks. Afterwards, transect walks were conducted with several members of the community of Long Lamai, who are interested in goat keeping, as well as for a certain period the visiting goat breeder from Kota Samarahan. The transect walks were implemented to identify potential fodder plants, grazing areas or soil surface conditions and to collect information about the water supply for goats and possible obstacles of introducing goats (Figure 5). All-encompassing, five transect walks were conducted as to different issues, from which four walks were spread over three days.

Figure 5: Local sights Napier grass during a transect walk (Photo: MH)

Resource Mapping

A resource map shows information regarding the occurrence, distribution, access to and use of resources in an illustrated way. It is often related to transect walks [FAO, 2001; ZEEUW AND WILBERS, 2004]. Information, gathered during the transect walks, enabled to picture areas of potential fodder plants, grazing areas and its features and to show graphically the significance attached to them. Therefore, the gained information was recorded and visualized with the assistance of the locals and satellite images of the surrounding of Long Lamai. The resource map was a useful tool to get an overview about distances between resources, grazing areas and the village and partially about the area sizes.

Interviews

Staff members of agricultural departments in Sarawak (Assistant director of Veterinary Department, Sarawak, Veterinary of the Miri Divisional Agriculture Office, Assistant veterinary officer of the Samarahan Divisional Agriculture Office) and also a goat breeder, located in Kota Samarahan, were interviewed to collect information about diverse aspects of livestock in Sarawak. The goat breeder manages the farm in the second generation and works also as a veterinary and adviser in his village and the proximity. Primary concern of the interviews was to gather information about animal husbandry related to Sarawak, which were non-existing or inadequately available in scientific literature, as predominant diseases and parasites, locally available treatments, supplements, goat breeds or prevailing production systems. (Questionnaire guidelines see Appendix III)

Workshops & Meetings

Workshops with different groups of the community of Long Lamai (Women Association, Youth Group) were held to involve the majority of the community in the process of the feasible study and to gain information about their knowledge regarding livestock and possible marketing structures. The subjects of the workshop were selected and determined before in accordance with the context of animal husbandry. For the workshop, the women, the youth, respectively, formed task groups of 4 to 6 persons and worked successively on four 'workstations'. The task was to write down all their information and knowledge related to the topic of the respective workstation. After a certain period of time, the groups switched to another workstation until each group worked on every topic. The topics of the four workstations were (Appendix II):

I. Knowledge about domesticated animals
II. Management of livestock
III. Marketing
IV. Potential of livestock

With members of the community, who are interested in keeping goats, meetings were held to discuss their ideas, opinions and potential limitations of the study regarding their cultural heritage and local conditions. The meetings were also used to prepare them for the abovementioned transect walks and resource mapping.
In Kota Samarahan a goat breeder was visited and frequently interviewed over three days to get an overview about the daily business as a goat farmer, to see the management of goats under humid tropical conditions and to discuss several issues regarding goat rearing in Sarawak. The focus was, among others, on the feeding of goats, treatment of diseases or parasites, housing and handling of female and male goats concerning reproduction. Additionally, the goat breeder was invited to visit Long Lamai to discuss already acquired information in the field and to clarify uncertainties.

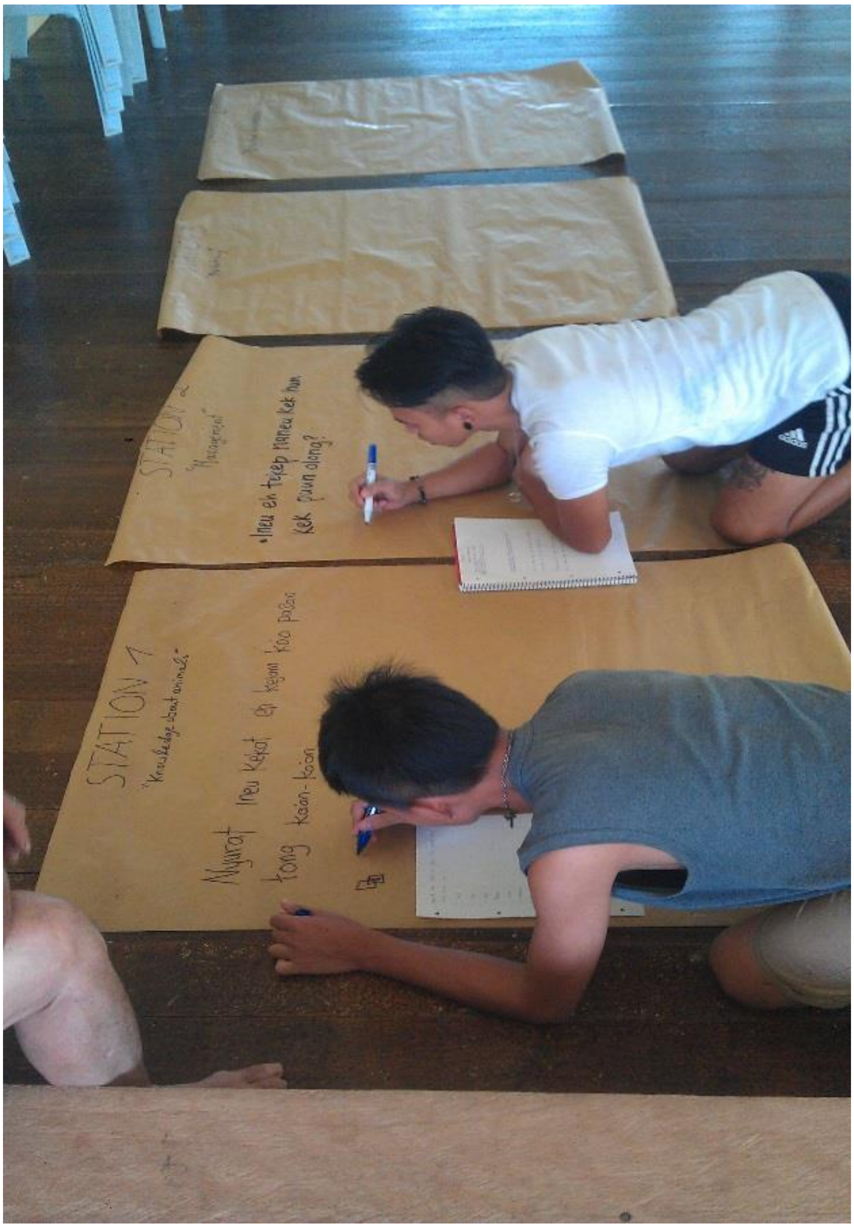

Figure 6: Youths preparing workshop posters; (Photo: MH)

Figure 7: Task group during workshop; (Photo: MH)

<u>Identification of potential fodder plants</u>

Potential fodder plants, available in Long Lamai, were spotted and recorded during the transect walks with the locals. Many plants were recognized by the Penan and plants, unknown by name to all participants of the transect walk, were identified by use of botanical literature. In addition to it, the goat breeder was of great assistance to identify more plants and also to state the suitability as potential fodder plants. Subsequent to the identification of the recorded plants, the suitability as potential fodder plants were controlled and verified by consulting relevant specialized literature. Merely a few plants were indeterminable, though the suitability as fodder plants were confirmed by the goat breeder.

4.2.2 Data analysis

In preparation for the on-site data collection in Sarawak, as well as afterwards, scientific literature was selected and surveyed regarding comparable animal husbandry of small ruminants in tropical regions. Local conditions were considered and assessed by means of external sources of information. Therefore, the information was divided in different aspects of animal husbandry, as, for instance, health management and production systems, as well as breeding, housing and feed resources, to ensure an all-encompassing overview. Due to the fact that animal husbandry in Long Lamai or in the neighboring villages is non-existent, information, knowledge and experiences are not available. The best opportunity is the comparison with small ruminant husbandry under similar environmental conditions. Small-scale farming of small ruminants under comparable environmental conditions, particularly in Indonesia, Thailand and Western Malaysia, outlines possible circumstances of goat keeping in Long Lamai. The comparison gives an overview about potential challenges, issues and prospects. Additionally, the data analysis via literature review is supported by the expertise and experience of the interviewed veterinaries and the goat breeder.

The interviews with the veterinaries and the goat breeder were briefly written down and subsequently analyzed and recorded in detail.

Obtained information by interviewing veterinaries and the goat breeder was collated and controlled with analyzed scientific literature, as well as with the circumstances in Long Lamai. The aim of the collation on site was to survey specifically stated issues, challenges and obstacles by the veterinaries and the goat breeder regarding goat keeping in Long Lamai. In addition to it, it was a meaningful approach to check mentioned suggestions and possibilities.

During the transect walks, brief notes were recorded and shortly discussed by the participants of the walk. After the transect walk, the recorded notes as well as emerged issues were exhaustive discussed and documented by a protocol.

The answer sheets of the workshops with the youth group and the women association were analyzed and recorded in written form. Specific issues, especially regarding the cultural identity and conventions were discussed afterwards with some community members in order to get a better impression and understanding.

Subjects of the meetings with community members interested in goat keeping were recorded and analyzed to gain information and to prepare the transect walks and the workshops concerning relevant issues.

Summarized, stated recommendations are made with the assistance of external specialized literature and its comparison with the data gained locally.

5. Results and Discussion

According to the interviewed veterinaries and statistical data from the department of agriculture (DOA) livestock farming in Sarawak is mainly focused on poultry and pork production, while the ruminant sector is still in its infancy. Information of the DOA estimated the livestock population in Sarawak as follows [DOA, 2014]:

Table 7: Extract of livestock population in Sarawak (2013)

	Pig	Chicken	Duck	Quail	Buffalo	Cattle	Goat	Sheep
Number of Animals	528.184	41.431.020	352.091	132.300	6.912	15.763	15.642	2.168

Source: Department of Agriculture Sarawak, [2014]: Livestock population statistics.

The reasons for the focus on pork and poultry production are many-faceted. Primarily, the high investment costs and the higher input deter the mostly small-scale farmers from raising ruminant livestock. Additionally, pigs and poultry are easier to rear in comparison to cattle or goats. Sarawak relies heavily on the import of live animals, beef, goat meat, mutton, and dairy products from Australia and New Zealand to meet the demand of domestic consumption and the processing industry.

To overcome the dependence on imports, the DOA initiated a livestock development program (Manual Program Pembangunan Ternakan) in order to promote and assist both progressive and rural farmers to keep ruminant livestock. Though, merely for proven farmers with experience in the livestock sector.

In the following chapter, the results from the data collection, conducted during the feasibility study in Sarawak, will be presented and discussed together for the purposes of clarity and comprehensibility.

5.1 Animal production system

5.1.1 Labor capacity and feeding management

The availability of labor is one important factor when determining the production system of keeping goats. The extensive systems are less labor demanding and include different operation cycles as intensive systems. Hence it is significant to have an overview about the available labor capacity and the commitment of the prospective goat farmers in Long Lamai.

During a meeting (May 20, 2016) with interested parties and potential goat farmers, the high work load of keeping goats was discussed whilst taking into account the seasonal fluctuation of working peaks due to rice harvest and preparation of the rice paddies. The seasonal fluctuation of working peaks is presented in the table below (Table 8):

Table 8 Time schedule of rice cultivation Long Lamai

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Hill Paddy		RH				CF	BS	S				
Wet Paddy			RH				PP		S			

RH= Rice harvest CF= Cutting secondary forests BS= Burning weeds/stubble PP=Preparing ponds S=Sowing

The participants ensured that the nutritional adequacy and care of the goats during working peaks is not adversely affected. Either they want to involve their families more closely to support them or form groups of goat keepers to compensate deficits of labor. This statement is supported by the results of the workshops with the women association and the youth group. Both the youth and the women stated that they would assist to take care of the goats in case of working peaks. Nevertheless, they have no knowledge of required working operations, thus they got no prospect about the imminent work load. In this regard, the prospective and intended level of productivity was discussed to estimate the extent of rearing goats. The participants did not consider a limitation of rearing goats as necessary in terms of work load, working operations and resource input. Though, they considered the market as a potential limiting factor (see chapter 5.8).

The interviewed veterinary assistant (Division Miri), the assistant director of the veterinary division (Department of Agriculture, Sarawak) and a former veterinary of the division in Miri questioned the dedication of the Penan and their knowledge concerning the imminent work load. Admittedly, the interviewees prefer an intensive system of keeping goats to avoid parasite infestation and to increase the productivity of goats. However, they cast doubt on the practicability in Long Lamai due to the lacking experience and habit of an engaging daily work.

5.1.2 Feeding systems

The decision for or against a specific feeding system depends on various influencing factors, such as vegetation, climate, available quantity and quality of feed and water, as well as labor capacity and the availability of land [DEVENDRA AND THOMAS, 2002].

A transect walk (May 17-19, 2016) with locals was conducted to explore the surrounding area of Long Lamai regarding potential grazing areas and suitable locations for sheds. In total, 13 potential areas were recorded and evaluated with regards to their suitability and manner of use (Figure 8 and 9). Additionally, the distances from the village to the individual areas were measured and care was taken to avoid walking distances longer than 20 minutes. Short distances between the village and the potential grazing area/shed location guarantee a lower loss of working time and a quick availability in case of need. Therefore, every area is accessible within 15 minutes. Besides the walking distance, objects of investigation and decision criteria regarding the suitability of grazing areas, defined with the assistance of the locals, were the size of the several sites, their prevailing vegetation and topology surrounding conditions, as well as the availability of water. In addition to that, a possible integration of the goats into adjacent rice paddy plots was screened.

During additional transect walks (May 21-23, 2016) with locals and a goat breeder from Kota Samarahan, the suitability of the previously identified grazing areas was discussed and confirmed.

According to DEVENDRA [1986b] small ruminant stocking rates of extensive systems in tropical Asia are usually 1-4 head/ha. Thus, due to the relatively small size of the various spotted potential areas (range from approx. 440 to 9200 m^2) (Table 9), apart from area 1 (26306 m^2), and the partially great value of the land for crop cultivation, an extensive systems should be avoided.

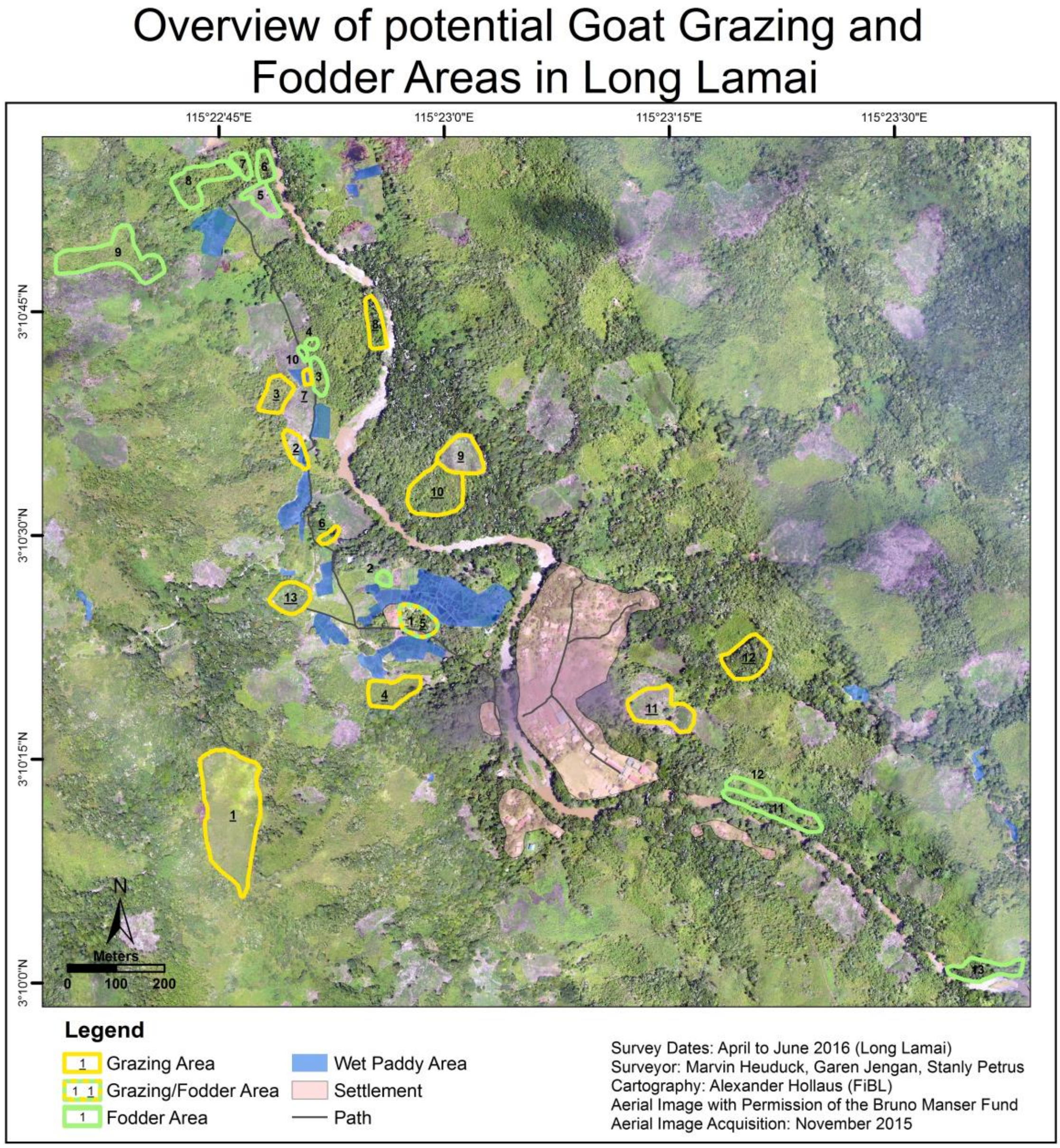

Figure 8: Potential goat grazing and fodder areas in Long Lamai (aerial)

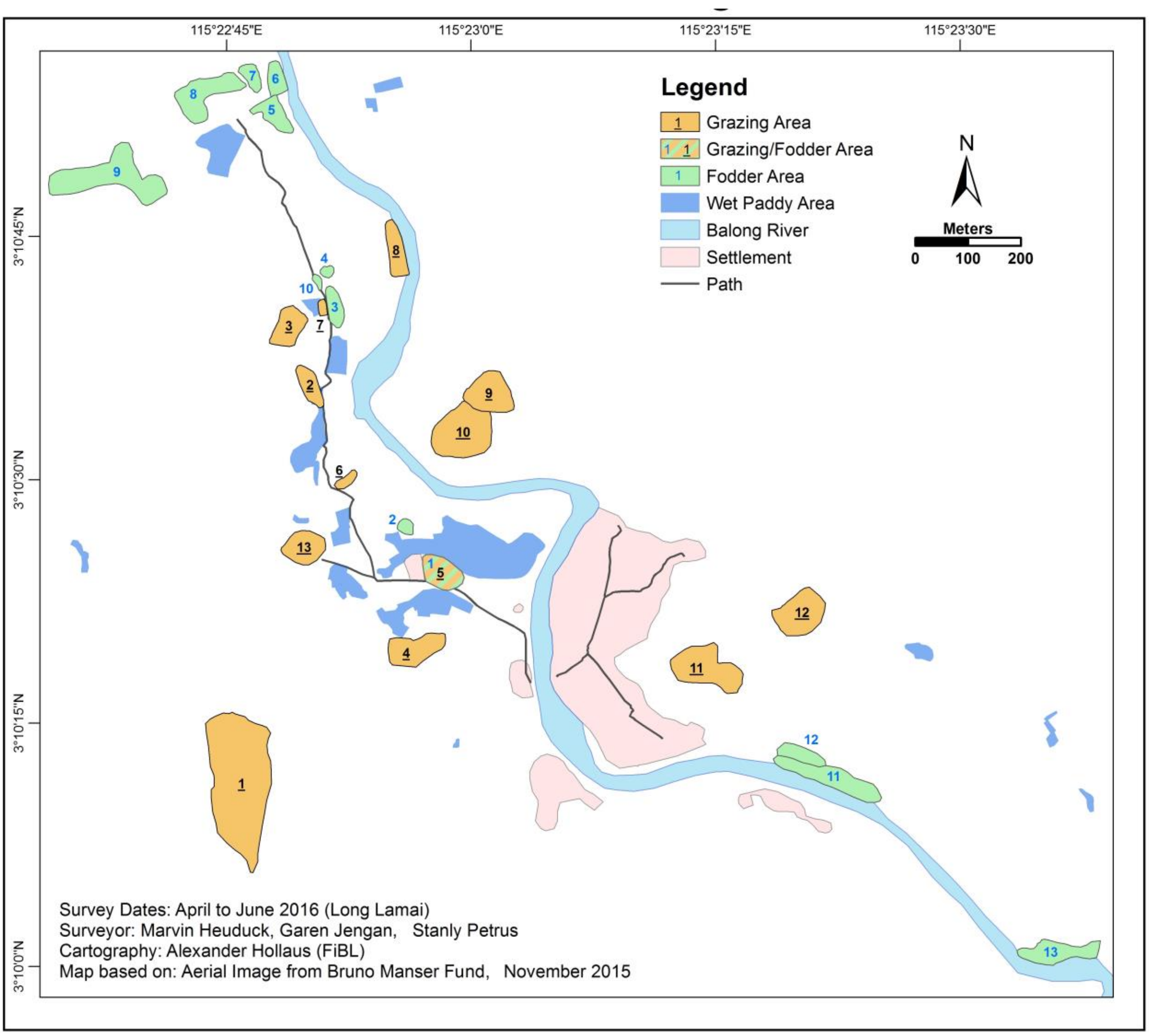

Figure 9: Potential goat grazing and fodder areas in Long Lamai

Table 9: Size (m^2) of the identified grazing areas

Grazing area	Area size (m^2)
Area 1	26306,0
Area 2	2331,3
Area 3	3518,7
Area 4	4882,5
Area 5	3777,4
Area 6	785,8
Area 7	443,2
Area 8	3049,0
Area 9	5438,5
Area 10	9196,1
Area 11	7853,7
Area 12	6127,5
Area 13	3936,8

An extensive pasture-based system is characterized as a system with low labor demand and low input, which is probably quite appropriate for the unexperienced Penan in terms of animal husbandry and missing knowledge. However, besides the insufficient size of the surveyed areas, the humid tropical climate with heavy rainfall is another constraint for an extensive system [DEVENDRA, 1993a; MCMILLIN ET AL., 2012]. Conformable to CHANIAGO [1993], DEVENDRA [1993], AGROMISA [2015] and statements of the assistant director of the veterinary division, exposition of goats to wet conditions is not desirable due to several reasons. The combination of the hot humid climate and extensive grazing facilitates is likely to lead to an increased risk of infestation with parasites and permanent free grazing may be risky due to predators such as snakes. Therefore, an extensive system of keeping goats is unfavorable. *Area 1* is relatively large in comparison to the other areas and a semi-extensive system seems to be practicable due to its vast extent. However, Lalang (*Imperata Cylindrica*) and Irop (*Scientific name unknown*) are the prevailing plants in this area and an indicator for low soil quality. Thus, a cultivation of alternative grasses and shrubs with sufficient quantities and quality of biomass for an (semi-) extensive system seems not to be feasible. Solely *Imperata Cylindrica* as feed source is not sufficient as a result of the low nutritional quality [FALVEY AND ANDREWS, 1979; SOEWARDI AND SASTRAPIPRADJA, 1976]. Regardless of the size of the area and the flock, an extensive pasture-based system is not an appropriate production system for the introduction of goats in Long Lamai due to the abovementioned factors.

Figure 10: Grazing area 1 (Partial view 1)
In the foreground Imperata Cylindrica, in the background secondary forest (Photo: MH)

Figure 11: Grazing area 1 (Partial view 2)
Foreground: Imperata Cylindrica, transition area: Irop, background: secondary forest (Photo: MH)

An (semi-) intensive feeding system seems to be suitable for the abovementioned limited availability of land. This is further reinforced statements of the assistant director, who stated that an (semi-) intensive system guarantees a maximum protection against environmental factors, such as the prevalent hot humid climate, parasites or predators. In regions with a similar climate as in Long Lamai, protection of small ruminants against the frequent and heavy rainfalls is required. Besides the goats getting wet, soaked soils, caused by heavy rainfalls, can pose a threat to the goats. Beyond that, the (semi-) intensive system ensures a quantitatively and qualitatively better provision of feed through the farmer. It enables the farmer to control the feed intake and to supplement as necessary. Furthermore, a permanent or close to permanent housing of goats facilitates the control and monitoring of the flock and individuals concerning mating, care and health management issues [AGROMISA, 2015; CHANIAGO, 1993; DEVENDRA, 1993a; HARYANTO AND DJAJANEGARA, 1993; MCMILLIN ET AL., 2012]. However, an (semi-)intensive system has a higher labor demand and requires a higher input of resources in comparison to an extensive feeding system.

The intensive system, preferred by most of the interviewees of the several departments of agriculture, implicates a zero-grazing approach, while a semi-intensive system would imply grazing for 2-4 h/day depending on weather conditions and availability of labor. This approach is endorsed by the veterinary officer of the agricultural department in Kota Samarahan and the visited and interviewed goat breeder, who also pursues a semi-intensive approach at his farm. They argue that a

temporarily granted grazing period of a couple of hours per day enables the goats to pursue their natural feeding behavior and habits. Additionally, it reduces the amount of feed, which must be provided during the housing period.
According to the farmer, he provides feed three times per day plus 1-2 hours of outside grazing. Fodder is provided in troughs or leaves hanging down from the ceiling. In case of rainfall, he stores the fodder the day before in the shed to avoid it getting wet and thus causing bloat or diarrhea. The composition of provided fodder is a variety of different leaves and chopped banana peels in the course of the day.
In the case of a temporary grazing period, attention must be paid to the separation of goats to avoid uncontrolled mating. The goat breeder also emphasized the importance of an appropriate duration of housing after rainfall to ensure the drying of the pasture with regards to parasite infestation and the emergence of bloat and diarrhea. An excessive duration of the grazing period would also adversely affect the mostly small pastures in terms of faecal egg shedding and overgrazing. Apart from excessive grazing, a balanced stocking rate is also necessary to avoid high parasite burdens, overgrazing and overcrowding. Stocking rates are, among others, determined by the prevailing production system. DEVENDRA AND BURNS [1983] stated feasible stocking rates of 16-60 goats/ha in an intensively managed pasture. Continuously grazing over a period of 16 weeks of the Malaysian Katjang goat with a stocking rate of 60 goats/ha was also reported by CHEN AND DEVENDRA [1990]. Stocking rates in a semi-intensive system with short grazing periods of a few hours per day may be higher. It also depends on the condition of the pasture and its vegetation. The size of the goat breeder's pasture is one acre ($4048m^2$) for currently 70 goats. The smallest spotted potential grazing area is area 7 ($443.2m^2$). Adjusted to the stocking rate of the goat breeder and in case of an adequate pasture management area 7 can support a flock size of 7-8 goats.
With regard to an (semi-) intensive system, the integration of a couple of potential grazing areas with tree cropping seems to be possible and reasonable. The areas 5, 10, 12 and 13 (Figure 8) feature a prevailing vegetation of perennial fruit trees, as, for instance mango, lasat, rambutan, jackfruit, guava or Durian. The fruit tree areas are sparsely used and managed by the Penan, but yet represent an essential source of food. The integration of goats, by grazing the understory of the native vegetation or potential leguminous cover crops is associated with several advantageous side-effects, inter alia increased soil fertility or beneficial soil activity of legumes. Conversely, the fruit trees provide shade against the sun and a certain protection from rainfall [DEVENDRA, 2005; DEVENDRA AND THOMAS, 2002]. Area 10 is characterized by a dense and impenetrable shrub layer, which impedes an effective utilization of the area and the understory. Appropriate clearing of the dense shrub layer is urgently required in order to integrate goats into tree cropping, whereas the areas 5, 12, as well as area 13 have merely a widely scattered shrub layer and predominantly small grasses and ground-cover

plants. Accordingly, all four areas require a reconditioning and improvement of the understory to ensure an adequate integration of goats into tree cropping. Upon request, the locals assured the feasibility of clearing the mentioned area and the cultivation of potential fodder plants. However, the water stream next to area 12, which has been proven supposedly disadvantageous for a sufficient supply of water during dry periods due to a remark of the locals, has to be observed under corresponding conditions. The locals were uncertain about the actual water supply of the stream during dry periods and suggested to ascertain the conditions more precisely. Under specific circumstances, storage of water in tanks is possible to overcome the dry periods with low rainfall (see Chapter 5.4).

5.1.3 Food-feed-cropping systems

Besides integration into tree cropping, another opportunity to successfully introduce and establish goats in Long Lamai seems to be the implementation of food-feed-cropping systems. Intercropping or relay cropping are potential possibilities to generate adequate crop yields for animal consumption. In addition, inter- or relay cropping facilitates to enhance the soil fertility through suitable feed crops, as legumes, and thus to increase the yield for food crops (e.g. rice). Similar to the options of inter- and relay cropping mentioned in the literature review [DEVENDRA, 1993a, 2000; DEVENDRA ET AL., 2000, 2001], a combination of rice with groundnut (*Arachis hypogaea*) or various leguminous forages (e.g. peas) is also practicable in Long Lamai. The community of Long Lamai is already cultivating several leguminous food crops (Appendix VI) for their own consumption, thus the knowledge and the necessary seeds to cultivate these plants are available. Cultivated *Arachis hypogaea* was spotted in the adjacent village, named Long Banga, which is inhabited by Kenyah, Saban and Kelabit. The cultivation of *Arachis hypogaea* in Long Lamai is unknown, but feasible. Aside from the positive effects, as nitrogen fixation, on the upland rice yield (hill paddy), a combination of food and feed crops via inter- or relay cropping, may also increase the yield of further food crops. The leaves, vines and pod husks of *Arachis hypogaea* or other legumes, such as peas and beans, can be used as fodder, whereas the actual fruit of the leguminous plant is usable for human consumption. Rice is the most important useful plant for the Penan and the basis of their livelihood, therefore an enhancement of growth conditions and increase of annual yields is desirable, especially for the reason that upland rice (hill paddy) in Long Lamai suffers from continuously low yields due to degraded and overused soils [WEISSHAIDINGER ET AL., 2012]. Intercropping with various legumes may be an opportunity to achieve this target with simultaneous increase of the feed yield to supply the goats. Additionally, non-leguminous crops, such as cassava or maize, are suitable for intercropping with rice, but do not have the same effects on the soil as legumes [DEVENDRA, 1993a, 2000].

The contour bunds of the lowland rice (wet paddy), on the contrary, are suitable for planting feed crops. Forage production along the paddy bunds is another possibility to produce quantitatively more fodder for goats [DEVENDRA ET AL., 2001; SINSINWAR, 1996; VICTORIO AND MOOG, 1995]. In Long Lamai, the rice bunds are mostly unmanaged and covered with weeds. The cultivation of (multipurpose) vegetables or grasses along the bunds facilitates a productive utilization accompanied by a potential to promote ecological plant protection. Various vegetables, as, for instance cowpea (*Vigna unguiculata*), can be used as a multipurpose plant. On the one hand, they serve as food and feed crops for human and animal consumption. On the other hand, they can reduce rice pests by providing a diverse habitat for beneficial organisms or natural enemies to rice pests and serving as biological barriers. Besides vegetables, grasses, such as sour grass (*Paspalum conjugatum*) or blue panic grass (*Panicum antidotale*), are also suitable for cultivation along rice bunds and can be harvested for animal consumption. Direct feeding by grazing may be risky due to possible trampling damage. In consequence of the intensified focus on lowland rice in Long Lamai and the related increase of rice bunds, the cultivation of feed crops along the bunds, seems to be logical and reasonable.

Both upland and lowland rice paddies in Long Lamai are arable for a rice-fallow rotation. However, rice fallows after harvest are currently unmanaged and lie idle. Hence, a good opportunity to improve the soil conditions and to produce further crops remains unused. Rice fallows can be used for cultivation of leguminous forages to provide additional fodder for goats or to increase soil fertility. Free roaming of the goats or a cut-and-carry approach are possible ways to use the additional forage [BURGERS ET AL., 2005; METZNER, 1983]. Leguminous plants are predestinated for the cultivation after rice due to the beneficial effects, such as nitrogen fixation. Potential legumes for a rice-fallow rotation, available in Long Lamai, are inter alia *Psophocarpus tetragonolobus, Vigna unguiculata, Vicia faba and Arachis hypogaea*. The fallow benefits from free roaming of goats by direct application of dung and urine. Though, excessive grazing onto the fallow may lead to soil compaction due to trampling and overgrazing of the young fallow [BURGERS ET AL., 2005].

Apart from a rice-fallow rotation, the rice field can be used for stubble grazing by the goats after harvest. The crop residues of rice may be a significant proportion of the goat's diet [DEVENDRA, 1986a; HARYANTO AND DJAJANEGARA, 1993]. In this regard, the potential integration of goats into the rice fields was studied during a transect walk with locals (May 27, 2016). Thereby the localities of potential grazing areas/shed locations were evaluated in terms of adjacent rice fields. Except for area 1, 8 and 10, all other areas are suitable for a temporary integration of goats either into upland or lowland rice fields. Area 9, 11 and 12 are next to hill paddies, whereas area 2, 3, 4, 5, 6, 7 and 13 are adjacent to wet paddy plots. After harvest a temporary integration of goats into the rice fields is possible to graze residues such as rice straw. The advantage of this measure is to benefit from the abundance of rice residues due to the large amounts of cultivated rice in Long Lamai, as well as the direct return of dung and urine from goats [AGROMISA, 2015; DEVENDRA, 1986a; CHEE AND PENG, 2006]. Based on the relatively small size of the rice fields, the grazing period should also be limited. Upon request, the locals assured the feasibility of the integration in reference to rights of land use. The adjacent rice fields are either in possession of the owner of the respective grazing area/shed location or at least owned by the family. Hence, the time-limited integration of goats into rice paddy plots, without claims of ownership, is an appropriate measure in view of a semi-intensive system to improve feeding and nutrition of the goats.

In summary, it can be stated that a semi-intensive feeding system, characterized by primarily stall-feeding and temporary access to a grazing area, is the most appropriate approach for the establishment of goats in Long Lamai. In this connection, the temporarily limited access depends on current weather conditions and the availability of potential grazing areas. The abovementioned 13 areas, integration into rice fallows or a rice-fallow rotation, as well as integration with tree cropping are suitable opportunities to introduce a successful mixed farming system. In addition, intercropping and forage production on rice bunds also facilitate the establishment of an effective food-feed cropping system and thus a sufficient provision of fodder.

5.2 Feed resources

The first field walks with locals to explore the surrounding of Long Lamai and to get a rough overview about the vegetation were carried out during the 06.-08. April 2016. Already known plants were recorded, new plants identified and indefinable plants were collected for a subsequent identification using literature and interviewing specialists. During the stay at the goat farm of Ahmad Bin Awang Ali in Kota Samarahan, further potential fodder plants or already in Long Lamai collected, yet undefinable, were identified and recorded through his explanations. In addition, the suitability and range of application, in terms of feed resource and medical plant, were discussed, together with preparation and provision of the fodder.

Besides various tree leaves, native grasses and vines, crop residues as chopped banana peels are part of goat's diet at the farm. Upon request, the goat breeder negated the occurrence of seasonal fluctuation regarding the fodder availability. Merely in the event of flooding fodder shortages may occur. The chopped banana peels can be stored up to 5 days and daily use as goat feed is acceptable. Chopped banana peels are an effective and cheap possibility to feed goats in Long Lamai due to the high availability of banana plants (*Musa spp.*) and fruits.

Furthermore, the goat breeder stated the positive effects of several fodder plants on does after giving birth. No specific details regarding the causing effects of these plants were made. Inter alia the leaves of *Zingiber spp., Merremia peltata, Uncaria lanosa var. ferrea, Artocarpus scortechinii* and *Manihot esculenta*. In addition to it, the leaves of cassava (*Manihot esculenta*) are used against internal parasites (see Chapter 5.5.3).

With the assistance of locals during several transect walks (April 28-30, 2016) and subsequent resource mapping the occurrence and partially the quantity of fodder plants in the surrounding of Long Lamai were recorded (Appendix VI). Focus of these walks was the recording of larger accumulations of fodder plants within a walking distance of maximum 20 minutes. 13 areas were listed, which are all located around the village in order to ensure an evenly distribution of fodder spots regardless of future grazing areas/shed locations. A more precise statement with regard to the quantity of available fodder is not possible, due to the vast extent of the area around the village and the conglomeration of different fodder plants and their wide spreading. Some spots had a homogenous vegetation regarding the prevailing fodder plants. In this case, it was possible to measure the area of the feed resources by estimating the vegetated surface area. In accessible areas it was also possible to count the cultivated fruit trees. These fodder spots are mainly characterized by Wild ginger (*Zingiber spp*.), Sugarcane (*Saccharum officinarum)*, *Pennisetum purpureum*, *Imperata cylindrica* and several fruit trees, as, for instance Jackfruit (*Artocarpus heterophyllus*), Guava (*Psidium guavara L*.), Lasat (*Lansium domesticum Jack*) or Rambutan (*Nephelium lappaceum*). Especially area 1, 12 and 13 consist of a large diversity of fruit trees (Table 10). Area 12 is the largest fodder spot of diverse fruit trees, which are suitable as feed resources (Appendix VI), with approximately 65 trees of 10 different types. Area 5 and 11 are areas of cultivated banana plants (*Musa acuminata*) with more than 300 plants, 40 plants, respectively. Remarkable is the extent of banana plants in area 5 and the low utilization. The area, known as *banana garden*, is freely accessible for the community and not a subject to rights of ownership. Whereas area 11, 12 and 13 are in possession of community members, who are not involved in the goat project. However, the locals assured that an agreement for the purpose of utilization is achievable.

Table 10 Identified fodder areas and the prevailing fodder plants

Fodder spot	Prevailing fodder plants
Area 1	Jackfruit (11), Guava (9), Lasat (3), Rambutan (3), Pineapple
Area 2	Fallow area; predominantly Lalang (*Imperata cylindrica*)
Area 3	Tap-Birai (*Artocarpus scortechinii*)
Area 4	Cowpea (*Vigna unguiculata*)
Area 5	Cultivated banana plants (*Musa spp* .) (>300)
Area 6	Wild ginger (*Zingiber spp* .)
Area 7	Tap-Birai (*Artocarpus scortechinii*)
Area 8	Beripun (*Artocarpus odoratissimus*)
Area 9	Wild ginger (*Zingiber spp* .)
Area 10	Napier grass (*Pennisetum purpureum*)
Area 11	Cultivated banana plants (*Musa spp* .) (35-40)
Area 12	Lasat (11), Rambutan (11), Mango (8), Malei (*Litsea garciae*) (8),Papaya (6), Durian (6), Jackfruit (5), Ice cream bean (4), Kedondong (*Spondias spp* .) (4) Betel nut (3), Coconut (3), Wild ginger (*Zingiber spp* .) (5)
Area 13	Rambutan (8), Malei (*Litsea garciae*) (6), Kedondong (4), Lasat (4), Durian (3)

(n) = quantity of plants

During the transect walks high quantities of various potential fodder plants were detected and recorded along the tracks by estimating the vegetated surface area, inter alia giant swordfern (*Nephrolepis biserrata*), midin (*Stenochlaena palustris)*, torpedo grass (*Panicum repens*) and blue panic grass (*Panicum antidotale*), as well as many spots of pineapples (*Ananas comosus L Merr*.).

Several exotic potential fodder plants, as vetiver (*Vetiveria zizanioides*), gliricidia (*Gliricidia sepium*), ice cream bean tree (*Inga Edulis*) and guatemala grass (*Tripsacum andersonii*), were introduced to Long Lamai by previously locally conducted projects. Besides the just mentioned exotic plants, many other fodder plants are located directly in the village, as, for example various fruit trees, cassava, *Kyllinga spp*. and wild hibiscus (*Hibiscus spp*.).

In addition, the locals cultivate several food crops for their own consumption, which are also suitable for utilization as goat feed, such as cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), taro (*Colocasia esculenta*), sugarcane (*Saccharum officinarum*), winged bean (*Psophocarpus tetragonolobus*) and cowpea (*Vigna unguiculata*). In view of the utilization of these crops, either as food or feed, conflicts of use may occur. The abovementioned food crops are important staples of the Penan in Long Lamai and thus significant for an adequate nutrition. An intensified use as feed may lead to deficient or unbalanced nutrition of people, as well as . However, sharing of these crops to mutual benefit is possible. Vines, leaves, pod husks, tubers, as well as stalks are usable as fodder.

Moreover, an enlarged cultivation of these crops is feasible due to the abovementioned food-feed cropping approaches. Upon request, the locals stated that conflicts of use would be improbable because of the high diversity of fodder plants and the high priority of the goat's well-being.

Nevertheless, conflicts of use are a significant issue in view of the goat's diet and should not be neglected. The excessive utilization of fruit trees (leaves) and crops (vines, leaves, etc.) as goat feed may adversely affect the availability of food for human consumption. Therefore, a balanced and adapted utilization is essential and an additional cultivation of fodder plants reasonable.

On the transect walks (May 21-23, 2016) with locals and the goat breeder from Kota Samarahan to prove the suitability of the identified grazing areas, more potential fodder plants were identified and recorded, as, for instance *Litsea garciae*, *Molastoma polyanthum* and *Conyza spp*.. In addition to it, further plants were spotted, which are, according to the goat breeder, suitable as fodder plants. Specific information regarding palatability or nutritiousness was not provided. These grasses were undeterminable, thus a statement concerning the botanical designation is not possible. The plants are called by the Penan as *Bahang, Ureu Jipun* (Figure 11), *Ureu Kemanen* (Figure 12) and *Ureu Bankut*.

Figure 12: Assumed fodder plant (Penan: Urei Jipun) (Photo: MH)

Figure 13: Assumed fodder plant (Penan: Ureu Kemanen); (Photo: MH)

Summarized, the surrounding of Long Lamai includes 61 different potential fodder plants. Made up of both more than 10 grass and more than 10 fruit tree species, as well as several ferns, shrubs and bushes, among them 8 leguminous fodder plants. The range of edible plant components comprises inter alia leaves, vines, fruit waste, stalks and tubers. Especially, grass and fern species occur in high abundance. In addition, fruit trees as banana (both wild and cultivated) or jackfruit (*Artocarpus heterophyllus*), as well as wild ginger (*Zingiber spp*.) are frequently found. Whereas several fodder plants, particularly the introduced exotic plant species, as gliricidia (*Gliricidia sepium*), vetiver (*Vetiveria zizanioides*) and the ice cream bean tree (Inga edulis) are of low abundance. An enhanced cultivation of these scarce species and thus a higher availability, especially of the leguminous *Gliricidia sepium*, may contribute to the upvaluation of the goat's nutrition. Though, it remains to be seen to what extent the Penan of Long Lamai follow this recommendation or if they simply utilize the already available fodder plants.

In view of the vast variety of potential fodder plants, 61 different species seem to be adequate to ensure a balanced diet for goats in the event of appropriate feeding management. Basically, a balanced diet is defined by satisfying energy and nutrient requirements. In case of goats, it is also important to consider the versatile feeding habits and the selective behavior. In this particular case, diverse tree leaves and grasses are available in high quantity and provide, in addition to fruit wastes and crop residues as rice straw, the basis for the goat's diet. Especially the absence of seasonality, with regards to foliage and maturity of fruits, ensures a year-round provision with a large variety of fodder. Merely a few fruits, as for instance pineapple (*Ananas comosus L Merr*.) and durian (*Durio zibethinus*) are seasonal. Consequently, seasonal fluctuation is almost to negligible.

The utilization of most of the recorded plants as adequate goat feed is scientifically proven, solely a few potential fodder plants are listed due to the statement of the goat breeder, particularly, the plants, which were undeterminable.

The combination of tree leaves, grasses, ferns, fruit waste and crop residues are appropriate to create a varying diet containing all necessary nutrients. However, in some cases the provision of specific tree leaves must be regulated and limited due to contained condensed tannins, which may adversely affect the goats [WANAPAT, 2009].

The availability of 8 leguminous fodder plants is additionally sufficient to provide protein for the goats. Though, the leguminous plants are subject to an enhanced cultivation to ensure an adequate provision and availability, due to the fact that they are currently merely cultivated in small amount for human consumption. Higher amounts of legumes are necessary to supply goats sufficiently all the year round without causing conflicts of use. Thus, as abovementioned, intercropping or rice-fallow rotations may be suited approaches to increase yields of leguminous feed crops, as groundnut (*Arachis hypogaea*) or cowpea (*Vigna unguiculata*). Furthermore, the integration and cultivation of gliricidia (*Gliricidia sepium*) into potential grazing areas is another possibility to improve the provision with protein containing plants without provoking usage conflicts. Apart from that, the integration of trees, shrubs and bushes into grazing areas also facilitates to meet the goat's feeding behavior and habits. Therefore, if possible, grazing areas should contain several shrubs and trees for permissive browsing. In case of the integration of trees, it is significant to consider that the growth of trees takes time. Thus, the utilization of the already existing stock of trees and cultivating new trees will be advantageous.

In reference to a zero-grazing/cut-and-carry system, the surrounding of Long Lamai provides a sufficing diversity of feed to supply the goats. The sufficiency and year-round availability of fodder, admittedly depends on flock size, but yet the absence of seasonality and thus of seasonal fluctuation, as well as the possibility to cultivate more feed crops and the high abundance of fodder plants lead to the conclusion that a sufficient and balanced nutrition of goats would be ensured. In case of an energy deficit, the production of concentrate supplements is an appropriate measure to overcome this lack (see Chapter 5.3). Besides the harvest of fodder plants for a cut-and-carry system, crop residues as banana peels or rice straw are also suitable.

A semi-intensive system, characterized by temporary grazing, comprises, besides the mentioned stall-/hand-feeding, an adequate grazing area to meet the goat's requirements. In the surrounding of Long Lamai, several grass species are both suitable and available. Though, solely cogon grass

(*Imperata Cylindrica*) is the only area-covering grass species in the surrounding of Long Lamai. Other species, as sour grass (Paspalum conjugatum) or torpedo grass (*Panicum repens*), are available in high abundance. However, potential grazing areas are not covered with these grass species. *Imperata cylindrica* is a suitable fodder plant, though it is of low quality and the palatability is questionable. This is stated by FALVEY AND ANDREWS [1979], as well as by the assistant director of the Veterinary Division, who questioned the intake of *Imperata cylindrica* by goats.

Additionally, *Imperata cylindrica* is an indicator of poor soil conditions, thus a cultivation to enhance this area may be difficult [FALVEY AND ANDREWS, 1979; SOEWARDI AND SASTRAPIPRADJA, 1976].

As a result, the cultivation and the partial establishment of fodder plants in the recorded potential areas is necessary to provide appropriate grazing areas with regards to diversity and quantity of fodder plants. Improved pastures, made up of mixtures of native grasses (e.g. *Paspalum conjugatum*) and exotic forage grasses (e.g. *Pennisetum purpureum*), as well as smaller trees (e.g. *Gliricidia sepium*), larger fruit trees (*Artocarpus heterophyllus*) as sun protection, and shrubs (e.g. *Uncaria lanosa var.ferrea*), are predestinated to meet the requirements of goats concerning their feeding behavior and habits, as well as the requirements of an optimal nutritional supply.

As abovementioned, a quantification of the available feed amount is difficult due to the heterogeneous distribution of the fodder plants and inadequate measuring equipment. However, the stated number of fruit trees, the spotted fodder areas and the general high aboveground biomass of the secondary rainforest surrounding Long Lamai, lead to the conclusion that the quantity of available fodder will not be an exclusion criteria regarding goat keeping. Exact data regarding the aboveground biomass (AGB) around Long Lamai in view of potential feed resources is not available.

Nevertheless, the fodder quantity is an important limitation factor of the manageable flock size. Notwithstanding the significance of the fodder amount, the limitation of the flock size of goats in Long Lamai will be effected more strongly by other factors. In general, it can be assumed that at least at the beginning, during the initial phase of an introduction and establishment of goats, the number of goats in Long Lamai will be relatively small (10-20 heads) with solely one sire

It can be stated that the feed resources, with regards to quantity and diversity, will be no challenging issue of the introduction and establishment of goats in Long Lamai. Solely conflicts of use may be a threat, though, which can be easily avoided as mentioned previously.

5.3 Feed supplementation

Feed supplementation in Long Lamai, by purchasing supplements must be considered as problematic due to the low financial resources of the locals and the remoteness of the village. Nevertheless, feed supplementation with hand-made supplements is possible to a certain extent. During the stay at the goat farm in Kota Samarahan, the suitability and the potential of copra cake and sago meal were discussed with the farmer.

Both coconut tree (*Cocos nucifera*) and sago palm (*Metroxylon sagu*) are available in the surrounding of Long Lamai and thus a potential feed supplement.

Copra cake, made by dried meat/kernel of the coconut, is a concentrate feed with high levels of dry matter (91%) and high-quality protein (18-30% CP) [AREGHEORE, 2006]. Coconuts are locally not available in abundance, yet under appropriate storage conditions and low moisture content copra cake can be stored for several months. Thus building up stocks in case of feed shortages is possible.

Additionally, sago meal is another potential concentrate feed available in Long Lamai. According to the goat breeder, shredded sago trunks have to dry for at least two days. Stored in sacks, it lasts for about six months. Under the hot, humid climate prevailing in Long Lamai and possible impurities during the processing, the credibility of this assertion regarding the duration of storage seems to be doubtful. In his statement he assured that sago meal (gross energy content of 170-180MJ/kg dry matter [YAHYA ET AL, 2011]) is especially good for pregnant and lactating does due to their high energy demand.

Salt and mineral licks are another important feed supplementation to meet the requirements of goats of a certain physiological status and productive performance. According to the statements of the goat breeder, who provides salt/mineral licks in every separate box of his goat shed, salt and mineral licks can be purchased for approx. 55RM (11.3€) at veterinary offices. Concerning the low financial resources and the remoteness of Long Lamai, the hand-made production of salt and mineral licks can be an appropriate alternative method. However, contents as salt or minerals must be purchased as well. In this regard, the assistant director of the veterinary division complained about the insufficient balance in terms of nutrient composition of hand-made salt and mineral licks. No literature is known regarding the disadvantageous imbalance of the nutrient composition of hand-made mineral licks. However, the stated concern about the insufficient balance seems to be comprehensible. Precise information and instructions must be provided to ensure a balanced nutrient composition. An instruction is provided by AGROMISA [2004] to construct a salt lick containing also other minerals by using bones, clay and salt.

Figure 14: Goat breeder Ahmad Bin Awang Ali rasps sago trunks; (Photo: MH)

5.4 Water

Reduced water supply can restrict feed intake and feed efficiency, and adversely affects reproduction, growth and milk production of goats [AGROMISA, 2004; KAWAS ET AL., 2011; QUINISA AND BOOMKER, 1998]. Therefore, an appropriate provision of water with regards to quality and quantity is essential. During the transect walks (May 17-19, 2016) to spot potential grazing areas and shed locations, the accessibility to water supply was also investigated. Distances to streams or rivers, as well as seasonal fluctuation of water availability and possibilities to taking the water were decisive criteria.

In most cases, according to the locals, the water supply by means of available water pumps is feasible. Merely area 1, 9 and 11 are, in some circumstances, unsuitable for adequate water supply. Either these areas are too remote or unfavorable located to pump up water from the stream/river to the shed. Area 12, as abovementioned, is located next to a relatively small stream, which may dry up during the dry period.

Water can be stored in unutilized water tanks, which are normally used for the water supply of the residential houses. Though, just a few water tanks, with a capacity of approximately 2,8m^3, are available and the acquisition costs to purchase additional water tanks are too high. Nevertheless, the available water tanks are a good opportunity for several areas to overcome drought periods to a certain extent. Long Lamai is located in the humid tropics with an average precipitation of roughly 300 mm per month [LAVILLE, 2008]. As already described in chapter 4.1, an actual dry season does not exist, solely drier periods with lower rainfall.

Usually, the streams carry clear water of good drinking water quality for goats. However, after heavy rainfall, the streams and the river carry a lot of water, which is muddy and of lower quality. Therefore, the water supply for one or two days should be stored in advance to avoid sedimentary drinking water.

According to the goat breeder, who provides water in several buckets in the shed, he has no determined quantity of water per day, and supplies as required.

5.5 Health management

Inadequate health management in case of diseases or parasite infestation may result in high economic losses due to reduced productivity or increased mortality of goats. Therefore, especially in Long Lamai, where veterinary care and diagnostic services are scarce and financial resources limited, preventive management measures to avoid infections and diseases, as well as alternative non-drug agents and traditional remedies are of high relevance. Vaccinations or anthelmintics are difficult to procure, thus alternatives, as, for instance the condensed tannins of *Manihot esculenta* [GRANUM ET AL., 2002; NETPANA ET AL., 2001; SOKERYA ET AL., 2009], have to fulfill these functions. In addition to it, the lack of knowledge of the community concerning symptoms, progression and treatment of diseases also intensifies the negative impacts of the deficient supply with veterinary care and diagnostic services. Thus, it is essential, aside from an adequate instruction regarding disease control, to introduce and establish preventive measures to avoid parasite infestation and diseases as good as possible. In case of occurring infections or diseases, effective alternative treatments are necessary to compensate the absence of drugs. In this regard, notably medical plants as traditional remedies are of particular importance. The therapeutic efficacy of several of these traditional remedies is unproven. Nevertheless, various communities and farmers in Southeast-Asia rely on these remedies [MATHIAS-MUNDY AND MURDIATI, 1991] and in some circumstances the potential goat farmers of Long Lamai have no alternative to medical plants to treat their infected goats. Consequently, the knowledge about these traditional remedies is beneficial even when the efficacy is not scientifically confirmed.

5.5.1 Prevalent diseases and metabolic disorders in Sarawak

The interviews with the mentioned staff members of the different departments of agriculture in Sarawak concerning the occurrence of diseases and parasite infestation, revealed that particularly infectious diseases as Brucellosis, Papillomatosis, Pasteurellosis (inter alia Hemorrhagic septicemia

(HS)), as well as Melioidosis and Caseous Lymphadenitis (CLA) are prevalent in goats. These statements are confirmed also by different authors [AGROMISA, 2015; GINTING ET AL., 1993; SANI ET AL., 2014].

In an interview the goat breeder stated that he never had any infectious diseases on his farm and the overall mortality rate is 0%. This statement seems very unrealistic under the given conditions.

Contagious diseases as Pasteurellosis are of utmost economic importance in the livestock sector of Sarawak due to the high morbidity and mortality. HS mainly occurs in cattle, but in Malaysia also HS-infections in goats are recorded [BENKIRANE AND DE ALWIS, 2002; OIE, 2013; SARAHEE AND FATIMAH, 1993]. Prevention and control of these infectious diseases should therefore be in the focus of the potential goat farmers in Long Lamai. Vaccination on a routine prophylactic basis is the major control measure to stop the spread of the diseases. Though, as antibiotics to treat the diseases, vaccinations are expensive and difficult to procure for the community. According to the interviewed veterinaries and the goat breeder, vaccination as a preventive measure is not necessary. In the district of Miri, the goat farmers use broad-spectrum vaccine approximately once a year. Consequently, the early identification of the diseases and an immediate separation of the infected animal to avoid further infections is of particular importance. In this regard, the significance of trained farmers is obvious. In the absence of veterinary services, the farmers are responsible for disease control and treatment of the goats.

In sum, contagious diseases are a major issue for the livestock sector in Sarawak and thus in Long Lamai, in the absence of veterinaries and trained farmers, it is an even more serious problem.

According to the statements of the veterinaries, abundantly occurring anemia is mainly caused by malnutrition and not by endo- or ectoparasites. This statement is in contradiction to findings of Zainalabidin et al. [2015], who documented the occurrence of tick-borne diseases in other parts of Malaysia. Therefore, the abundance of ticks in the humid tropical climate of Sarawak suggests that tick-borne diseases also occur in Sarawak. Metabolic disorders, as bloat or diarrhea, are quite common in Sarawak. Bloat is mainly caused by excessive intake of feedstuff with a high content of water or protein [GINTING ET AL., 1993]. The goat breeder indicated that at his farm notably leaves of *Musa spp*. and *Litsea garciae* cause bloat in goats. During rainy periods the goats stay in the shed to prevent the intake of too moist forage and thus the emergence of bloat. Acute bloat must be treated promptly, therefore, the assistant director of the department of agriculture in Sarawak recommends the utilization of defoaming agents administered by a trocar. Alternatively, a sharp knife or a bamboo stick, suitable for opening an incision into the rumen, are usable to relieve the bloat. Subacute bloat can be treated by anti-bloat capsules. Another low-priced possibility to treat bloat in a subacute case is the oral administration of cooking oil. Preventive measures to reduce the emergence of bloat are a balanced diet and an adequate pasture composition in case of (partial) pasture feeding. Increasing the fiber intake (e.g. rice straw) of goats will reduce bloating, as well as a balanced pasture composition of grasses and legumes [Agromisa, 2015]. Anti-bloat capsules or defoaming agents are, as all other medications, too expensive and not permanently available for the community of Long Lamai. Therefore, the abovementioned preventive management measures and, in case of (sub)-acute bloat the penetration of the rumen through a knife or bamboo stick and the oral administration of cooking oil, are recommended. Upon request, the goat breeder ascribed the emergence of diarrhea at his farm to a sudden change of the diet from dry roughage to wet forage. Information about diarrhea caused by infections at his farm is unknown. However, it is reasonable to assume that diarrhea caused by infections also emerges. Especially kids less than five months of age are susceptible and affected by coccidiosis, a common cause of diarrhea [Zainalabidin et al., 2015]. Good husbandry practices, as providing clean water, removal of manure and regular cleaning of the shed, are the best preventive measures to avoid diarrhea caused by infection. Besides preventive measures and drug agents, traditional remedies (Appendix V), as, for instance the leaves of the papaya tree (*Carica papaya*), are also useful and abundant in Long Lamai to treat bloat and diarrhea.

5.5.2 Occurrence of ectoparasites

Ectoparasites, as ticks and scabies, are, according to the veterinaries and the goat breeder, common in the sector of goat production in Sarawak and cause reduced productivity regarding weight gain, reproduction and milk yield. Dorny et al. [1994] estimated prevalence of *S. scabies* to be 55.8 % among goats in Peninsular Malaysia. To avoid infestation with mites and ticks, the goat breeder refuses young goats' admittance to the pasture until the age of approximately four months. Additionally, the shed floor is regularly cleaned with antiseptics and detergent agents. Goats are checked nearly every day for parasites and in case of parasites infestation all goats are imbrued with a detergent against ectoparasites. The utilization of traditional remedies seems also in this regard to be a beneficial and inexpensive treatment measure. Coconut meal (*Cocos nucifera*), tubers of *Manihot esculenta* and the root of *Derris elliptica* for example, are plant parts, which are assumed as advantageous in case of scabies infestation [ISRN, 1991].

5.5.3 Gastrointestinal parasites

Apart from bacterial diseases as Pasteurellosis or Brucellosis, the infestation with gastrointestinal parasites is the major issue of goat production in Sarawak. According to the veterinaries of the departments of agriculture in Sarawak, endoparasites as *Haemonchus contortus*, *Trichostrongyles spp*. and *Eimeria spp.* are widely spread and cause severe economic losses. The humid tropical conditions in Sarawak, as well as overcrowding, inadequate nutrition and insufficient preventive measures facilitate the development and spreading of these pathogenic nematodes. Anthelmintic agents to control and treat the infestation with gastrointestinal parasites are common in the livestock sector. However, according to the veterinaries, resistance against anthelmintic agents is also a distributed common problem in Sarawak and an effective treatment of endoparasite infestation is difficult and costly. This statement is congruent to various findings in literature, which recorded a high occurrence of parasitic resistance in Malaysia [DORNY ET AL., 1993, 1994, 1995; CHANDRAWATHANI ET AL., 1999]. Nevertheless, the veterinaries advise to deworm the goats frequently in order to control the infestation with gastrointestinal parasites. In a continuous grazing system they favor a deworming frequency of once per month, whereas in a rotational grazing system a frequency of once in three months seems to be sufficient. The goat breeder from Kota Samarahan, who keeps his goats in a semi-intensive system, prefers deworming nearly every six months and on demand. Information about the efficacy of the used anthelmintics with regard to the mentioned resistance is not known. The assistant director of the veterinary division stated that using faecal egg-count (FEC) to monitor the worm burden in goats is necessary to arrange adjusted deworming. Though, due to missing equipment, financial resources and knowledge, FEC-monitoring is not practicable In Long Lamai. A generally applicable recommendation concerning the deworming frequency is not reasonable. The frequency of deworming depends *inter alia* on the wetness/dryness of the area, the overall health of goats, population density in shed and pasture, as well as on scheduling of kidding. In addition, differences between bucks, does and kids are common. Yet, deworming 4-6 times per year is conventional. Therefore, the veterinaries and the goat breeder pointed out the utmost importance of preventive management measures to avoid infestation with gastrointestinal parasites. Grazing after rainfall or directly after sunrise must be prevented, since the worm burden is generally high at that time. In case of grazing, a rotational system, if possible, is preferable. The feasibility of rotational grazing systems in Long Lamai is described more closely in chapter 3.5.1. In addition to an adequate grazing system, the removal of dung is another useful measure to prevent infestation of goats [Agromisa, 2004, 2015].

Besides conventional anthelmintics, alternative non-drug agents are a good opportunity to treat infestation with gastrointestinal parasites. The goat breeder feeds leaves of cassava (*Manihot esculenta*) and taro (*Colocasia esculenta*) to reduce infestation with parasites at his farm. The effects of condensed tannins as an anthelmintic agent in goats by feeding forage of cassava (*Manihot esculenta*) or taro (*Colocasia esculenta*) are observed and recorded decreasing worm burdens [KUBDE ET AL., 2010; NETPANA ET AL., 2001; WALLER ET AL., 2009]. Though, SENG ET AL. [2007] stated that short-term feeding of fresh cassava shows limited evidence of anthelmintic effects, while cassava feeding over an extended period of time may prove beneficial. In the context of cassava supplementation, the goat breeder drew attention to the indispensable strict limitation of these forages due to the toxic effects of the secondary metabolites. This corresponds with findings of LANDAU ET AL. [2000] and SILANIKOVE ET AL. [1996], who also mentioned the toxic effects of hydrocyanic acids and related damage to organs and the digestive tract. As a consequence of the high content of cyanogenic glycosides [SOTO-BLANCO AND GÓRNIAK, 2010], the leaves have to be dried/wilted first to reduce the concentration of these toxic acids [WANAPAT, 2002; RAVINDRAN, 1992]. In this regard, the goat breeder recommended withering up to one or two days to reduce the content of secondary metabolites and thus the adverse effects. Furthermore, according to him, in dry periods, when cassava is not that moist, providing cassava leaves up to three days per week is tolerable. Yet, WHEELER ET AL. [1975] observed that sulfur, provided as sulfur licks, protected ruminants against cyanide toxicity by detoxifying cyanide of dietary origin.

The application of condensed tannins seems to be at least a beneficial method to treat and reduce worm burdens in Long Lamai in the absence of effective conventional anthelmintics. Conventional anthelmintics are costly, hard to procure and resistances widely spread. Whereas, for instance, cassava is already available and abundant in Long Lamai. Its cultivation to produce higher amounts in order to avoid conflicts is also easily possible. Merely the exact and demand-actuated limitation of tannin-containing forages may be a possible issue. Information about restrictions and quantities are necessary to ensure an adequate treatment of goats in case of endoparasite infestation. According to the veterinary assistant of the division Miri, betel nut (*Areca catechu*) is a common traditional treatment against parasites among goat farmers in Sarawak. A certain potential as traditional treatment against parasites is proved by findings of TANGALIN [2010] and ISKANDAR ET AL. [1983]. Several betel nut trees are also available in Long Lamai, and thus an additional opportunity to reduce worm burdens without drawing on chemical anthelmintics.

Summarizing the aforementioned conditions in Sarawak and Long Lamai regarding health management issues, it can be said that the expensive and difficult supply of the village with veterinary drugs, as well as a lack of knowledge concerning adequate care and treatment, are a major issue and threat for a sustainable and effective goat production in Long Lamai. Contagious diseases, as Pasteurellosis or Brucellosis, can cause severe economic losses and may threaten the goat stock of the potential farmers in case of inadequate care or untreated infections. Without a medical training in order to identify and treat diseases and parasite infestation, keeping goats in Long Lamai is a questionable and economically risky issue. Veterinary drugs can be, to a certain degree, substituted with alternative and traditional remedies. Though, the efficacy of these remedies is not fully known and conventional drugs seem to be mostly more efficient. Nevertheless, the utilization of alternative and traditional remedies in Long Lamai may be an adequate method to treat diseases or parasite infestations. In case of gastrointestinal parasites, the utilization of alternative non-drug agents, as condensed tannins, may be even more efficient than the application of conventional anthelmintics as a result of the prevalence of resistances.

An alternative method, breeding of goats resistant to internal parasites, will be discussed in more detail in chapter 5.6.

5.6 Breeding management

5.6.1 Breed choice

The choice of the goat breed is, with regards to environmental and climatic adaptation, growth rate and prolificacy, an important issue to ensure an efficient and sustainable goat production [Barker, 1996; Costa et al., 2000; Faye et al., 2002]. The goat breeder, a potential supply source of young goats, rears Katjang, Kalahari Red, Anglo-Nubian and Boer goats at his farm. However, he is merely selling crossbreeds, namely Anglo x Boer, Anglo x Katjang and Anglo x Kalahari Red. According to his statements, crossbreeds between Anglo-Nubian and Katjang, Anglo-Nubian and Kalahari Red, respectively, are more resistant against parasites as pure breeds. Crossbred Anglo x Boer are more adapted to the climate conditions than pure-bred Boer goats, benefit from the high prolificacy of the Boer, but are also of smaller size. In this context, it should be noted that both Kalahari Red and Boer goats originally come from arid regions [Kotze et al., 2004; Nimbkar et al., 2000; Warmington and Kirton, 1990] and thus the suitability in this particular environment is doubtful. The goat breeder suggested Anglo x Katjang and Anglo x Boer for meat production in Long Lamai due to the adaptability of Katjang and the higher growth rate of Boer goats. Though, Anglo-Nubian and particularly the Boer goats are not native to humid regions, thus the capability for adapting to the humid climate in Long Lamai is, as already mentioned, questionable [Agromisa, 2015; Almeida et al., 2006; Dhanda et al., 2003; Erasmus, 2000; Saithanoo, 1996; Pralomkarn et al., 1997]. Although the Boer crossbreds are of larger size and higher fertility, adaptability to the prevailing conditions is more important as a breed selection criterion. The high humidity in Long Lamai may cause thermal stress and can affect the health status and productivity of the goats negatively [Alexandre and Mandonnet, 2005; Devendra, 1987]. Crossbreeds of Katjang and Anglo-Nubian are preferable due to the adaptability to climatic conditions and the resistance against parasites. Production criteria, as for instance growth rate, mature size or carcass merit, are desirable, but in the case of Long Lamai of subordinate significance. Adaptability to climate conditions, feedstuff and environmental factors as parasite prevalence are of utmost importance. The focus should be on maintenance through decreasing mortality and increasing reproduction. Therefore, native goat breeds, as the Katjang goat or crossbreds of Katjang, are more favorable and should be preferred, even if the meat production performance is lower.

5.6.2 Breeding objectives

The aforementioned adaptive traits, as resistance to parasites/diseases and adaptation to the climate conditions, as well as fertility, should not only be in the focus of breeding decisions. Parasite resistance and high fertility are also important breeding objectives. As described in chapter 5.5, veterinary care and drugs are scarce in Long Lamai, hence breeding for resistances and adaptability may a relevant and helpful method to circumvent this issue [Alexandre and Mandonnet, 2005; Rekik et al., 2012; Shrestha and Fahmy, 2003]. Nevertheless, breeding for resistance is difficult to implement and a costly issue and therefore not feasible in Long Lamai, whereas high fertility is important to compensate lower growth rates or mature size and thus to maintain productivity. When goat production is successfully established in Long Lamai, breeding can the extended to selection criteria as for instance growth rate or maximum live-weight. However, at the beginning, to introduce and establish a functioning and efficient goat keeping, selection for the mentioned traits is necessary and must endure. Adaptive traits, as resistance to heat, humidity or parasites, influencing the production performance, will be difficult to identify due to the abovementioned conditions of missing knowledge, financial resources and equipment. The breeding objectives, respectively the breeding practice should be oriented to easily detectable performance traits. Therefore, the assumption that best performing animals are also the best adapted, is a good possibility to take these traits into consideration [Mueller et al., 2015]. This recommendation is undergirded by statements of the locals, who indicated during a meeting (May 20, 2016) their lack of knowledge in terms of the purpose of breeding objectives and selection.

The approach of the goat breeder concerning breeding objectives and selection is not known. During the visit at the farm and the interviews no common thread was recognizable running throughout the breeding management regarding specific traits or merits.

Figure 15: Meeting with potential goat farmers (partial view); (Photo: MH)

5.6.3 Breeding population and inbreeding

A large breeding population is essential to provide sufficient genetic variability for productively important traits, which allows to increase the intensity of selection. Though, large breeding populations are most likely not to expect in Long Lamai due to already mentioned limiting factors as experience, finances and market. While small breeding populations facilitate the emergence of inbreeding.

Inbreeding is, especially in tropical regions, a major problem among small-scale goat farmers [KOSGEY ET AL., 2006]. Such as is, according to the veterinary assistant of the Division Miri, in nearly all parts of Sarawak. He pointed out that the purchase of new bucks may too costly and an interchange between farmers is not common. Consequently, the local farmers accept the adverse impacts of inbreeding as the only possibility to ensure the continued existence of their goat flock and to maintain the production. In the case of Long Lamai, the prospective farmers should be informed about the perils of inbreeding and how to avoid it. During the meeting (May 20, 2016) the potential goat farmers also mentioned inbreeding, referable to the high costs of bucks, as a possible and serious challenge of reproduction and adequate management in Long Lamai (Figure 14). More precise information regarding the impacts of inbreeding was not made. This indicates that inbreeding is known as undesirable, but also indicates that less is known about breeding in general. The majority of the prospective goat farmers also admitted, upon request, the ignorance regarding the purpose of breeding except for ordinary reproduction.

5.6.4 Breeding program

Implementation of an appropriate breeding program may be a difficult task and will be subject to certain requirements. It is probable that, in case of an introduction of goats, the assumed flock size(s) will be relatively small (10-20 heads) with one sire per flock, due to the known limitations. Consequently, the genetic variability may be extremely low if all goats are purchased from the same goat breeder. Small animal populations and single sire flocks impede the introduction of an efficient and sustainable breeding management. Nevertheless, in a certain way, the implementation of a community-based breeding program (CBBP) is feasible [MÜLLER ET AL., 2015], as long as several separated flocks exist. On the basis of a collaborative working group, the potential goat farmers share and use their own genetic resources to produce offspring and breeding males. The mutual exchange of breeding animals will reduce or at least postpone the emergence of inbreeding to a certain degree. During the mentioned meeting, a possible collaboration between the individual goat farmers was discussed. On the one hand, to reduce and compensate deficits of expertise and financial solvency and on the other hand, to increase the genetic variability. Some potential goat farmers agreed and already discussed possible working groups. However, to establish and improve the breeding management one large group, consisting of all potential goat farmers would be beneficial and desirable to extend the options. To prevent conflicts in a community-based breeding program, a fair division of work and resource input, as well as output, is necessary. Additionally, it is essential to come to a mutual agreement concerning the breeding objectives and selection criteria. Despite a mutual agreement on objectives and exchange of genetic resources, the insufficient infrastructure and the missing knowledge about breeding issues impair the implementation of an adequate breeding program. In this regard, the interviewed veterinaries also mentioned the significance of accurate pedigree and performance recording. Without a routine data recording and performance evaluation, the achievement of breeding objectives is not feasible. Regardless of data recording and breeding expertise, the expectable small flock size(s) will be the major issue of an appropriate reproduction in Long Lamai. Hence, the extension of the genetic variability by additional purchase may be a possibility to avoid it.

Thus, a regularly replacement of the buck every 2-3 years is necessary to avoid inbreeding. It is unfavorable to use bucks from the same flock for replacement of old animals. In this context, care must be taken to ensure that newly acquired bucks originate from an intensive system, similar to the presumed intensive system in Long Lamai, in order to avoid the adverse effects of possibly occurring genotype-environment interactions. Under the assumption of an initial phase with merely 10-20 goats and one sire, selected breeding for resistances, adaptability or performance can be neglected. In the course of time, associated with an extension of the goat population, a community-based breeding program may be an opportunity for the prospective farmers in Long Lamai.

5.6.3 Mating

Controlled mating is a possible strategy to reduce the level of inbreeding and can help to concentrate kidding seasons during periods of the year when there are no working peaks in the crop production [Agromisa, 2004, 2015; Alexandre and Mandonnet, 2005]. Even if the year-round availability and provision of feed should not be a problem in Long Lamai, high birth rates at times of rice harvest or field cultivation can be inconvenient (Table 8). Controlled mating could be also a useful tool to adjust the supply of goats to the demand of the market, if there is a fluctuating one. Therefore, the goat breeder prefers monitored to uncontrolled mating. As a consequence of the abovementioned facts, it seems to be reasonable to implement controlled mating in Long Lamai. Time of mating and frequency should be matched to the prevailing conditions and requirements. According to the goat breeder and the interviewed veterinaries, a frequency of 3 kiddings in two years is economically reasonable and manageable.

In summary, it can be stated that the breeding management, besides an adequate health management, is the most challenging issue of keeping goats in Long Lamai. Expected low genetic variability, missing opportunities to extend the genetic pool and missing knowledge regarding breeding issues affect the management negatively. Thus inbreeding will be, as in the most parts of Sarawak, a major problem of goat reproduction. Nevertheless, the collaboration between the potential goat farmers and the exchange of breeding animals is a possibility to reduce problems. In addition to it, the selection of native breeds, as the Katjang or crossbred Katjang, should be preferred regarding their adaptability to the prevailing environmental and climatic conditions.

However, the supposed small goat population leads to the conclusion that breeding, at least at the beginning, should be focused on reproduction per se with a regular introduction of new bucks. With an extension of the population a more elaborated breeding program can be developed.

5.7 Housing

Adequate housing of goats is essential to protect them against the harsh tropical weather conditions prevailing in Long Lamai. In addition to it, appropriate housing is indispensable to ensure demand-actuated management of the goats, as separation of sexes or in case of births and diseases, as well as physical provisions to provide fodder and to clean the shed easily. Potential locations for sheds were already discussed in chapter 5.1.3. In total, 13 areas were recorded, which are suitable to provide sufficient space to build a shed. Four of these locations, namely area 5, 6, 12 and 13, are canopied by fruit trees, which prevent the sun from heating up the shed too much. The remaining areas consist solely of low-growing vegetation without covering trees. Regarding the positioning, the goat breeder stated that sheds, located in the forest, may attract too many flies and other insects in comparison with freestanding sheds. Though, these areas are either at the edge of the forest or small freestanding areas of fruit trees, thus the insect burden should not be that high. Only area 13 could be affected due to the position and the denser growth of trees and understory.

Figure 16: Area 5 canopied by several fruit trees (inter alia guava and jackfruit) (photo: MH)

Figure 17: Area 5 with adjacent rice paddy on the left side (Photo: MH)

A stilted housing type, elevated from the ground, is preferable to protect the goats from high precipitation and parasites [AGROMISA 2004, 2015; CHANIAGO, 1993; KOCHAPAKDEE AND SAITHANOO, 2014]. Floor heights of 1.5 – 1.8m are recommended by the veterinaries and the goat breeder to remove the dung under the shed easily. The goat shed in Kota Samarahan also had a slatted floor with a height of 1.6m above the ground.

As construction material for the floor, bearing beams and boxes, both bamboo and constructional timber are available. Bamboo is abundant in the surrounding of Long Lamai and with the aid of a specific technique it is flexible and universally usable. However, the assistant director of the department of agriculture rejects bamboo as a suitable construction material due to fast rotting and vulnerability to insects. Constructional timber is, according to the Penan of Long Lamai, amply available. Not directly next to the village, but at a convenient distance. Though, also the utilization of timber to construct a shed is possible. In this regard, the Penan mentioned the fact that building supplies, as nails or brackets, are expensive and difficult to procure. They are uncertain about their financial resources to purchase the needful building supplies. Constructions, made of bamboo, can be attached and joined by the use of vines or roots without utilization of nails. Though, the durability of these materials is questionable.

Corrugated iron sheets are preferable as roof material due to the resistance to weather, long durability and effectiveness regarding protection against direct sunlight or rainfall [AGROMISA, 2004].

The Penan of Long Lamai are already using corrugated iron sheets to cover their houses. However, corrugated iron sheets are costly and the transport to the village is fairly effortful. Alternative roof materials, as banana leaves or *Imperata cylindrica,* are abundant in the immediate vicinity. Yet, leaves as roof material have to be replaced regularly due to fast rotting. Whereas *Imperata cylindrica* is common for thatched roofs in Indonesia [POTTER ET AL., 2000] and indeed characterized by its durability. In addition to it, thatched roofs, made of *Imperata*, have insulating properties in contrast to roofs of corrugated iron sheets. On this basis and especially due to financial reasons, using alternative roof materials are recommended.

Separation of goats on the farm in Kota Samarahan is, in accordance with AGROMISA [2004, 2015] and CHANIAGO [1993], done by the sex of the goats, their age, as well as state of health. The shed (Figure 15, 16) encompasses an area of approximately $90m^2$, consisting of seven boxes (average size: $7.5m^2$) and one storage room for fodder and medication. The bucks are permanently separated from the rest of the flock. Additionally, pregnant does, as well as handicapped, infected or new born goats have separated boxes. However, the walls of the boxes do not impede the goats, due to their climbing skills, to enter other boxes. This fact could have adverse effects, in case of infected goats or to prevent unintended mating. Hence, any contact between infected and healthy goats should be avoided through appropriate boxes to halt spreading of diseases.

The low financial resources are, as is often the case in Long Lamai, an obstacle of building a shed and providing suitable housing for the goats. Nevertheless, construction materials, as bamboo or constructional timber, are available, as well as *Imperata cylindrica* as an alternative adequate roof material. Consequently, housing of goats to meet the requirements of appropriate management is feasible.

Figure 18: Shed of the goat breeder (exterior view); (Photo: MH)

Figure 19: Shed of the goat breeder (interior view); (Photo: MH)

5.8 Market/Marketing

The introduction of goats is not merely an approach to extend the sources of food of animal origin at times when hunting wild animals gets more difficult from time to time. It is also an opportunity to increase the livelihood options of the potential goat farmers and their families. Though, for selling goats a market is necessary, which provides sufficient demand and purchasing power. In this context, the farmers mentioned the prospective market as the potential limitation factor.

Possible markets for goats in the proximity of the village were discussed firstly during the meeting with the potential goat farmers (May 20, 2016) and secondly as a topic during the workshops with the women association and the youth group of Long Lamai. In addition to it, the interviewed veterinaries as well as the goat breeder were asked about potential marketing structures.

The most obvious solution is the selling of goat meat in Long Lamai. Yet, the purchasing power of the village residents is, assumedly, limited. Therefore, the selling price must be adjusted to the low financial resources without forgetting the financial and resource input of the farmers. Furthermore, the village residents, as well as the potential goat farmers themselves, have never tried goat meat and do not know the taste of it. Thus, the potential intention to buy goat meat for the own consumption is not particularly verified. A tasting-event (June 5, 2016) for the potential farmers and their families was organized to serve goat meat in order to test if they like it or not (Figure 17). The response was consistently positive. It can be assumed that majority of the village residents will also like it.

Figure 20: Tasting-event with community members (Photo: MH)

The farmers also mentioned the Muslim teachers and their families (approx. 9-12 persons) of the primary school in Long Lamai as potential consumers of goat meat. Upon request, the Muslim teachers confirmed the assumption of the farmers that the purchase of goat meat is also, besides the everyday consumption, interesting for feast days and official holidays.

Both the farmers and the participants of the workshops also recommended the neighboring villages Long Puak and Long Banga as potential markets. Long Banga is a center village, consisting of several ethnic groups (predominantly Saban and Kenyah), with about 200-300 residents and a relatively good transport connection (airport and roads to the coastal area around Miri). The farmers mentioned a goat farm in Long Banga 5 to 6 years ago. The background of the cessation of the goat meat production is unknown.

Long Puak, on the contrary, is a very small village with maximum 30 residents. The exact number varies due to temporary residents. Though, few potential goat farmers from Long Lamai alleged that the residents of Long Puak are loath to consume goat meat. The reason for this assumption and its veracity are unknown.

Apart from Long Lamai and the neighboring villages, the potential goat farmers were thinking to expand sharply and to supply larger cities as Miri and Marudi, as well as Bario in the Kelabit highlands. However, the farmers do not have the necessary knowledge, experience, financial resources and infrastructure to realize such a business venture. It is of utmost importance to be realistic and to inform the prospective goat farmers regarding possible marketing structures, constraints and limitations. Therefore, local marketing in Long Lamai and possibly the adjacent villages is more appropriate and reasonable. Nevertheless, the marketing of the goat meat may be a challenging issue.

5.9 Dedication and Knowledge

The Eastern Penan of Long Lamai were, as abovementioned, originally nomadic hunter-gatherers and settled down a couple of decades ago. Due to their cultural persuasion, domesticated animals were or are part of the family and thus keeping animals to consume them afterwards was not an issue. This persuasion was loosened over recent years, so that several village residents of Long Lamai nowadays decided to keep and consume animals.

Nevertheless, the cultural persuasion and the nomadism of the past have let to the circumstance that the potential farmers have no knowledge and experience with regard to animal husbandry. Furthermore, routine works, as the cultivation of rice paddies, its preparation, as well as the harvest are not part of the daily work. Hence, the Penan of Long Lamai are not used to daily work, as the keeping of goats required.

The interviewed veterinaries mentioned commonly emerging problems at small-scale goat farms in Sarawak due to insufficient dedication and zeal of the farmers. Keeping goats is often considered as a part-time job with low labor requirements. Consequently, the management and as a result the productivity, are inadequate. In this context, all interviewees stated that the missing experience and knowledge of keeping animals, in connection with insufficient dedication on the part of the potential goat farmers, will be probably a challenging issue.

The potential goat farmers, on the contrary, asserted that the dedication will not be a problem. They are willing to invest time and effort to conduct a successful goat meat production.

Both the veterinary assistant of the division Miri and the goat breeder from Kota Samarahan recommended a training to learn, at least, the basics of keeping goats. For that reason the veterinary assistant suggested a weeklong workshop for prospective goat farmers conducted by the department of agriculture. Whereas the goat breeder proposed to invite a few potential goat farmers for several weeks at his farm to impart the fundamentals and to give an overview about the daily business of keeping goats.

A weeklong workshop seems to be inappropriate to impart all the necessary information about keeping goats against the backdrop of missing experience in animal husbandry. A combination of both the weeklong training offered by the department of agriculture and the training of the goat breeder should be preferred in order to gain a broad spectrum of information

The training at the goat farm in Kota Samarahan, alternatively, may be a good option for the potential goat farmers to learn more about goats and the related issues. During a training for several weeks, it is possible to get an overview about various essential issues and circumstances, which can occur in keeping goats, as, for instance, the birth of kids, diseases or parasite infestation, as well as the mating period. However, the expenses for this trip, the transport and the provisions at the farm are problematic, even if the training, conducted by the goat breeder, is for free.

Nevertheless, as already mentioned before, a training to learn the basics of animal husbandry is inevitable and reasonable to establish an efficient and sustainable goat meat production in Long Lamai. Hence, an investment in training is necessary, especially under consideration of the fact that the introduction of livestock is a totally new and unknown issue for the Penan.

5.10 Financial Situation

Regardless of animal husbandry related issues, the financial situation, as well as the lack of knowledge, and in some circumstances the marketing, are serious challenges of keeping goats in Long Lamai. Financial resources are necessary to purchase goats, possibly veterinary medications, as well as to finance a required training. Yet, the potential goat farmers are, by their own admission, unable to bear the financial burden without any support.

The difficult issue of the financial burden is closely related to the problematic situation concerning the missing experience and knowledge of animal husbandry. Missing experience and knowledge in keeping goats aggravates the successful introduction and establishment of goats in Long Lamai and thus increases the financial risks to lose investments. For that reason, the potential goat farmers suggested to start the project as one group to limit the financial risks and to reduce the handicap of missing experience.

6. Conclusion

The introduction and the sustainable establishment of goats in Long Lamai, as an additional source of income and food, seem to be a challenging and doubtful issue. Solely focused on aspects of animal husbandry, as feed resources, breeding and health management, goat keeping in Long Lamai might be feasible. Feed resources and areas for housing and grazing are sufficiently available, as long as the number of goats remains low. Local breeds, as the Katjang goat, are adapted to the humid tropical conditions and could be introduced to the area. Appropriate management and care of the goats support adequate health status and low rates of diseases. In addition, various plants are available in the surrounding of Long Lamai, which can be used as medical treatments against parasites and diseases.

However, health management and breeding are also the major threats to efficient goat production. Insufficient veterinary care and provision of medical drugs related to contagious diseases jeopardize the goats' health and thus the economic endeavor. Regular replacement of breeding bucks to avoid inbreeding and the establishment of a community-based breeding program remains a challenge.

Nevertheless, the missing experience and knowledge of keeping livestock combined with a high financial burden is the most significant risk, which justifies doubts of the reasonableness of goat keeping in Long Lamai. The existing lack of knowledge concerning breeding, care and treatment of goats threaten the sustainable persistence of an effective production and thus may cause severe economic losses. Generally, the financial burden of an introduction of goats can be stated as immense. The incurring costs of purchasing goats, medical treatments, building supplies and the transport, as well as incurring costs of an instruction training exceed by far the financial means of the community. External support regarding financial resources and knowledge transfer is inevitable to implement this undertaking.

Apart from that, the social background and the ethnical heritage with regard to the dedication of the Penan for the daily business of goat keeping may be challenging. Though, as long as the claim of ownership and the responsibilities are clarified, the risk of missing dedication is circumstantial.

Production goals and number of animals are closely related to the market, which encompasses, most likely, merely Long Lamai and the adjacent Long Banga. Though, nothing is well-known about the quantity of possible sales.

In case of financial support and appropriate training, in order to revoke the abovementioned doubts concerning missing knowledge and financial burdens, a maximum of 20 goats to introduce and establish a sustainable goat production is recommended.

The decisive factors for this recommendation are, in particular, the limitation by the market, as well as the workload in due consideration of the prevailing conditions regarding health management and breeding. The adverse working conditions impair an adequate management and care of goats and thus increase the required working time.

After a successful and sustainable establishment of goat production accompanied by sales higher than expected, an increase of the number of goats is feasible.

7. Summary

The Penan, originally a folk of nomadic hunter-gatherers in Borneo, Malaysia and followers of the Animism were not permitted to keep livestock for cunsumption by virtue of the principles of their cultural persuasion. The community of Long Lamai, a village of the Eastern Penan, located in the upper reaches of Sarawak's Baram River basin, with a population of nowadays approx. 600 people, was the first major settlement of Penan in the Upper Baram region roughly 60 years ago. In 2014 a co-operation of Keruan, a local Penan self-help organization, the Research Institute of Organic Agriculture (FiBL Austria) and the Bruno Manser Fund (Switzerland) started a project with the focus on "Sustainable agriculture and resource management in the Upper Baram Area" (SARM).

By reasons of decreasing hunting success and increasing demand for protein of animal origin and approachability towards livestock keeping, members of the community of Long Lamai expressed an interest in continuing their previous project discussions regarding the introduction of goats as a livestock component in their developing agricultural system.

Purpose of this study was to assess the feasibility of goat keeping in Long Lamai under consideration of all important aspects of animal husbandry, while taking account of social and financial issues. For that reason, on the one hand, scientific literature was reviewed regarding animal production systems, feed resources, health and breeding management, as well as housing systems in the context of Southeast Asia. On the other hand, on-site data collection was carried out to get an overview about local conditions. Transect walks with locals were conducted to explore the surrounding of Long Lamai, as well as workshops and meetings with community members to gain more information about a possible introduction of goats and potential challenges. In addition to it, veterinaries of several agricultural departments in Sarawak were interviewed and a goat farm in Kota Samarahan was visited.

Especially the aspect of health management of the goats may prove difficult to introduce and establish an appropriate goat keeping system in Long Lamai. The prevailing hot, humid climatic conditions, the high parasitic load, resistances against anthelmintic agents, as well as the inadequate supply of veterinary care are major threats in view of endoparasite infestation and animal health in general. Additionally, the missing knowledge and experience of the Penan relating to animal husbandry compound this fact.

Available local crossbreeds, as Katjang x Anglo-Nubian, in combination with adequate breeding for adaptation and resistance may improve this issue. Though, due to the already mentioned missing knowledge, as well as insufficient financial resources and equipment, breeding objectives should be oriented to easily detectable performance traits.

Besides that, the surrounding of Long Lamai provides a large variety and quantity of feed resources, as well as various grazing areas and the possibility of the integration of goats into rice or tree cropping. Yet, several aspects, as for instance the high precipitation rate, result in the recommendation of a (semi-)intensive production system with time-restricted access to grazing areas.

Apart from aspects of animal husbandry, the mentioned lack of knowledge and low financial resources, as well as the social and cultural background with regard to the dedication of the Penan, raise doubts whether goat keeping is feasible and reasonable in Long Lamai or not.

Financial and technical support is inevitable to introduce and establish goat keeping in Long Lamai successfully. Financial resources to purchase goats and equipment and an appropriate instruction training in order to overcome the lack of knowledge and experience are basic elements of implementing a goat project in Long Lamai.

Furthermore, it remains to be seen if the dedication of the prospective goat farmers is acceptable regarding the unfamiliar daily business of keeping goats.

In case of an introduction of goats, merely up to 20 heads are recommended due to the abovementioned factors and the non-transparent market situation and the low purchasing power of the community.

8. Zusammenfassung

Den Penan, ursprünglich ein Volk von nomadischen Jägern und Sammlern und Anhängern des Animismus, war es, gemäß den Prinzipien ihrer kulturellen Überzeugung, nicht erlaubt Tiere für den eigenen Konsum zu halten. Die Gemeinde von Long Lamai, ein Dorf der östlichen Penan im Regenwald von Borneo, niedergelassen vor ca. 60 Jahren mit einer heutigen Population von ungefähr 600 Einwohnern, war die erste größere Penan-Siedlung am Oberen Baram Fluss. Im Jahr 2012 initiierte eine Kooperation von Keruan, einer lokalen Selbsthilfe-Organisation der Penan, dem Forschungsinstitut für biologischen Landbau (FIBL Österreich) und dem Bruno Manser Fond (Schweiz) ein Projekt mit dem Schwerpunkt nachhaltiger Landwirtschaft und Ressourcenmanagement in der Region um den Oberen Baram.

In Zuge dessen drückten mehrere Gemeindemitglieder ihr Interesse hinsichtlich Ziegenhaltung aus, um ihre landwirtschaftliche Lebensgrundlage zu erweitern. Auslöser waren mit der Zeit erschwerte Jagdbedingungen, die Zunahme des Eiweißbedarfs tierischen Ursprungs, sowie eine kulturelle Öffnung gegenüber Tierhaltung.

Zielsetzung dieser Machbarkeits-Studie war es die Realisierung von Ziegenhaltung unter Berücksichtigung diverser tierhaltungstechnischer Aspekte zu beurteilen, sowie der Notwendigkeit von finanziellem und fachlichem Support.

Hierfür wurden, neben ausführlicher Sichtung wissenschaftlicher Literatur mit Bezug zu Ziegenhaltung in vergleichbaren tropischen Regionen, vor Ort Daten erhoben. Gemeinsam mit Teilen der einheimischen Bevölkerung wurde die nähere Umgebung um das Dorf erkundet und diverse Workshops und Meetings abgehalten. Ziel war es einen Überblick über die örtliche Situation zu erlangen in Hinblick auf tierhaltungstechnische Aspekte wie Produktionssysteme, Futterressourcen, veterinärmedizinische Versorgung, Züchtung und Behausung. Darüber hinaus wurden Veterinäre aus dem Bundestaat Sarawak interviewt, um sachkundige Informationen über den dortigen Nutztiersektor zu erhalten und um mögliche Probleme von Ziegenhaltung in Long Lamai zu erörtern. Des Weiteren wurde ein Ziegenzüchter in Kota Samarahan besucht, um einen Eindruck bezüglich der Haltung von Ziegen in feucht-warmen Klima zu erhalten.

Insbesondere tiermedizinische Aspekte, die im Zusammenhang mit dem feucht-warmen Klima, dem hohem Vorkommen von Parasitenbefall, Resistenzen gegenüber Anthelminthika und unzureichender veterinärmedizinischer Versorgung stehen, stellen ein großes Problem für eine mögliche Ziegenhaltung in Long Lamai dar. Erschwerend hinzu kommt die Tatsache, dass die Penan, aufgrund ihres kulturellen Erbes, keine Erfahrungen im Bereich der Tierhaltung besitzen. Gezielte Züchtung mit Hinblick auf Resistenzen und Anpassung gegenüber lokalen Bedingungen lassen sich aufgrund unzureichender finanzieller Mittel, sowie dem bereits erwähnten unzureichenden Wissen nur schwer realisieren.

Ungeachtet der tiermedizinischen und züchterischen Aspekte, verfügt die Umgebung von Long Lamai über eine hohe Diversität und Quantität an Futterpflanzen, sowie geeignete Weideflächen. In diesem Zusammenhang ist auch eine Integration in Reisbrachen oder Obstbaumareale möglich.
Im Falle einer Einführung von Ziegenhaltung in Long Lamai ist ein (semi-)intensives Produktionssystem mit beschränkter Weidezeit zu empfehlen, um die oben genannten eventuellen Probleme so gering wie möglich zu halten.
Abgesehen von den bereits erwähnten tierhaltungstechnischen Aspekten, stellen insbesondere das fehlende Fachwissen und die geringen finanziellen Mittel, sowie der soziale und kulturelle Hintergrund der Penan in Hinblick auf notwendiges Engagement, die Realisierbarkeit und Sinnhaftigkeit von Ziegenhaltung in Long Lamai in Frage. Ohne finanzielle Unterstützung und einer angemessenen Schulung in Sachen Tierhaltung ist die Haltung von Ziegen in Long Lamai nicht zu realisieren

Appendix

Appendix I: Chemical composition of tropical feedstuff (on dry matter basis)

Scientific name	Common name	Component	DM (%)	DE (MJ/kg)	ME (MJ/kg)	GE (MJ/kg)	CP (%)	DCP[1] (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	Ca (%)	P (%)
Ananas comosus	Pineapple	Bran	87.4	-	-	13.43	4.80	-	1.9	25.50	63.3	4.5	0.29	0.24
Ananas comosus	Pineapple	Pulp	12.0	-	10.1	-	3.30	-	-	26.00	-	-	0.40	0.10
Arachis hypogaea	Groundnut	Leaves, stems	17.6	-	-	14.22	19.90	-	4.8	34.50	30.9	9.9	-	-
Arachis hypogaea	Groundnut	Meal	86.0	-	11.7	-	34.00	-	-	27.00	-	-	0.20	0.60
Arachis hypogaea	Groundnut	Leaves	92.6	11.8	9.67	-	19.17	14.40	2.72	14.20	47.16	16.75	0.45	0.52
Arachis hypogaea	Groundnut	Stem	93.2	9.21	7.53	-	7.10	3.10	0.65	36.23	45.81	10.21	0.88	0.28
Arachis hypogaea	Groundnut	Seed hulls	89.5	-	-	-	10.15	6.00	0.72	-	-	9.38	0.48	0.48
Artocarpus heterophyllus	Jackfruit	N/A	36.6	-	13.2	6.53	19.1	-	4.1	17.4	48.5	8.3	1.38	0.16
Artocarpus integra	Champedak	Leaves	35.3	-	12.02	-	15.22	10.7	2.6	17.5	-	18.4	1.05	0.1
Averhoa carambola	Starfruit	N/A	32.6	-	13.2	-	15.3	-	3.9	14.4	-	7.0	1.46	0.16
Bambusa spp.	Bamboo	Hay	87.7	-	-	-	12.00	-	0.8	27.00	42.2	18.0	0.19	0.13
Bambusa spp.	Bamboo	Seeds	9.3	-	-	-	10.00	-	-	11.00	75.0	3.6	-	-
Brachiaria brizantha	Palisade grass	N/A	93.5	9.83	8.03	-	10.08	5.9	2.20	30.08	47.19	10.45	0.59	0.26
Brachiaria decumbens	Signal grass	N/A	91.8	9.83	8.08	-	10.21	6.0	1.57	28.87	48.77	10.58	0.49	0.16
Cocos nucifera	Coconut	Oil cake	90.2	14.57	11.97	-	21.21	16.30	8.98	12.78	48.89	8.14	0.46	0.4
Cocos nucifera	Coconut	N/A	40.8	-	10.9	-	10.9	-	4.4	22.1	-	4.7	0.54	0.04
Cocos nucifera	Coconut	Copra meal	90.0	-	12.5	-	20.00	-	-	7.00	-	-	0.20	0.70
Coffea spp.	Coffee	Seed hulls	86.6	9.88	8.12	-	11.54	7.3	1.35	37.07	42.45	7.59	0,33	0.22
Desmodium spp.	Tick trefoil	N/A	90.9	10.09	8.28	-	11.58	7.3	2.01	29.19	47.58	9.64	0.65	0.13
Elaeis guineensis	Oil palm	Kernel cake	90.6	-	-	18.07	19.00	-	2.0	16.00	58.8	4.2	0.23	0.31
Elaeis guineensis	Oil palm	press fibre	86.2	-	-	17.61	4.00	-	21.0	36.40	23.3	9.0	0.30	0.13
Elaeis guineensis	Oil palm	Mill	90.0	-	-	17.66	10.6	-	17.0	18.3	42.0	12.1	0.75	0.5
Elaeis guineensis	Oil palm	Leaves, petioles	91.4	-	-	-	4.90	-	2.2	27.2	51.3	5.8	-	-
Elaeis guineensis	Oil palm	Kernel cake	89.0	-	12.2	-	19.00	-	-	13.00	-	-	0.30	0.70

DM = Dry matter, DE= Digestible energy, ME= Metabolized energy, GE= Gross energy, CP= Crude protein, DCP= Digestible crude protein, EE= Ether extract, CF= Crude fibre, NFE= Nitrogen free-extract

[1] Digestible crude protein for goats. Data in minus range due to methodological reasons

Adapted from: Chee [1989], Sudaryanto [1992], Omojola et al. [2012], Fadiyimu et al. [2012], Winugroho [1999]

Appendix I continued.

Scientific name	Common name	Component	DM (%)	DE (MJ/kg)	ME (MJ/kg)	GE (MJ/kg)	CP (%)	DCP_1 (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	Ca (%)	P (%)
Gliricidia sepium	Gliricidia	Leaves	90.5	11.72	9.58	-	23.62	18.6	4.29	24.00	38.28	9.81	2.35	0.35
Gliricidia sepium	Gliricidia	Stem	91.2	9.33	7.66	-	10.17	6.00	1.63	49.68	30.05	8.47	0.97	0.31
Gliricidia sepium	Gliricidia	N/A	25.0	-	-	23.08	14.70	-	5.4	19.90	55.3	4.7	0.46	0.14
Glycine max	Soybean	Cake	88.8	16.91	13.85	-	42.85	36.5	3.32	6.03	40.02	7.78	0.67	0.63
Glycine max	Soybean	Seed (dry)	93.2	-	-	-	18.02	13.30	-	-	-	5.78	0.75	0.38
Glycine max	Soybean	Expeller	89.9	17.33	14.19	-	46.38	39.8	3.69	6.19	35.86	7.88	0.45	0.65
Glycine max	Soybean	Flour	86.6	20.01	16.41	-	39.05	32.90	11.30	3.23	41.27	5.15	0.42	0.2
Glycine max	Soybean	Meal	89.0	-	13.7	-	47.20	-	-	8.00	-	-	0.27	0.70
Hevea brasiliensis	Rubber	Seed meal	89.0	-	-	14.69	3.50	-	11.2	33.60	47.0	4.7	0.13	0.5
Imperata cylindrica	Cogongrass	N/A	92.7	9.62	7.91	-	7.68	3.70	1.88	31.25	49.81	9.38	0.55	0.14
Inga Edulis	Ice cream bean	N/A	43.8				17.3		3.17	22.0	49.8	8.42	0.7	0.04
Leucaena leucocephala	Ipil-ipil	N/A	34.3	-	-	18.4	29.9	-	2.4	17.4	40.7	9.65	0.74	0.12
Leucaena leucocephala	Ipil-ipil	Leaves (Malaysia)	30.0	-	-	22.18	22.00	-	6.9	19.60	47.2	4.4	0.55	0.13
Leucaena leucocephala	Ipil-ipil	Leaves,stems,pods	30.1	-	-	32.59	17.40	-	3.9	30.50	43.6	4.6	0.30	0.14
Leucaena leucocephala	Ipil-ipil	Leaf meal	92.0	-	10.9	-	26.70	-	-	21.00	-	-	2.20	0.30
Mangifera indica	Mango	N/A	46.3	-	11.1	-	10.4	-	6.0	21.0	-	6.3	1.63	0.12
Manihot esculenta	Cassava	Root peelings	90.8	10.84	8.87	-	11.95	7.7	1.55	14.77	56.67	15.06	0.64	0.36
Manihot esculenta	Cassava	Leaves	91.8	13.48	11.05	-	26.29	21.0	8.64	17.51	39.45	8.11	1.73	0.42
Manihot esculenta	Cassava	Stem	-	-	-	-	10.9	-	-	-	-	8.5	1.9	0.4
Manihot esculenta	Cassava	N/A	21.7	-	-	8.45	22.60	-	2.9	8.10	60.4	6.0	0.98	0.2
Manihot esculenta	Cassava	Waste	90.0	-	12.0	-	2.00	-	-	3.00	-	-	0.60	0.20

DM = Dry matter, DE= Digestible energy, ME= Metabolized energy, GE= Gross energy, CP= Crude protein, DCP= Digestible crude protein, EE= Ether extract, CF= Crude fibre, NFE= Nitrogen free-extract

[1] Digestible crude protein for goats. Data in minus range due to methodological reasons

Adapted from: Chee [1989], Sudaryanto [1992], Omojola et al. [2012], Fadiyimu et al. [2012], Winugroho [1999]

Appendix I continued.

Scientific name	Common name	Component	DM (%)	DE (MJ/kg)	ME (MJ/kg)	GE (MJ/kg)	CP (%)	DCP[1] (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	Ca (%)	P (%)
Metroxylon sagu	Sago	Refusee	26.0	-	-	13.06	1.90	-	0.4	6.00	88.8	3.0	0.05	0.04
Metroxylon sagu	Sago	Rasps	89.0	-	10.0	-	0.50	-	-	5.00	-	-	0.64	0.02
Morus spp.	Mulberry	N/A	-	-	-	-	15.00	-	7.4	15.30	48.0	14.3	2.42	0.42
Musa paradisiaca	Banana	Peelings	86.7	12.47	10.21	-	6.46	2.5	4.03	9.82	69.49	10.20	0.21	0.42
Musa paradisiaca	Banana	Stem	95.0	8.96	7.36	-	3.51	-0.1	2.12	39.04	46.30	9.03	-	-
Musa paradisiaca	Banana	Leaves	93.0	10.67	8.75	-	15.22	10.7	9.07	21.91	41.45	12.35	1.30	0.35
Musa paradisiaca	Banana	Petiole	94.9	9.38	7.70	-	7.11	3.1	1.86	37.01	45.47	8.55	1.26	0.1
Musa paradisiaca	Banana	N/A	27.1	-	-	-	16.10	-	8.4	23.70	42.2	9.4	-	-
Musa paradisiaca	Banana	Whole plant	18.5	-	-	-	3.70	-	3.6	28.00	46.9	17.8	0.22	0.12
Musa paradisiaca	Banana	Fruit (green)	22.0	-	13.0	-	5.75	-	-	4.00	-	-	0.06	0.20
Nephrolepis biserrata	Giant Swordfern	Stem	15.94	-	-	3.75	4.35	-	1.24	31.30	55.33	7.78	-	-
Nephrolepis biserrata	Giant Swordfern	Leaves	27.62	-	-	3.78	12.76	-	1.70	23.22	54.73	7.52	-	-
Oryza satica	Rice	Bran, 1st grade	88.1	15.23	12.51	-	14.61	10.1	9.81	9.36	57.59	8.63	0.30	1.12
Oryza satica	Rice	Bran, 2nd grade	86.8	13.18	10.80	-	14.49	10.0	10.31	13.53	50.14	11.53	0.51	0.98
Oryza satica	Rice	broken	88.5	15.28	12.51	-	12.46	8.1	3.84	0.87	78.45	4.38	0.15	0.07
Oryza satica	Rice	Straw	92.0	-	5.5	-	3.90	-	-	39.00	-	-	0.50	0.20
Panicum maximum	Panic grass	N/A	92.9	9.62	7.91	-	9.43	5.3	2.15	30.36	46.82	11.24	0.99	0.23
Paspalum dilatatum	Dallis grass	N/A	92.4	10.13	8.33	-	12.94	8.6	3.34	29.15	43.95	10.62	1.00	0.31
Pennisetum purpureum	Napier grass	N/A	21.0	-	7.5	-	8.50	6.6	-	34.00	-	17.64	0.50	0.3
Phaseolus vulgaris	Kidney bean	Seed hulls	95.0	9.71	7.96	-	5.26	1.4	0.35	48.31	41.62	4.46	0.47	0.05
Psophocarpus tetraganolobus	Winged bean	N/A	92.7	19.25	15.78	-	38.98	32.90	17.75	7.26	31.64	4.37	-	0.56

DM = Dry matter, DE= Digestible energy, ME= Metabolized energy, GE= Gross energy, CP= Crude protein, DCP= Digestible crude protein, EE= Ether extract, CF= Crude fibre, NFE= Nitrogen free-extract

[1] Digestible crude protein for goats. Data in minus range due to methodological reasons

Adapted from: Chee [1989], Sudaryanto [1992], Omojola et al. [2012], Fadiyimu et al. [2012], Winugroho [1999]

Appendix I continued.

Scientific name	Common name	Component	DM (%)	DE (MJ/kg)	ME (MJ/kg)	GE (MJ/kg)	CP (%)	DCP₁ (%)	EE (%)	CF (%)	NFE (%)	Ash (%)	Ca (%)	P (%)
Saccharum officinarum	Sugarcane	Mollases	65.8	-	-	-	2.40	-1.20	0.1	-	-	6.15	1.55	0.49
Saccharum officinarum	Sugarcane	Bagasse	95.3	-	-	13.31	2.70	-	0.3	37.40	53.9	5.7	0.11	0.31
Saccharum officinarum	Sugarcane	Tops	24.0	9.21	7.53	20.15	3.80	-	1.8	50.80	51.5	4.9	0.18	0.02
Saccharum officinarum	Sugarcane	Green tops	26.0	-	-	17.36	6.40	-	1.7	33.90	50.4	7.6	-	-
Sesbania grandiflora	Hummingbird tree	Leaves	91.1	8.87	7.28	-	25.99	20.8	5.22	40.42	17.56	10.81	2.34	0.27
Sorghum bicolor	Sorghum	Flower	90.9	9.79	8.03	-	9.04	4.9	1.42	33.80	48.23	7.51	0.48	0.18
Sorghum bicolor	Sorghum	Stem	93.4	9.33	7.66	-	7.57	3.6	1.53	35.03	45.86	10.01	0.63	0.26
Sorghum bicolor	Sorghum	Leaves	93.4	9.58	7.87	-	11.70	7.4	2.18	36.48	39.83	9.80	0.61	0.27
Sorghum bicolor	Sorghum	Straw	-	-	-	17.36	3.50	-	1.7	39.70	45.4	9.7	-	-
Tamarindus indica	Tamarind	Seed hulls	-	-	-	-	9.10	-	0.6	11.30	75.5	3.5	0.26	0.76
Zea mays	Maize	Stem	89.0	9.79	8.03	-	6.57	2.60	0.91	26.47	58.74	7.31	0.35	0.16
Zea mays	Maize	Leaves	89.9	10.71	8.79	-	15.78	11.20	2.71	22.95	45.45	13.11	0.89	0.33
Zea mays	Maize	Grain	88.3	15.57	12.76	-	11.06	6.8	4.44	2.14	79.76	2.6	0.16	0.35
Zea mays	Maize	Stover	25.0	-	9.9	-	5.50	-	-	30.00	-	-	0.34	0.1

DM = Dry matter, DE= Digestible energy, ME= Metabolized energy, GE= Gross energy, CP= Crude protein, DCP= Digestible crude protein, EE= Ether extract, CF= Crude fibre, NFE= Nitrogen free-extract

₁ Digestible crude protein for goats. Data in minus range due to methodological reasons

Adapted from: Chee [1989], Sudaryanto [1992], Omojola et al. [2012], Fadiyimu et al. [2012], Winugroho [1999]

Appendix II: Workshop with the women association and the youth group

- Station 1: *'Knowledge about domesticated animals'*

  Write down all the information you have concerning domesticated animals. Different species, advantages/disadvantages of specific species, etc.

- Station 2: '*Management of animals'*

  Write down the requirements of keeping livestock. What do I need to keep animals? What kind of responsibilities do I have, if I keep animals? Who takes care of the animals, when the man is prevented?

- Station 3: '*Marketing*'

  Have you ever eaten goat meat and if yes did you like it? Do you know any potential markets for meat except of the community of Long Lamai? Do you think the people in Long Lamai would eat got meat? How often would they consume it?

- Station 4: '*Potential of livestock'*

  Do you see any risks of keeping animals? Do you know any advantages and disadvantages of keeping animals for the community/farmers/environment? Do think it is a good idea to keep animals in Long Lamai?

Appendix III: Questionnaire – Guidelines

The below mentioned keywords provided the framework for the conducted interviews with veterinaries, the local goat breeder and community members.

Animal production systems:

- Prevailing production systems in Sarawak
- Obstacles, challenges of prevailing production systems in Sarawak
- Possible issues of goat keeping in Long Lamai
- Average size of goat flocks (average in Sarawak)
- Intended number of goats in Long Lamai
- Dedication of the community members
- Supply of labor (who is responsible for the goats in Long Lamai?)
- Fluctuation of labor (working peaks due to harvest, field cultivation etc.)
- Space available (grazing, housing, distance to the village)
- Climatic conditions (seasonality, precipitation, etc.)
- Possibilities of systems integrated with tree cropping
- Integration into crop agriculture
- Stocking rate (head/ha) on pasture
- Level of productivity
- Potential risks: predators, thieves, etc.
- Water supply (pasture, grazing strip, etc.)

Animal housing systems:

- Space available for Shed
- Site/Position available
- Stocking density
- Separation of goats
- Construction material available for shed
- Management system to decide between partial or permanent stalling
- Construction material available for enclosures, hedges/living hedges
- Bedding material
- Climatic conditions (depending on construction material)
- Potential risk factors: predators, thieves, etc.
- Supply of labor to clean the shed

Appendix III continued.

<u>Breeding:</u>

- Purpose of production (meat, milk, etc.)
- Adaptation to climatic conditions
- Available breeds (in Sarawak)
- Costs for does/bucks
- Prolificness of available breeds
- Resilience against predominant parasites/diseases
- Daily live-weight gain
- Average litter size
- Mature weight (female)
- Average age of first kidding
- Adaptation of Metabolism
- Benefits of crossing indigenous and exotic breeds
- Disadvantages of crossing indigenous and exotic breeds (e.g. loss of immunity)
- "Purity" of genetic material: uncontrolled crossbreeding
- Relevant properties for production (e.g. reproduction, growth (meat production)
- Environmental factors (climate, feed. hygiene, housing, general care)
- Inbreeding (occurrence in Sarawak, causes, possibility to replace bucks)
- Possibilities to breed for adaptive/ production traits
- Mortality rate (embryonic, kids)
- Reasons for Mortality
- Possibilities to record (properties, mating period etc.)
- Castration
- Heritability
- Mating periods and frequency (according to the equilibrium between variable poor resources and high levels of requirements of the flock)

Appendix III continued.

Feeding systems:

- Space available for grazing/browsing (quality/quantity)
- Supply of labor
- Frequency of daily feeding
- Amount of daily feeding/ Diet
- Grazing in rice fields or not due to multiple cropping
- Potential risk factors: predators, thieves
- Possibilities of rotational/continuous grazing
- Presentation of the feed
- Distance to pastures, sources of feed
- Distance to water supply

Fodder:

- Available feedstuff (native grasses, legumes, trees, shrubs, etc.)
- Quantity of available feed resources
- Possibilities to cultivate grass species; used for pasture and fodder production.
- Possibilities to cultivate feed resources in general
- Conflicts of use (feed-food)
- Seasonal fluctuation
- Necessity of feedstuff variety to meet goats' selective behavior
- Possibilities to produce Hay/Silage
- Local knowledge about potential forage crops/plants
- Possible by-products
- Availability of supplements + costs
- Knowledge to produce concentrate supplements
- Supply of available feed and nutrient composition to cover energy, protein, mineral and vitamin requirements. According to number of animals, pregnancy of does, kids etc.
  →Available types of foodstuff and quantity
  →Supply of salt to produce salt licks
- Water supply:
  → Source/Origin
  → Quantity (according to number of animals)
  → Quality
  → Preparation/provision of water; day and night (continuous)
  → Water places + drinking troughs (shed/pasture)

Appendix III continued.

<u>Health management:</u>

- Availability of anthelmintic agents + costs
- Traditional medicines (efficacy, etc.)
- Availability of disinfectants (e.g. navel infections) + costs
- Afterbirth disinfection to avoid internal infections (e.g. salt water solutions)
- Possibilities to separate sick goats (quarantine facilities)
- Vaccination (availability, costs, necessity)
- Antibiotics (availability, costs, necessity)
- Availability of veterinary care in/around Long Lamai
- Recording system
- Rotational grazing as a nematode control (Prevalence in Sarawak)
- Supply of labor (individual care, hoof trimming, etc.)
- Potential mineral deficiencies
- Digestive problems (bloat, diarrhea, etc.)
- Internal parasites (worms)
- External parasites (mites, ticks)
- Acaricide agents (availability, costs, necessity)
- Prevailing infectious diseases (Brucellosis, Anthrax, Foot-and-Mouth disease, Mastitis, etc.)
- Treatments (Sulphonamides, etc.)
- Disposal of waste/manure
- Toxic plants

Appendix IV: Traditional medical plants and remedies available in Long Lamai.

Penan	Common name	Bot. Name	Part used	Application	References
Balak	Banana	*Musa spp.*	Leaves	Bleeding after giving Birth	Gultom et al [1991], Murdiati and Muhajan [1991]
			Blossom of green banana	Gastrointestinal Parasites	
			Stem	Bloat, Anemia, Fever, Appetizer, Diarrhea	
			Blossom	Worms, Diarrhea	
			Leaves	Diarrhea	
			Fruit	Diarrhea	
Betan	Coconut	*Cocos nucifera*	Oil	Scabies, Hoof infection, Bloat	Murdiati [1991], Murdiati and Muhajan [1991]
			Meal	Scabies	
			Meat	Worms	
			Water	Milk production, Eye disease	
			Shell	Hoof infection	
			Midrib of leaf	Milk fever	
Bolo	Bamboo	*Gigantochloa spp.*	Shoots	Worms	Murdiati [1991], Gultom et al. [1991], Murdiati and Muhajan [1991]
			Leaves	Bloat, Diarrhea, Retention of afterbirth	
Buas	Unknown	*Premna cordifolia Brand.*	Leaves	Bloat, Diarrhea	Local goat breeder
Duyan-alo'	Soursop	*Annona muricata*	Fruit	Lice	Murdiati and Muhajan [1991]
Jambu Bateu	Guava	*Psidium guajara*	Leaves, Roots, Stem	Diarrhea, Dystocia	Sangat-Roemantyo and Riswam [1991], Murdiati [1991]
Kayeu Siang	Unknown	*Molastoma polyanthum*	Leaves	Bloat	Basripuzi et al. [2013]
Kupi	Coffee	*Coffea canephora*	Seeds	Bloat	Murdiati and Muhajan [1991]
Laka-Bekawit	Unknown	*Uncaria lanosa var.ferrea*	Leaves	After giving Birth	Sangat-Roemantyo and Riswam [1991], Local goat breeder
Laka Payau	Unknown	*Merremia peltata*	Leaves	After giving Birth	Local goat breeder
Laka-Tuvah	Unknown	*Derris elliptica*	Root	Scabies, Araricide	Gultom et al [1991], Murdiati and Muhajan [1991]

Appendix IV continued.

Penan	Common name	Bot. Name	Part used	Application	References
Majan	Papaya	*Carica Papaya Gaerth.*	Latex Leaves Fruit Stalk of leaf	Worms Bloat,Diarrhea, Worms, Appetizer Poisening Bloat	Sangat-Roemantyo and Riswam [1991], Gultom et al. [1991]
Parai	Rice	*Oryza spp.*	Seeds	Diarrhea	Sangat-Roemantyo and Riswam [1991], Murdiati and Muhajan [1991]
Peletek	Kacang panjang	*Vigna unguiculata*	Leaves	Fattening	Ma'sum [1991]
Repé	Mango	*Mangifera indica*	Leaves	Diarrhea	Gultom et al [1991]
Sepa'	Betel Nut	*Areca atechu*	Seeds Leaves	Worms, Diarrhea, Skin disease Insect repellent	Sangat-Roemantyo and Riswam [1991], Murdiati [1991]
Tabo	Sugarcane	*Saccharum officinarum*	Leaves	Dystocia	Murdiati and Muhajan [1991], Gultom et al. [1991]
Tap-Birai	Unknown	*Artocarpus scortechinii*	Leaves	After giving Birth	Local goat breeder
Teusan/Té Usan	Pineapple	*Ananas comosus*	Fruit	Worms, Fever	Sangat-Roemantyo and Riswam [1991], Murdiati [1991]
Tobo	Wild Ginger	*Zingiber spp.*	Rhizome	Cold, Appetizer, Diarrhea, Influenza	Sangat-Roemantyo and Riswam [1991], Gultom et al. [1991]
Ubei	Cassava	*Manihot esculenta*	Leaves Tuber	Worms Scabies, Hoof infection, Diarrhea	Sokerya et al. [2009] Murdiati [1991], Gultom et al. [1991], Murdiati and Muhajan [1991]
Ujung bunga'	Wild Hibiscus	*Hibiscus spp.*	Leaves	Low milk production	Murdiati and Muhajan [1991]
Ureu Lalang	Cogongrass	*Imperata Cylindrica*	Root	Diarrhea	Murdiati and Muhajan [1991]
Unknown	Gliricidia	*Gliricidia sepium*	Leaves	Scabies	Gultom et al [1991]

Appendix V: Potential fodder plants available in Long Lamai

Penan	Malay	Common Name	Bot. Name	Seasonality	Plant component	Reference
Bahang	/	Scissor grass	Unknown	Evergreen		Local goat breeder
Balak	Pisang	(cultivated) Banana	Musa spp.	Evergreen/Fruit non-seasonal	Leaves, Fruit waste	Van Mele et al. [1994]
Belirau	/	/	Unknown	Evergreen	Leaves	Local goat breeder
Beripun	Tarap	/	Artocarpus odoratissimus	Evergreen/Fruit seasonal	Leaves, Fruit waste	Jagtap and Bapat [2010]
Betan	Kelapa	Coconut	Cocos nucifea	Evergreen/Fruit non-seasonal	Fruit waste (as meal)	Devendra and Leng [2011]. Ranjhan [1985]
Bolo	Bambu/Buluh	Bamboo	Bambusa spp./ Dendrocalamus spp.	Evergreen	Leaves	Halvorson et al. [2004]
Buas	Pokok Singkel/ Singki	/	Premna cordifolia Brand.	Evergreen	Leaves	Local goat breeder
Duyan	Durian	Durian	Durio zibethinus	Evergreen/ Fruit seasonal	Leaves, Fruit waste	Van Mele et al. [1994]
Duyan-alo'	Durian Belanda	Sour-sop	Annona muricata	Evergreen/Fruit non-seasonal	Seeds	Fasakin et al. [2008]
Irop	/	/	Unknown	Evergreen	Leaves	Local goat breeder
Jambu Bateu	Jamba-batu	Guava	Psidium guajara L.	Evergreen/Fruit non-seasonal	Leaves, Fruit waste	Azevêdo et al. [2011]
Julut	Paku Uban	Giant Swordfern	Nephrolepis biserrata	Evergreen	Leaves	Omojola et al [2012], Babayemi et al. [2006]
Peletek tana'	Kacang Tanah	Groundnut	Arachis hypogaea*	Evergreen/ Pods non-seasonal	Leaves, Vines, Pod husks	Devendra and Leng [2011], Devendra et al. [2011]
Kayeu nutun ibot	Sambung/Sambug	/	Unknown	Evergreen	Leaves	Local goat breeder
Kayeu Siang	Senduduk	Blue Tongue	Melastoma polyanthum/malabathricum	Evergreen	Leaves	Van Mele et al. [1994], Basripuzi et al. [2013]
Kedodong	Kedondong	June plum	Spondias spp.	Evergreen	Leaves	Lans [2001], Carew et al. [1980]
Kelakat	Arak Babi	/	Crudia scortechinii*	Evergreen	Leaves	Local goat breeder
Kupi	Kopi	Coffee (Robusta)	Coffea canephora	Evergreen	Pulps, Hulls, By-products	Devendra and Leng [2011]
Laka Payau	Rombok	/	Merremia peltata	Evergreen	Leaves	Anh et al. [2012]
Laka-Bekawit	Kelait	/	Uncaria lanosa var.ferrea/gambir	Evergreen	Leaves	ngat-Roemantyo and Riswam [1991], Local goat breede
Lasat	Langsat	/	Lansium domesticum Jack	Evergreen/ Fruit seasonal	Leaves, Fruit waste	Fernandez [1991, 1995]
Majan	Pepaya	Papaya	Carica Papaya L.	Evergreen/Fruit non-seasonal	Leaves, Fruit waste	Heuzé and Tran [2015], Adiwimarta et al. [2010]
Malai (grass)	/	Blue panic grass	Panicum Antidotale	Evergreen		Minson [1990], Prasad et al. [1995]
Malei	Mengkalak/Engkala	/	Litsea garciae	Evergreen	Leaves	Local goat breeder
Meté	Rambutan	/	Nephelium lappaceum	Evergreen	Leaves	Van Mele et al. [1994], Peters et al. [1979]
Nakan	Buah Cempedak	Champedak	Artocarpus interger	Evergreen/ Fruit non-seasonal	Leaves, Fruit waste	Peters et al. [1979]
Paduk	Nangka	Jackfruit	Artocarpus heterophyllus	Evergreen/Fruit non-seasonal	Leaves, Fruit waste	Djajanegara et al. [1982], Kusmartono [2011]
Pakeu Paya'	Midin	/	Stenochlaena palustris	Evergreen	Leaves	Setianah et al. [2004]
Parai	Padi	Rice	Oryza spp.	Seasonal	Straw	Devendra and Mahadevan [1986], Ranjhan [1985]
Peletek	Kacang panjang	owpea/Asparagus bea	Vigna unguiculata*	Evergreen/ Pods non-seasonal	Leaves, Vines, Pod husks	Ravhuhali et al. [2011], Mthetho et al. [2015]
Peletek Kebit	Kacang parang	Faba bean	Vicia faba*	Evergreen/ Pods non-seasonal	Leaves, Vines, Pod husks	Acuti et al.[2009], Heuzé et al. [2016]

* Legumes

Appendix V continued.

Penan	Malay	Common Name	Bot. Name	Seasonality	Plant component	Reference
Peletek nyelégéng	Kacang-botol	Winged bean	Psophocarpus tetragonolobus*	Evergreen/ Pods non-seasonal	All parts edible	Yap et al. [1979]
Ba'an petuh	Peria	Bitter gourd/melon	Momordica charantia**	Evergreen/ Fruit non-seasonal	Fruit waste	Katerere and Luseba [2010], Priscilla et al. [2014]
Peta	Petai	Stink bean/Bitter bean	Parkia speciosa*	Evergreen/ Pods non-seasonal	Leaves, Pods	Peters et al. [1979]
Pidau nulah	Belimbing	Starfruit/Carambola	Averrhoa Carambola	Evergreen	Leaves	Peters et al. [1979]
Repé	Pauh/Mangga	Mango	Mangifera indica L.	Evergreen/ Fruit seasonal	Leaves, Fruit waste	Agromisa [2015], Peters et al. [1979]
Seka	/	Wild Banana	Musa acuminata/Musa balbisiana	Evergreen/ Fruit non-seasonal	Leaves, Fruit waste	FAO [1992], Poyyamozhi and Kardivel [1986]
Sepa'	Pinang	Betel nut	Areca catechu	Evergreen/ Fruit non-seasonal	Dried Areca Sheats	Gowda et al. [2012]
Tabo	Tebu	Sugarcane	Saccharum officinarum	Evergreen	Stalk	Mui et al. [2000], Devendra and Leng [2011]
Tap-Birai	Pokok Buan	/	Artocarpus scortechinii	Evergreen	Leaves	Local goat breeder
Tebiu	/	(tall) Fleabane	Conyza spp./poss. Conyza sumatrensis	Evergreen	Leaves, Stem	MLA [2007], Omar [2012]
Teusan/Té Usan	Nanas	Pineapple	Ananas comosus L Merr.	Evergreen/ Fruit seasonal	Leaves, Fruit waste	Devendra and Leng [2011], Müller [1978]
Tingin	/	/	Sterculia spp.	Evergreen	Leaves	Koné and Atindehou [2008]
Tobo	/	Wild Ginger	Zingiber spp.	Evergreen	Stalk, Root	Sangat-Roemantyo and Riswam [1991]
Ubei	/	Cassava	Manihot esculenta Crantz	Evergreen/ Tuber non-seasonal	Leaves, Tuber	Devendra and Leng [2011], Van Mele et al. [1994]
Ubei Laka	Ubi Keledek	Sweet Potato	Ipomoea batatas	Evergreen/ Tuber non-seasonal	Leaves, Tuber, Vines	Devendra and Leng [2011], Wanapat [2008]
Ujung Bahang	Mintong/Mantong	/	Kyllinga spp./poss. polyphylla	Evergreen		Lusigi et al. [1984], Aregheore et al. [2006]
Ujung bunga'	Bunga Raya	Wild Hibiscus	Hibiscus spp.	Evergreen	Leaves, Stem	Agromisa [2015], Khan [1965]
Unknown	Rumput napier	Napier Grass	Pennisetum purpureum	Evergreen	Leaves, Stalk	Magcale-Macandog et al. [1998], ILCA 1979
Unknown	/	Gliricidia	Gliricidia sepium*	Evergreen	Leaves	Fadiyimu et al. [2012], Merkel et al. [1999]
Unknown	/	Ice cream bean tree	Inga Edulis*	Evergreen	Leaves	Molungoy and Kang [1986], Fadiyimu et al. [2012]
Upa	Gladiyam	Taro	Colocasia esculenta	Evergreen/ Tuber non-seasonal	Leaves, Tuber	Babayemi and Bamikole [2009]
Ureu	Lalang	Cogongrass	Imperata cylindrica	Evergreen		Falvey [1981], Komolong et al. [1988]
Ureu Bankut	Bankut/Bunkat grass	/	Unknown	Evergreen		Local goat breeder
Ureu Jipun	Bakut	(Japanese grass)	Unknown	Evergreen		Local goat breeder
Ureu Kelubau	Rumput Kerbau	Sourgrass	Paspalum conjugatum	Evergreen		Van Mele et al. [1994], Chee and Wong [1985]
Ureu Kemanen	/	/	Selaginella spp.	Evergreen		Local goat breeder
Ureu layan ujung Pa	/	Vetiver	Vetiveria zizanioides	Evergreen		Liu et al. [2002], Balasankar et al. [2013]
Ureu Ngeliket	/	Torpedograss	Panicum repens	Evergreen		Kumalasari et al. [2014], Van Thu [1997]
Ureu Rapa'	Guatamala	Guatemala grass	Tripsacum andersonii	Evergreen	Leaves	Chee and Peng [2006], Heuzé et al. [2015]
Uvut	Sagu	Sago	Metroxylon sagu	Evergreen	Trunk (as meal)	Local goat breeder, Abdullah et al. [2000]

* Legumes

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